Kostadis J. Papaioannou and Michiel de Haas

Weather shocks and agricultural commercialization in colonial tropical Africa: did cash crops alleviate social distress?

Article (Accepted version) (Refereed)

Original citation:
Papaioannou, Kostadis J. and de Haas, Michiel (2017) *Weather shocks and agricultural commercialization in colonial tropical Africa: did cash crops alleviate social distress?* World Development, 94 . pp. 346-365. ISSN 0305-750X
DOI: 10.1016/j.worlddev.2017.01.019

Weather Shocks and Agricultural Commercialization in Colonial Tropical Africa:

Did Cash crops alleviate social distress?

Kostadis J. Papaioannou,

London School of Economics and Political Science

&

Michiel de Haas,

Wageningen University

Keywords: Africa; rural livelihoods; economic history; colonialism; social distress; tropical agriculture; agricultural commercialization; environmental history

JEL Codes: N17, N57, Q17, F54 , D74

Corresponding author: Kostadis J. Papaioannou, kostadis.papaioannou@wur.nl, affiliation: Department of International Development, London School of Economics and Political Science, mailing address: 6-8th Floors, Connaught House, London, United Kingdom, fax: +44 (020) 7955 6565, visiting address: Houghton Street, London, WC2A 2AE, United Kingdom.

Acknowledgments

We are indebted to Erwin Bulte, James Fenske, Ewout Frankema and Ted Miguel whose comments and suggestions substantially improved this study. For useful comments, we thank Gareth Austin, Felicitas Becker, Peter Bent, Cédric Chambru, William Collins, Daniel Curtis, Leigh Gardner, Jose Martinez-Gonzalez, Leander Heldring, Solomon Hsiang, Noel Johnson, Niek Koning, Paul Lane, Paolo Malanima, Maarten Voors, Pieter Woltjer, and the participants of the International Workshop in Historical Ecology at Uppsala University, Sweden (November 2014), the Thesis Workshop Series at the London School of Economics and Political Science (LSE), United Kingdom (February 2015), the seminar of Political Economy, Economic History, Growth and Development at Groningen University, Netherlands (February 2015), the Economic History Graduate seminar at Oxford University, United Kingdom (May 2015), the Datini-ESTER advanced seminar in Prato, Italy (May 2015), the ERSA Workshop at Stellenbosch University, South Africa (May 2015), the XII[th] World Economic History Congress in Kyoto, Japan (August 2015), the Social Science History Association conference in Baltimore, USA (November 2015), the Development seminar at UC Berkeley, USA (February 2016) the African Studies seminar at the Graduate Institute, Geneva, Switzerland (March 2016) and the European Social Science History Conference in Valencia, Spain (May 2016). We are grateful for the financial support of the European Research Council under the European Community's Seventh Framework Programme (ERC Grant Agreement no. 313114) as part of the project *Is Poverty Destiny? A New Empirical Foundation for Long-Term African Welfare.* Any remaining mistakes are our own.

Abstract

A rapidly growing body of research examines the ways in which climatic variability influence economic and societal outcomes. This study investigates how weather shocks triggered social distress in British colonial Africa. Further, it intervenes in a long-standing and unsettled debate concerning the effects of agricultural commercialization on the abilities of rural communities to cope with exogenous shocks. We collect qualitative evidence from annual administrative records to explore the mechanisms linking weather extremes to harvest failures and social distress. We also conduct econometric testing on a novel panel dataset of 143 administrative districts across west, south-central and east Africa in the Interwar Era (1920-1939). Our findings are twofold. First, we find robust evidence that rainfall anomalies (both drought and excessive precipitation) are associated with spikes in imprisonment (our proxy for social distress). We argue that the key causal pathway is the loss of agricultural income, which results in higher imprisonment for theft, unrest, debt and tax default. Second, we find that the impact of weather shocks on distress is partially *mitigated* by the cultivation of export crops. Our findings suggest that, even in the

British colonial context, smallholder export crop cultivation led to higher private incomes as well as greater public investment. Our findings speak to a topic of considerable urgency today as the process of global climate change accelerates, generating more severe and unpredictable climatic extremes. An increased understanding and identification of *adaptive* and *mitigating* factors, would assist in targeting policy interventions and designing adaptive institutions to support vulnerable rural societies.

Keywords: Africa; weather shocks; economic history; climate vulnerability; food crisis; agricultural commercialization

JEL Codes: N17, N57, Q17, F54 , D74

1. Introduction

For centuries, thinkers and scholars have sought to understand whether and how climatic conditions influence societies and the economy. A better understanding of this causal link promises insights into why some economies have thrived *historically* while others languished, how *contemporary* societies can design effective policies and institutions to shield against current climate extremes, and how *future* climate change may impact human society. In recent years, a proliferation of rigorous studies has emerged, aiming to quantify and assess the effects of climate extremes on economic and social outcomes (Hsiang et al., 2003; Dell et al., 2014). This surge can be explained partly by rising public concerns about climate change and its potentially ensuing distortive effects on human development; partly by greater popular awareness of the critical role that climate might play in affecting social and economic outcomes; and partly by methodological advances and data availability, aided by improvements in computing power.

The adverse impact of climatic variability on social outcomes has proven particularly pronounced in developing regions, with Sub-Saharan Africa (henceforth abbreviated to Africa) being the most vulnerable one. This does not come as a surprise, as a large share of the population depends on rain-fed subsistence agriculture, with less than 5% of the cultivated area being irrigated (FAO 2014). In such a context, climate-induced harvest failures can easily spill over into food insecurity, economic distress and social destabilization. Africa's rising population densities, pervasive climate change and resurging socio-political instability make this continued vulnerability to the vagaries of climate a most pressing concern (Morton, 2007).

While climate extremes have an undoubted and significant impact on societies, human affairs are not *uniformly determined* by climate. Instead, the effects of climate are mediated by a wide variety of geographical, cultural, institutional and commercial factors (Sen, 1981; Thompson, 1971; Watts & Bohle, 1993). The key question, then, is which factors enable the *mitigation* of adverse impacts of climate extremes, and how such factors can be propagated through targeted policy interventions (Adger, 2000; Folke, 2006; Gallopin, 2006).

Whether agricultural commercialization aggravates or mitigates the vulnerability of rural communities is the subject of a multifaceted, heated and long-standing debate among historians, policy makers and social scientists (Von Braun & Kennedy, 1994; Govereh & Jayne, 2003). This study aims to use Africa's past experience with smallholder-based export production during the colonial era to generate new insights on the impact of agricultural commercialization on the abilities of rural communities to cope with weather shocks. We provide new district-level evidence on the link between weather shocks and social tension and distress in British colonial Africa during the interwar era (1920-1939), as well as on the mediating role of smallholder-based export crop production.

The data for our analysis have been compiled from annual *Colonial Blue Books* and *Administration Reports*, stored in *The National Archives of the UK* in London. Data was collected for over 200 sub-national administrative units in Botswana, Gambia, Ghana, Kenya, Malawi, Nigeria, Sierra Leone, Tanzania, Uganda and Zambia (see figure 1).[1] Exploiting the extensive and consistent administrative records that remain from Britain's African empire, we are able to provide new material on a world region for which systematic data collection is notoriously difficult, and, as a consequence, also expand the historical time horizon.

[1] Not all of these districts included sufficient data to end up in our final analysis. Our baseline results include 143 districts. For Nigeria and Zambia, we use provinces instead of districts, as data was not consistently reported below the province level (see Papaioannou 2016).

Figure 1. *Countries included in this study, with internal administrative borders, ca. 1930*

Notes: See main text.

Our research strategy has both a qualitative and econometric component. *First*, we critically examine the colonial administrative records to improve our understanding of the mechanisms that explain the impact of drought and excessive rainfall on harvest outcomes and distress. *Second*, we econometrically test the link between weather shocks and social distress, as well as the mediating impact of export crop cultivation. To that end, we obtain observations on annual rainfall and imprisonment, and construct a novel panel dataset at the sub-national level. We also construct two indicators to measure each district's involvement in export crop cultivation. To measure social distress, we use annual fluctuations in imprisonment at the district level. While colonial prisons locked people up for a wide range of distress-related behaviours, such as debt, tax and fine default, petty thefts and civil disobedience (Bernault, 2007; Hynd, 2011), imprisonment spikes in years of weather shocks provide us with a particularly valuable inroad to capture social distress.

We justify the setting of our analysis in interwar British colonial Africa on a number of grounds. First, Britain administered a vast African empire. The extensive bureaucratic legacy has allowed us to construct a consistent district-level dataset spanning approximately one-fifth of Africa's landmass and one-third of its population in this period. Second, the geographic and temporal scope provides data for over 200 sub-national administrative units. In some of these units, crops were grown on a considerable scale for export, while in others agricultural production was primarily geared towards subsistence. Our temporal scope encompasses the interwar period, a period of relative calm between the violent early-colonial conquest and the highly politicized post-war road to independence (Killingray, 1986).

Our qualitative evidence suggests several different mechanisms through which both drought and excessive rainfall result in harvest failures, adversely affecting agricultural incomes and provoking distress. The econometric estimates for our full sample, using fixed-effects models, confirm this relationship and reveal a robust *U-shaped* impact of weather shocks on different measures of imprisonment. The effect is not symmetrical. A 'negative rainfall shock' (drought), measured as a one standard deviation decrease from the long-term rainfall mean, is associated with 16.0 standard deviation increase in total imprisonment, and a 'positive rainfall shock' (excessive rainfall), measured as a one standard deviation increase from the long-term rainfall mean, is associated with an even stronger 24.8 standard deviation increase in total imprisonment. These effects are similar in magnitude to accumulated evidence from other studies reviewed by Hsiang et al. (2013). The results are robust to using two different indicators of annual rainfall anomaly, as well as range of alternative formulas for parameterizing rainfall shocks.

Having established a robust overall relationship between rainfall anomalies and annual spikes in imprisonment for our full dataset, we test if this relationship is mediated by smallholder-based export crop cultivation. Our results show that a one standard deviation change in rainfall (in either direction) is associated with 10.2 standard deviation change in total imprisonment in districts with substantial export crop production, as compared to 33.9 standard deviation change in districts with negligible or no export crop production. This finding suggests that imprisonment spikes in districts with relatively high amounts of export crop income per capita were significantly less affected by weather shocks. We argue that this finding indicates that commercialization of smallholder agriculture did have a *mitigating* effect on rural communities' vulnerability to weather shocks. The fact that our findings pass a wide range of robustness tests, increases our confidence in the actual production of export crops playing a crucial role in mitigating the impact of weather shocks.

The remainder of the paper is structured as follows. Section 2 places our study in the context of several related literatures. Section 3 introduces our qualitative evidence on the link between climate extremes, loss of agricultural income and distress. Section 4 discusses the data for our econometric analysis. Section 5 econometrically demonstrates a causal link between rainfall and imprisonment. Section 6 econometrically demonstrates that export crops mitigates the effect found in Section 5. Section 7 discusses the implications of our findings and concludes.

2. Related Literature

2.1 The impact of climate on economy and society

Over the past decade, scholars and policy makers have become increasingly aware of the short-run and long-run impact of climatic factors on a wide range of economic, social and political outcomes. The goal of this sub-section is to provide a brief overview of the most important links between climatic fluctuations and societal outcomes suggested in the literature. For a more extensive and profound summary on the new climate-economy literature, we encourage readers to consult Dell et al. (2014) for a general discussion, Burke et al. (2014) for conflict outcomes, Deschenes (2014) for health outcomes, Auffhammer et al. (2013) for climatic modelling, and Hsiang (2016) for nuances on climate econometrics.

While some scholars dispute the evidence linking weather to conflict outcomes (Klomp & Bulte, 2013; Buhaug et al., 2014), a range of studies have found that climatic variability not only triggers conflict (Fjelde & von Uexkull, 2012; Hendrix & Salehyan, 2012; Papaioannou 2016), crime (Iyer & Topalova, 2014; Blakeslee & Fishman, 2015; Papaioannou, 2017), and full-blown civil war (Blattman & Miguel, 2010), but also processes of democratization (Brückner & Ciccone, 2011). Scholars are divided on the mechanisms that explain the 'climate-society nexus' (Almer & Boes, 2012; Buhaug, 2010), but harvest failures are found to be a prime candidate, especially in settings where people's incomes rely heavily on rain-fed farming and where small fluctuations in crop yields can have devastating effects on livelihoods (Barrios et al., 2010; Iyer & Topalova, 2014; Blakeslee & Fishman, 2015; Brückner & Ciccone, 2011; Miguel et al., 2004; Schlenker & Lobell, 2010; Papaioannou, 2017).

Recent contributions have begun to investigate different time periods (Papaioannou, 2016; Jia, 2014), employ a more fine-grained, sub-national scope (Harari et al., 2013; Raleigh & Urdal, 2007) and use more non-binary indicators as the dependent variable (Papaioannou, 2016; 2017). Moreover, a number of studies have employed detailed case study analyses to uncover the key mechanisms leading from weather variability to social distress, civil unrest and political upheaval (Adano et al., 2012, Benjaminsen et al., 2012; Ember et al., 2012; Witsenburg & Adano, 2009). Among those who take precipitation as the key independent variable, some find that drought is the prime reason for societal destabilization (Couttenier & Soubeyran, 2011; Maystadt & Ecker, 2014), while others argue that both droughts and excessive rainfall fuel higher social tension (Papaioannou, 2016; Papaioannou, 2017; Fjelde & von Uexkull, 2012; Hendrix & Salehyan, 2012).

The effects of climate extremes on local societies are not uniform nor predetermined, but instead mediated by geographical, cultural, institutional, commercial factors (Sen, 1981; Watts & Bohle, 1993; Papaioannou & Frankema, 2017). In the words of E.P. Thompson, social unrest should not be seen as a mere "spasmodic" response to adverse conditions, and "a bad harvest, or a down-turn in trade" are not in themselves sufficient explanations of social outcomes (Thompson, 1971). The key question, then, is which factors mitigate the impact of weather shocks, and how such factors can be propagated through targeted policy interventions. The mitigation of vulnerability to climate extremes has been a key priority issue in recent literatures investigating sustainable rural livelihoods (Chambers & Conway, 1992; Ellis, 2000; Scoones, 2009) and adaptive strategies to cope with climatic variability and change (Adger, 2000; Folke, 2006; Gallopin, 2006; Ahmed et al., 2009).

Our contribution here is fourfold. Firstly, we use qualitative evidence to explore the *mechanisms* running from weather shocks to social distress. Second, our dependent variable (imprisonment) is *continuous* and *fine-grained*, and allows us to pick up relatively minor fluctuations in social distress in the wake of these shocks. Third, we provide *new data* on a historical period that is so far understudied. Fourthly, and most importantly, we econometrically test for the *mitigating* effect of agricultural commercialization on vulnerability to weather shocks.

2.2. Agricultural commercialization and weather shocks in a colonial context

It seems obvious that agricultural production systems play a particularly crucial part in determining societies' abilities to cope with exogenous shocks. However, the ways in which agriculture may enhance the resilience of African communities, in a context of erratic and changing weather conditions, has been a particularly contentious issue among scholars and policy makers (Bryceson, 2002; Collier & Dercon, 2014; Giller et al. 2009; Raikes & Gibbon, 2000; Papaioannou & Frankema, 2017). The empirical evidence on the impact of agricultural commercialization on resilience to weather shocks is mixed. On the positive side, increased openness to external markets has been associated (a) with higher incomes, and (b) with farmers' improved abilities to 'smooth consumption' and diminish short-term risks (Burgess & Donaldson, 2010; Fafchamps, 2003; Myint, 1958; Von Braun & Kennedy, 1994). Agricultural commercialization has also been argued to provide rural communities with access to new crops, inputs and agricultural technologies and to incentivize governments to invest in infrastructure, famine prevention and extension services, each with the potential to alleviate feasible adverse effects of volatile climatic conditions (Goetz, 1993; Govereh & Jayne, 2003; Maxwell & Fernando, 1989; Tosh, 1978; Von Braun & Kennedy, 1994). At the same time, scholars have drawn ample attention to the fact that market access is not a uniform blessing to vulnerable rural communities. When attention is diverted from subsistence production, production for markets may induce hunger and malnutrition, while commercialization may result in the erosion of 'traditional insurance mechanisms', induce stratification, subject farmers to volatile markets, and facilitate external exploitation and extraction, each of which in fact makes societies more vulnerable to weather-induced shocks (Bates, 1981; Scott, 1976; Vaughan, 1987; Von Braun & Kennedy, 1994; Watts, 1983).

The literature has exposed numerous and sometimes conflicting parallel mechanisms that influence the effect of export-based agricultural commercialization on distress in the wake of weather shocks. We do not claim to test the validity of the individual mechanisms proposed on either side. Instead, we take a previously underexplored angle and methodology and empirically test the '*weighted' or 'net' outcome* of the variegated mechanisms running from export crop cultivation to vulnerability to weather shocks. In statistical terms, we tease out an *'average'* or *'overall treatment effect'* of export crops on types of distress that resulted in imprisonment in interwar British colonial Africa.

While we argue that our findings have broader implications and are relevant for contemporary debates on agricultural commercialization, it is also important to acknowledge the particularities of the context from which our results are drawn. The volume of agricultural exports expanded markedly during the era of colonial rule (~1880-1960) (Frankema et al., 2015). In many cases, colonial rulers attempted to introduce or expand export crops through coercion and exploitation. In some countries, such as Kenya or Zimbabwe, settlers expropriated land and barred African smallholders from producing the most profitable crops (Mosley, 1983). In others, such as Mali, Congo or Mozambique, rural communities were forced to cultivate and sell crops for export rather than subsistence (Isaacman, 1996; Roberts, 1996; Likaka, 1997). However, uniformly equating the 'export crop revolutions' in early twentieth century Africa with colonial exploitation would not do justice to the agency and initiative of African smallholders (Tosh, 1980; Austin, 2014a). The expansion of cocoa production in Ghana and Nigeria was driven by African rural capitalists (Hill, 1997), while the expansion of commercial groundnut production in the Gambia and Northern Nigeria, as well as the introduction of tobacco and cotton in Uganda, Tanzania and Malawi, were conditional on the productive choices of millions of African rural households (Bryceson, 1990; Hogendorn, 1978; Mandala, 1990, Swindell & Jeng 2006; Wrigley, 1959). In northern Nigeria, smallholders massively took up groundnut farming, while British colonial interests preferred to see cotton exported (Hogendorn, 1978). The cultivation of cotton in Uganda and groundnuts in the Gambia were primarily driven by indigenous agents, and their cultivation attracted scores of migrants from across the colonial borders (Swindell & Jeng, 2006; De Haas, 2017).

A number of characteristics were common to the great majority of export crop cultivating smallholders during the colonial era. Firstly, they were cultivating in a *land abundant* context in which labour was the primary factor constraining further expansion (Tosh, 1980; Austin, 2008). Secondly, farmers continued to cultivate food crops and to pursue food self-sufficiency (Tosh, 1980). A typical cotton growing household in eastern Uganda, for example, only devoted 2.5 out of its total 8.0 acres cropped annually to cotton, and the remainder to food crops such as millet and groundnuts, primarily for home consumption (De Haas, 2016). Cocoa farmers in Nigeria and

Ghana were, perhaps, the exception to this rule, due to the high profitability of cocoa, although even they cultivated considerable amounts of food crops alongside their cash crop (Austin, 2014b). Thirdly, export crops were cultivated with basic technology (hand cultivation, few external inputs and mostly unimproved seeds) (Tosh, 1980). As a result, yields were typically modest, but at the same time, smallholders did not have to incur large debts in order to participate in export crop cultivation. In some cases, export crops were explicitly 'state sponsored', and inputs such as cotton seeds or coffee seedlings were freely distributed.

While the introduction and expansion of export crops in British colonial Africa may not have exclusively or even primarily been driven by colonial policies, smallholders' productive choices were undoubtedly shaped by colonial occupation. Even though households were not formally obliged to cultivate crops in most cases, they were often pressurized to do so by chiefs and local administrators, or subjected to indirect force by the required payment of colonial taxes to market their produce (Bryceson, 1990; Mandala 1990; Wrigley 1959). Therefore, colonial state interventions may well have prevented some of the potential gains of agricultural commercialization from accruing to rural producers themselves.

Colonial rule also affected the spatial distribution of agricultural commercialization. In some areas, the introduction of motorized transport and new agricultural technologies under colonial rule may have enhanced the productive capacities of rural producers, while in others, it is possible that the lack of investment and the introduction of taxes spurred rural impoverishment and outmigration of young men, contributing to a deepening of regional inequalities. It is well conceivable that without colonialism, these districts would have benefited even more from agricultural commercialization, or that districts that ended up as marginalized subsistence economies during the colonial era would have fared better if colonial states had made more efforts to increase their access to external markets.

Our finding that regions growing export crops are more resilient to weather shocks, begs (rather than answers) further questions about the interfering role of colonialism. For now, we simply face the reality that there is no empirical counterfactual at hand to answer such questions (Heldring & Robinson, 2012).

3. Qualitative evidence

3.1. Weather shocks, harvest failures and social distress

Our sources provide a unique opportunity to engage with debates over the effects of weather anomalies on rural African societies. The British colonizers set up a hierarchically organized system of administration in their African dependencies. Territories were subdivided into provinces and districts. The maintenance of law and order was largely left to African policemen, prison guards and native authorities, who operated as 'indirect rulers' under the supervision of British administrative officers. Elaborate administration accounts were kept, and local officials reported on a regular basis to their supervisors on a range of issues. We use annual administrative reports obtained from the Departments of Agriculture, Native Affairs, Police, Justice and Prisons. These reports are consistent in their coverage of issues over time and across colonies, giving us a uniquely comprehensive insight into local conditions across a wide area and a timespan of 20 years.

The reports are rich in relevant content. At the same time, we must be aware of the colonial context in which they were produced. British colonial services were understaffed, and local administrators' accounts reveal strong prejudice and paternalistic and derogatory attitudes towards local populations. On top of that, previous scholars have pointed out that civil servants, in order to inflate their achievements and benefit their own careers, had an incentive to focus on 'progress' and paint a rosy picture to superiors, which may compromise some of the reliability of local administrative accounts (Killingray, 1986). We read the reports critically, and argue that some statements in them can be more readily accepted than others. For example, an agricultural officer describing the impact of drought on seed germination seems to us more unproblematic than a district commissioner attributing starvation to "the apathy of an ease loving people" (Sierra Leone 1923), or an episode of social unrest to the "idleness and nomadic instinct" of the groups involved (Kenya, 1933).

The impact of weather conditions on agricultural outcomes is extensively discussed by colonial administrators, who make regular note of weather-induced agricultural failure, resulting in higher levels of distress. Both *too little* and *too much* rainfall are routinely proffered as causes of depressed agricultural incomes.

Droughts are frequently mentioned as a catalyst for suppressed yields. In severe cases, drought is also associated with complete crop failure, dust storms and soil erosion. For instance, the agricultural report of 1920 Gold Coast states that the food crops in Volta River "were exceedingly scarce" as "the drought during the early part of the year is causing many of the crops to fail and all crops realised high prices" (Gold Coast, *Agricultural Report* 1920). Similarly, in 1927, the commissioner of Zaria District (Northern Nigeria) noted that the "considerable decrease [in foodstuffs] is accounted for by a drought which occurred after planting had taken place" which made it "impossible for peasants to cultivate their land" (Nigeria, *Provincial Report* 1927).

Diminished water supplies to wells, surface water sources and pastures, also associated with lack of rainfall, negatively impacts upon livestock. To prevent starvation, people moved with their livestock, which in turn increased their susceptibility to disease and further weakened underfed herds. An administrative account discusses how these varied drought effects simultaneously struck Baringo District (Kenya): "The year 1933 has been one of the worst in living memory. A complete failure of the long rains caused enormous losses among stock, ruined the crops in the low-lying parts and made the harvest on Masop very late. It is safe to say 50 per cent of the cattle died" (Kenya, *Native Affairs* 1933).

Regular mention is also made of the adverse effects of ***excessive rainfall*** on agriculture. These effects run via different mechanisms. Heavy precipitation and resulting floods damaged crops and created unfavourable conditions for harvesting, storage and transportation of agricultural produce. In 1936, the Rufiji District (Tanzania) suffered "a great flood", which "destroyed the main crops of one-third of the population" (Tanganyika, *Native Affairs* 1936). Similarly, "a truly phenomenal rainfall" in Owerri Province "severely injured the crops" and led to "widespread shortage of available food supplies" (Nigeria, *Agricultural Report* 1922). In The Gambia, as a result of abnormally heavy rainfall, the groundnut crop "suffered severely during the ripening and reaping period. [...] Fermentation was rapid and much damage was done to the nuts and to the quality of soil. The extent of this damage was widespread and felt throughout the country" (The Gambia, *Agricultural Report* 1927).

Administrative accounts also link heavy rainfall to increased prevalence of plant diseases. In Ondo Province (Nigeria), 'black pod disease' destroyed an estimated 30 percent of the cocoa harvest during a year of heavy rainfall (Nigeria, *Agricultural Report* 1933). Reports also recount how parasitic organisms thrived under conditions of heavy rainfall. A serious increase in weevil infestation in the Trans Nzoia District (Kenya) was attributed to "abnormal[ly wet] weather conditions" (Kenya, *Agricultural Report* 1930).

Examples of the negative impact of droughts as well as excessive rainfall on agriculture can be found in both very wet and very dry regions. That positive and negative rainfall shocks compromise agricultural outcomes in such a wide range of agro-ecological settings makes sense, considering that smallholders built their farming systems around an expected quantity of rainfall. Similarly, the physical environment was also conditioned by an expected level of rainfall. While lots of rain may seem beneficial to a dry savannah, its soils may be incapable of absorbing the precipitation, resulting in run-off, floods and waterlogging. For example, Machakos (Kenya), a district with an average annual rainfall of only 40 inches, experienced an exceptionally wet year after a number of consecutive years of drought. A colonial officer noted that “despite the very heavy rain during the year, the condition of the Reserve has not improved; it has in fact degenerated further, particularly in regard to water supply. Owing to large areas being denuded of grass, the erosion caused by the heavy rains must have been enormous” (Kenya, *Native Affairs* 1930).

The administrative accounts frequently link rainfall shocks to food price spikes and subsequent social distress, which took the shape of increased petty crime and livestock raids and thefts. In Northern Nigeria in 1927, “the rainfall, which was considerably below the average, caused a partial failure of the guinea corn and yam crops in certain districts of the province. There was a definite shortage which caused the price of grain to soar to three or four times the normal price [from 0.12 to 0.65 pence per bag]” (Nigeria, *Provincial Report* 1927). The district commissioner concluded that “with the high prices which prevailed the native had a hard time to make both ends meet and a certain amount of distress has been apparent.” The police report of that same year reported that “petty theft was frequent in Kano. About April petty theft reached alarming proportions and special efforts were made to combat it.” The annual imprisonment rates exhibited an increase of about 61 per cent, forcing the Commissioner to state that “there is no doubt that the reason for the increase of crime is mainly economic” (Nigeria, *Police Report* 1927).

Examples like the ones above can be drawn systematically from the sources. The native commissioner of Turkana district, a pastoral area in Kenya, pointed out that the shortage of water and grazing resulting from a drought in 1929, “led to more migration and possibly more squabbles, crime and bloodshed than usual” (Kenya, *Native Affairs 1930*) Only four years later, “a phenomenal drought” led to “famine and poverty” as well as a “constant anxiety of raids and massacres on the frontier. [...] The Turkana have been driven in unprecedented numbers to encroach on the grazing and water supplies of their more fortunate neighbours" (Kenya, *Native Affairs* 1933). In that same year, the severe drought and resultant stock mortality in the Masai District (Kenya) "led to an increase in crime. Actual hunger caused many sheep thefts and raids into Tanganyika Territory. Counter raids have proven serious." The local imprisonment rate of the year exhibited a sharp increase from 255 to 408 convicts (Kenya, *Native Affairs* 1933). The Kenya police report of 1933 points out that "stock theft shows a 60 per cent. increase in the number of cases brought to court, while the number of persons convicted has nearly doubled. This large increase may be attributed to the difficult times experienced by the natives owing to the failure of the rains" (Kenya, *Police Report* 1933).

An episode of abnormally high rainfall in Saltpond and Winneba District (Gold Coast) resulted in crop damage, failure and 'resultant stress', 'shortage of the food supply' and high prices. The incarcerated population increased by 25% and 37%, respectively (Gold Coast, *Agricultural Report*, 1925). In Rufiji District (Tanganyika) in 1930, "for a considerable period 15,000 natives were homeless owing to the floods and many lost their houses, stock and crop." The local police commissioner noted that "there was an increase of cattle theft, perhaps due to the shortage of food" and that "cases of theft predominated" mainly owing to the food shortage. The number of thefts rose to 1028 compared to 600 the previous year – an increase of 71 per cent (Tanganyika, *Native Affairs* 1930).

Conversely, colonial officers sometimes also explicitly attributed the *absence* of tension and distress to low prices due to favourable weather, which can be assumed to have positively impacted food production. The Gambia police, for example, noted that "with such favourable weather conditions coupled with the low price of foodstuffs, it was only to be expected that the crime figures should be satisfactory and never in the past 30 years has the total number of reports of serious crime been so small as in 1934. It is too much to hope that such a peaceful state of affairs can become normal" (Gambia, *Police Report* 1934).

While we find such causal inferences by colonial officials more plausible and satisfactory than the essentialistic assessments of the local population's 'natural responses' to adverse conditions mentioned above, we should still receive them with a degree of scepticism since attributing social tension and distress to exogenous weather variation also conveniently diverted attention from the potential negative impact of colonial interventions themselves.

3.2. Export crops and vulnerability

Our study of the administrative record highlights that the impact of export crops on resilience in the wake of exogenous shocks was already a contested issue among colonial administrators. A southern Nigerian agricultural director expressed the concern that cocoa "considerably reduced the output of food", and increased smallholders' vulnerability to weather anomalies. An episode of "great shortage of food" was attributed "partially to the cocoa boom and partially to the drought" (Nigeria, *Agriculture* 1930). Likewise, the agricultural commissioner of Gold Coast stated in 1921 that "with the successful development of cocoa-growing there has been a marked tendency to neglect the cultivation of foodstuffs and to depend on imported provisions. In an essentially agricultural country this is not satisfactory or what one might expect. In the same interior districts a shortage of foodstuffs is actually felt." He argues that the shortage of food crops became so pronounced that "the value of local grown products has soared to unheard of prices in recent years," leading to "widespread distress" (Gold Coast, *Agriculture* 1921).

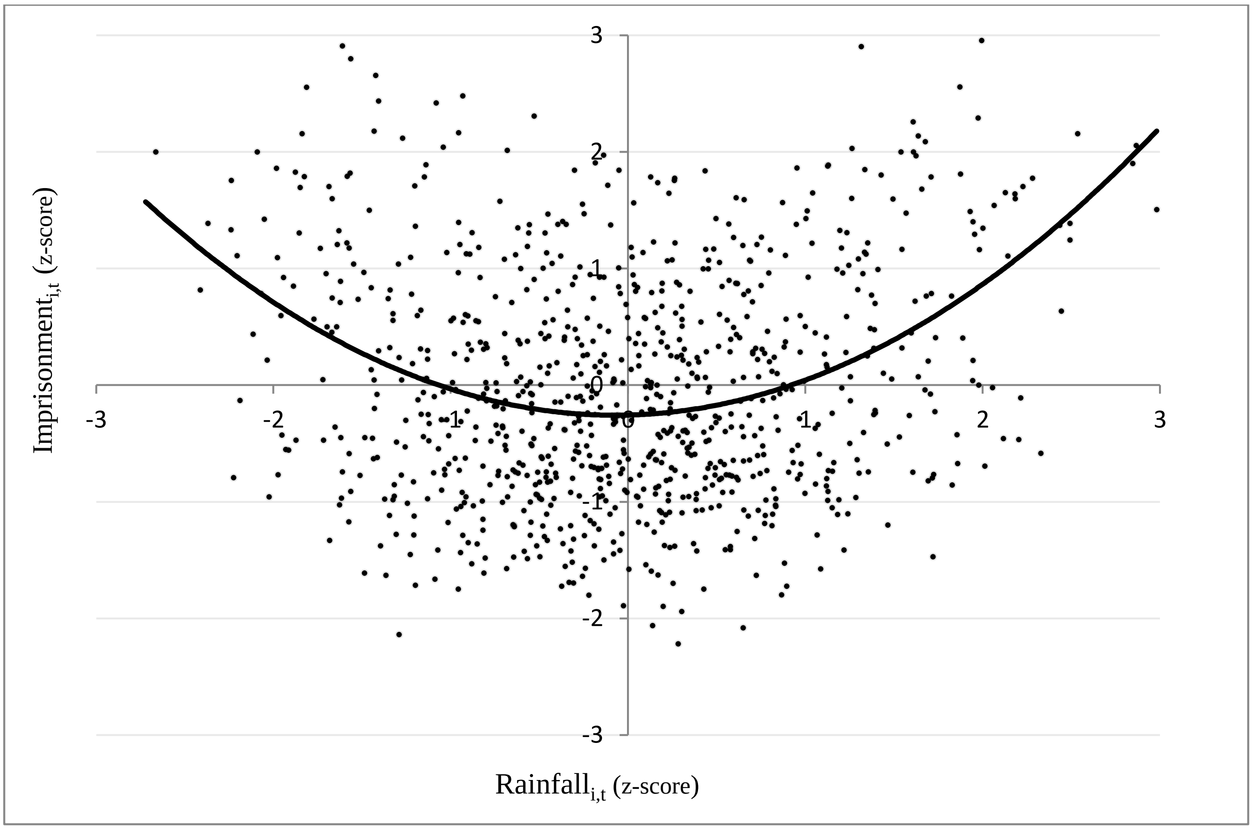
Other colonial administrators were more optimistic, highlighting the diversification of risk that came with the adoption of export crops. A drought in Central Kavirondo (Kenya) "proved disastrous to food crops", while the cotton crop "fared better [...]. The failure of the food crops accentuated the value of cotton, for those who had it to sell were able to subsist on their own resources" (Kenya, *Agriculture* 1937). In addition, several native officers of Tanganyika reported that farmers only began cultivating export crops "when they had ensured for themselves and their dependents an adequate food crop" (Tanganyika, *Native Affairs* 1930), and that smallholders prioritized food security over cash income as "the planting of food crops is the first consideration and poor planting rains very often cause unavoidable delay in the planting of export crops such as cotton with the result that low yields are obtained" (Tanganyika, *Native Affairs* 1933).

While we find that colonial reports are rather straightforward when it comes to the adverse impacts of negative and positive rainfall shocks on agriculture and, with some reservations, social tension and distress, we conclude that the reports are more ambiguous and problematic when it comes to assessing the role of agricultural commercialization. This ambiguity in the colonial sources reflect similar disagreement in the scholarly literature. We conclude that the reports are insufficiently impartial and too imprecise to provide us with much guidance in the process of assessing how export crop adoption affected the vulnerability of rural districts to weather fluctuations. Previous studies have used unpublished correspondence, fieldwork or oral history to probe beyond, and provide a counterweight to, the biases and limitations inherent in colonial administrative records. The labour intensive nature of such in-depth research has confined most studies to one particular colonial territory or district. We opt for a different research strategy by collecting quantitative data covering a wide geographical scope for econometric analysis. While we acknowledge that a wide range of, potentially opposing, mechanisms will underpin our overall findings, and that such mechanisms deserve full attention of scholars and policy makers, we find it equally worthwhile to draw up the balance, and take stock of the *overall treatment effect* of export crops on social tension and distress (cf. Kennedy & Von Braun, 1994).

4. Data

Our key variables of interest are imprisonment (the number of individuals admitted in year *t*) and rainfall (annual precipitation in inches in year *t*). We standardize both variables by computing their z-scores. Figure 2 provides a simple scatter-plot of the standardized rainfall anomalies against standardized annual imprisonment. Without any additional econometric testing, the figure brings out the non-linear (U-shaped) relationship between the two variables for the full sample. In other words, when rainfall deviates from the expected mean *in either direction*, the number of imprisoned individuals also spikes. We further explore this relationship econometrically in section 5 and include our export crop interaction effect in section 6. All variables, including our *observable* and *unobservable* controls are discussed below. Summary statistics are provided in Table 1.

Figure 2. *Weather shocks and imprisonment in districts across British colonial Africa (1920-1939)*



Notes: Both indicators are the result of 'standardizing' process using the z-score computation: $(x_{i,t} - \bar{x}_i) / \sigma_i$, where $\bar{x}_i$ is the long-term mean of each district, $x_{i,t}$ is the annual observation in time t for district i, and σ_i is the standard deviation of each panel, that is for every i.

Table 1. *Summary Statistics: District by Year Data*

Variable	Obs.	Mean	Std. Dev.	Min	Max
Panel (a): Dependent variables					
Total imprisonments *	2714	0.00	1.00	-2.60	3.70
Imprisonments for debt *	2076	0.00	1.00	-1.70	3.50
Imprisonments for less than 3 months*	2671	0.00	1.00	-2.30	3.80
Imprisonments for more than 3 months*	2672	0.00	1.00	-2.80	3.90
Panel (b): Independent variable of interest					
Rainfall long-term mean, Stations	2900	46.91	24.12	15.80	144.10
Rainfall anomaly, Stations*	2529	0.00	1.00	-3.20	3.30
Rainfall anomaly squared, Stations*	2529	1.00	1.32	0.00	10.89
Absolute rainfall anomaly (Linear), Stations*	2529	0.80	0.58	0.00	3.30
Rainfall long-term mean (Matsuura & Wilmott)	3200	47.01	21.73	12.70	139.70
Rainfall anomaly (Matsuura &Wilmott) *	3200	0.00	1.00	-3.50	3.30
Rainfall anomaly squared, (Matsuura & Wilmott) *	3200	1.00	1.33	0.00	12.25
Absolute rainfall anomaly (Linear), (Matsuura & Wilmott) *	3200	0.81	0.58	0.00	3.50
Negative rainfall shocks	2529	0.17	0.38	0.00	1.00
Positive rainfall shocks	2529	0.18	0.38	0.00	1.00
Panel (c) Interaction variables					
Export crop *production* value (£) per capita	3220	0.52	1.47	0.00	10.10
Export crop suitability, categorical (FAO-GAEZ) [£]	3220	3.72	0.81	1.05	5.51
Food crop suitability, categorical (FAO-GAEZ) [£]	2680	2.86	0.79	1.06	5.91
Panel (d): Control variables (time-varying)					
Population density (persons per square mile)	3260	52.98	74.60	0.13	801.44
Whites per 1000 of the population	3240	5.28	20.37	0.00	395.10
World market prices of relevant export crops	2176	100.76	40.12	31.00	303.00
Panel (e): Control variables (time-invariant)					
Rainfall coefficient of variation (CV)	2900	0.21	0.07	0.10	0.40
Pre-colonial centralization, categorical (Murdock)	3180	2.45	0.94	1.00	4.00
Railway, dummy	3260	0.41	0.49	0.00	1.00
Settler agriculture, dummy	3260	0.17	0.37	0.00	1.00
Cocoa cultivation, dummy	3260	0.07	0.26	0.00	1.00
Coastal, dummy	3220	0.18	0.38	0.00	1.00
Livestock units per 1000 of the population	3260	706.27	2197.98	0.00	24528.70

Source: See sub-sections 2.4.1 till 2.44.

* indicates that the z-score computation was used to these variables.

[£] indicates that these variables were re-scaled and run from 1 (least suitable) and 8 (most suitable)

4.1 Rainfall

To measure rainfall shocks, we use annual precipitation data from meteorological stations. The great majority of districts under British rule contained at least one such station. Our main explanatory variable is the *absolute* value of standardized rainfall deviation from the long-term mean ($AbsoluteRainfallDeviation_{i,t}$), which yields comparable results with the current economic literature (Hsiang et al., 2013; Dell et al., 2014). In order to capture the non-linear effect of rainfall shocks on imprisonment, we also present the results using the rainfall deviation square term ($RainfallDeviationSquare_{i,t}$). We also employ drought and excessive rainfall dummies, defining 'negative rainfall shock' as a dummy which takes the value of 1 when annual rainfall exceeds more than one standard deviation below, and 'positive rainfall shock' as one standard deviation above the long-run mean. This approach is similar to Iyer and Topalova (2014), Papaioannou (2017) and Jia (2014), among others. The summary statistics of the weather indicators are presented in panel (*b*) of Table 1.

Our annual rainfall indicator does not capture the effects of years of normal annual rainfall with unfavourable distribution, nor years with below or above annual rainfall in which the abnormal precipitation occurred outside the growing season. Despite these limitations, we find the use of annual data largely unproblematic. Annual rainfall data is widely used in the economic literature (Miguel et al., 2004; Hsiang et al., 2013; Dell et al., 2014). Moreover, using annual rainfall figures for over ~2,500 observations is unlikely to result in a type I error (finding a relationship when there is none), but rather to underestimate the effect. A concern with our collected rainfall data could be that historical records have a tendency to suffer from under-reporting and observer's bias (Daly et al., 2007). Such bias may distort an annual total appear as a drought, when there really was none. To address such concerns, we replicate our results with rainfall data obtained from the University of Delaware dataset (Matsuura & Wilmott, 2009), which has been corrected for measurement bias.

4.2. Imprisonment

We collect annual district-level data on total imprisonment (including remand prisoners), as well as three subcategories: (1) short imprisonments (3 months or less), (2) long imprisonments (>3 months)[2] and (3) imprisonment for debt. Each district we include in our dataset has at least one prison within its borders. If more than one prison was present, we take the sum. Unfortunately, we do not possess specific information about convictions for different types of offenses. Yet, we argue that the convictions for petty property offences and tax and fine defaults, dominate the short imprisonments, whilst violent offences are likely to be much more prevalent among the long imprisonments. Following Blakeslee and Fishman (2014), Iyer and Topalova (2015) and Papaioannou (2017), who find that property crimes respond more strongly to economic distress than violent crimes, we expect the 'short imprisonment' variable to be more responsive to weather shocks than the 'long imprisonment' variable.

It is important to state upfront that our research design (1) does not (intend to) capture variation in *absolute levels* of imprisonment across colonial districts, and (2) does not imply that colonial imprisonment should be attributed primarily to harvest failures, let alone climate. Colonial coercive capacity varied considerably from place to place (both across districts and colonies), and incarceration happened to an extent at the discretion of local administrative officers or native authorities. Colonial imprisonment was an instrument of social control, used to lock up criminal, deviant and destitute elements of society, including debt, tax and fine defaulters (Bernault, 2007; Branch, 2005; Hynd, 2011; Killingray, 1986).

Within this context, we can exploit *annual fluctuations* of imprisonment to assess the impact of rainfall extremes on distress. If weather extremes result in loss of agricultural income, and if people have no buffer to cushion this loss of income, we may expect a rise in behaviours and activities that result in imprisonment, including: (1) incidences of distress-induced petty property theft (cf. Papaioannou, 2017), (2) tax, debt and fine defaults resulting in imprisonment

[2] For Kenya, the cut-off point is >6 months. Excluding Kenya from the analysis does not change our results.

(Hynd, 2011); and (3) rebellion and civil disobedience in responses to the fact that rulers prove unable to provide people with a basic level of security and income. Note that our interpretation explicitly accounts for the fact that behaviours resulting in colonial imprisonment may not have been perceived as 'criminal' by African populations, and that we use the descriptive term 'imprisonment' rather than the more contentious 'crime'.

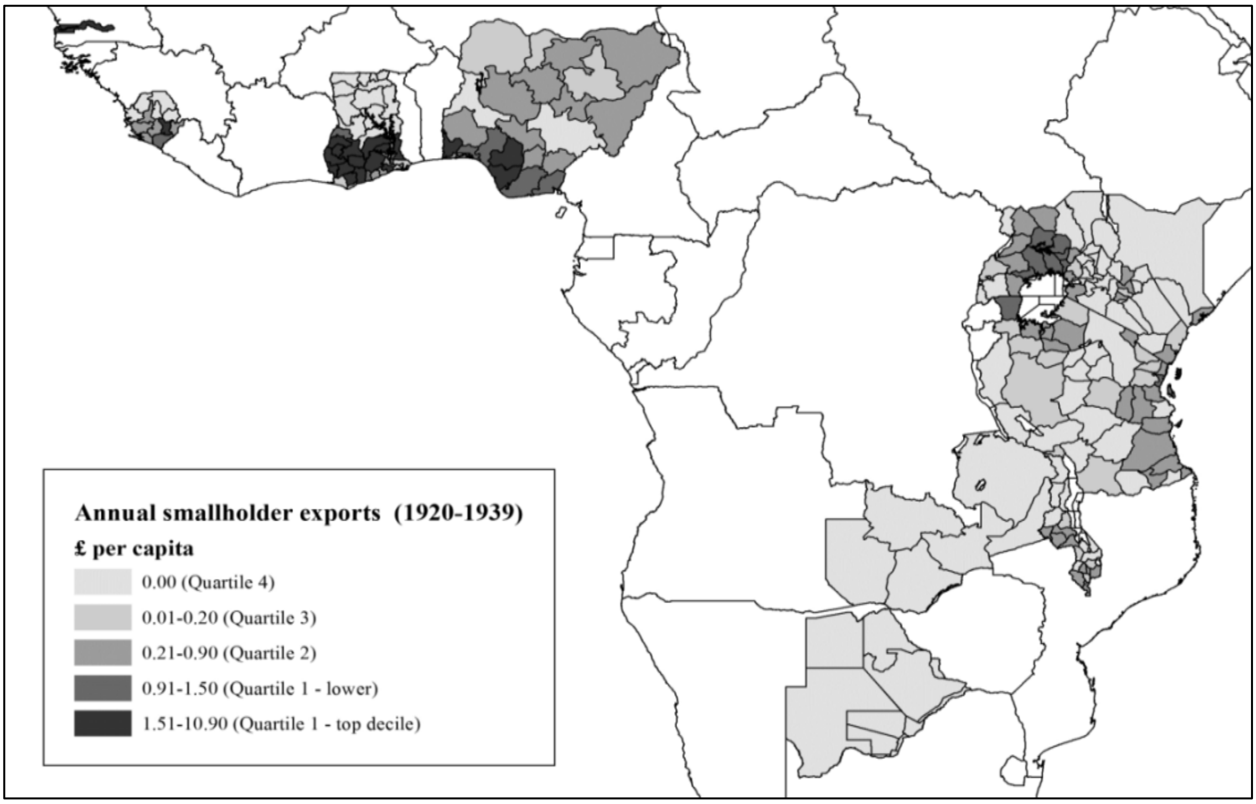
We exploit the following logic to test if weather shocks have a different impact on social tension and distress (i.e. imprisonment) in districts with smallholder-based export crop cultivation compared to districts without. When, in a particular district, imprisonment spikes are pronounced during years of weather shocks (i.e. inflated numbers of debt, tax and fine default, petty thefts and incidences of civil obedience), we take this as an indication that this district is particularly vulnerable to such shocks. If, in another district, imprisonment spikes are mild or absent in years of weather shocks, we take this as an indication that people were able to (1) prevent a fall in agricultural income, for example by cultivating a more diversified or weather-resistant crop portfolio, or (2) cushion the impact of such a fall, for example through the presence of a food relief campaign, or the availability of stored wealth to compensate for lost income. More discussion on potential mechanisms is provided in the conclusion.

We are aware that imprisonment is an imperfect measure of social distress. Males were strongly overrepresented in Africa's colonial prisons, so we are unfortunately not able to capture the gendered impact of weather shocks, which is a particularly regrettable omission considering women's crucial role in agricultural production (Carswell, 2003; MacKenzie, 1999; Vaughan, 1987). Similarly, our data also does not allow us to assess the heterogeneous impact of weather shocks on different social classes or occupational groups. Finally, we have no information about the exact reasons of imprisonment. Despite these limitations, the variable also has its own pronounced strengths. Imprisonment figures are highly responsive to small fluctuations, and the data is uniquely consistent over a considerable geographical and temporal scope. Moreover, we have no reason to believe that the link between annual rainfall and imprisonment statistics was somehow the result of systematic and purposeful manipulation by colonial officials (who could not have fathomed that future research would use yet-to-be-developed econometric techniques to investigate the relationship between rainfall shocks, imprisonment and export crops). Our quantitative results, therefore, are much less susceptible to the kind of colonial manipulation that biases the narrative record.

4.3. Export crop production

To measure the impact of agricultural commercialization on vulnerability to weather shocks, we have constructed a new indicator to estimate *export crop production* at the district level. This indicator is based on the average value (1920-1939) of colony-level exports of export crops (Frankema et al., 2015), divided over the districts within the colonies on the basis of colonial maps and smallholder acreage, and production estimates that tell us where export crops were cultivated. We standardize the values using district population estimates. More details are provided in Appendix B. Figure 3 shows the value per capita of smallholder-grown export crops for each of the districts in our dataset divided into four quartiles (and the top decile separated from the remainder of the first quartile). The resulting spatial distribution of export crop incomes is in accordance with our expectations. Smallholder export crops in interwar British colonial Africa were concentrated in The Gambia (groundnuts), coastal Ghana (cocoa), coastal Nigeria (cocoa and palm oil), northern Nigeria (cotton and groundnuts), the Lake Victoria area (cotton and coffee), coastal Tanzania (cotton, copra and cloves) and southern Malawi (cotton and tobacco). As expected, the cocoa growing regions in Ghana and Nigeria produce the highest export values per capita.

Figure 3. *Export crop production estimate*



***Sources**:* Map constructed by the authors in ArcGIS on the basis of digitized colonial maps. See Appendix B online for further information

In the remainder of our analysis, we split our dataset into halves, the bottom half representing districts in which smallholder production was subsistence oriented, and the top half those in which smallholders cultivated significant amounts of export crops. We have made sure that our results are not driven by a random cut-off point by using alternative cut-off points, quartiles and trimmed samples. Still, we admit that the distinction between "export" and "subsistence" districts is rudimentary. Some districts which did not cultivate crops for export were involved in the commercial production of food crops for local markets. For example, Carswell (2003) argues that smallholders in Kigezi District (Uganda) cultivated 'food crops as export crops' (cf. Von Braun & Kennedy, 1994). We maintain, however, that the income from commercialized food crop cultivation tended to be small compared to income from export crops, for the following reasons: (1) marketing infrastructure in the colonial era was geared towards export and not interregional food trade, (2) markets for food crops were small due to low urbanization rates and land-abundance, (3) universal cultivation of food crops resulted in low market value in good years and food scarcity in bad years (Binswanger & McIntyre, 1987; De Janvry et al., 1991). The main source of income in non-export crop districts tended to be labour migration to more commercialized areas.[3] Our dataset also includes some districts which were dominated by settler agriculture, urban centres or mining areas, for which we control in our analysis (by excluding them from subsamples). While measurements on the district level may brush over within-district variation, our approach is much more refined than most related contributions covering similarly large areas, which tend to distinguish ‘peasant’ and ‘settler’ economies at the country level (Bowden et al. 2008; Moradi & Baten, 2005), and even to classify Africa into macro-regions (Amin, 1972).

To provide more robust evidence for the *causal* impact of export crop cultivation, we construct an alternative export crop indicator which is exogenously determined. This indicator is based on *crop suitability indices* for the most important export crops (cocoa, coffee, cotton, tobacco, palm oil, groundnuts and coconuts) obtained from the FAO-GAEZ project. This suitability index runs from 1 (most suitable) to 8 (least suitable).[4] Similar to other studies that have successfully exploited the exogenous nature of the crop suitability indicators to proxy for adoption or production of various types of crops (Nunn & Qian, 2014; Jia, 2014; Fenske & Kala, 2015), we take the average of the gridded suitability values within the borders of each colonial district. We construct our indicator by combining all relevant export crops, using the average suitability for all export crops for each districts.[5]

Using export crop suitability increases our confidence that institutional factors do not drive our results. However, districts which were more suitable to export crops may have been those with generally more suitable land, better soil and more favourable rainfall patterns. To rule

[3] Which was also a key source of income among the smallholders in Kigezi described in Carswell (2003)
[4] To facilitate interpretation, we have re-scaled this variable so that 1 denotes ‘least suitable’ and 8 ‘most suitable’).
[5] We also created an indicator that includes only the single most suitable export crop per district. Using this alternative indicator yielded very similar results.

out the possibility that our indicator of export crop suitability captures general agricultural suitability (which may in its own right result in higher weather-shock resilience), we also construct an indicator of food crop suitability, equally based on FAO-GAEZ data. We include, maize, millet, sorghum, cassava, yam, potato, sweet potato and rice, and follow a similar procedure as described above for our export crop suitability indicator.

4.4. Control variables

We include a number of time-variant controls, reported in Table 1, panel (d). Firstly, annual total population is estimated on the basis of colonial 'native' censuses, and expressed in terms of population density (per square mile). White population per 1000 of the population is estimated on the basis of 'non-native' censuses. World market prices of relevant export commodities are taken from *Wageningen African Commodity Trade Database* (Frankema et al., 2015).

Secondly, we include a range of observable time-invariant controls, reported in Table 1, panel (e). Pre-colonial centralization is based on the variable "Jurisdictional Hierarchy beyond Local Community" in Murdock's ethnographical atlas (Gray 1999). Pre-colonial chiefdoms and states are defined as places with more than one level of jurisdictional hierarchy beyond the local community. Livestock per 1000 of the population is estimated on the basis of the district averages of livestock censuses (1920-1939). We use observable time-invariant controls to control for the interaction of several observable district-specific characteristics with a linear time trend to take into account their heterogeneous impact (if any) over time. For example, districts with high presence of livestock may become more (or less) resilient in 1939 than in 1920, due to stock accumulation.

Thirdly, we use unobservable time-invariant controls, reported in Table 1, panel (f). This set of controls is estimated by interacting each district with a linear time trend and labelled district-specific effects (DSE). They control for any other unobservable characteristics that we may expect to change over time, such as the possibility that (a) colonial authorities extended their coercive capacity over time (Branch, 2005); (b) previous episodes of distress have made districts more vulnerable, affecting future responses to weather shocks; (c) regions with higher incomes are better off over time because they are able to store wealth; and (d) distress may have been attenuated by the gradual expansion of public infrastructure such as roads and railways, facilitating food relief programs.

5. Results: Rainfall and imprisonment

5.1. Model

To test the effect of rainfall shocks on social distress, we estimate the following equation:

$$Y_{i,t} = \beta_1 \, AbsoluteRainfallDeviation_{i,t} + \delta Z'_{i,t} + \nu_i + \mu_t + (observable \times time)_{i,t} + (unobservable \times time)_{i,t} + \varepsilon_{i,t}\,. \quad (1)$$

where $Y_{i,t}$ denotes the annual standard deviation of imprisonment. $AbsoluteRainfallDeviation_{i,t}$ denotes the absolute rainfall deviation of each district i from the historical long-term mean of the same district. $Z'_{i,t}$ denotes a vector of institutional and economic determinants of tension which we control for in order to avoid any potential omitted variable bias. ν_i and μ_t are district and year fixed effects, respectively. We use these to control for omitted heterogeneity at the level of districts and time periods. These controls are crucial in controlling for factors that may affect the levels of prisoners across all districts in the same year, such distress caused by the Great Depression. To address autocorrelation concerns of weather shocks the standard errors are clustered by district. $(Observable \times time)_{i,t}$ denotes the *observable* district specific characteristics when interacted with a linear time trend (t) and $(unobservable \times time)_{i,t}$ denotes district-specific effects (*DSE)*. ε_{it} is the error term. In all estimations we control for spatial correlation (cross-sectional dependence) by adjusting standard errors following Hoechle (2007).

This way we deal with the issue of migration and spatial spill-overs of distress (for example 'hunger' migration across district borders).

5.2. Results

Table 2 presents our main results, which indicate a robust and significant effect of weather shocks on social distress. The absolute term of rainfall deviation yields a positive sign and maintains a highly statistical significant coefficient throughout our different specifications (columns 1-5). The results in column 4 indicate our preferred and most robust specification. A one standard deviation increase or decrease in rainfall causes a 25 standard deviation increase in social distress. This result is crucial not only for its statistical significance but also for its economic significance.

Table 2. *Weather Shocks and Social Distress*

Dependent variable Imprisonment deviation	(1) OLS	(2) OLS	(3) OLS	(4) OLS	(5) OLS
Absolute rainfall deviation	0.2919	0.2744	0.2700	0.2509	0.1698
	[8.55]***	[6.71]***	[6.66]***	[6.41]***	[3.74]***
Population density					0.0024
					[0.82]
Whites per 1000 of the population					0.0059
					[0.31]
World market prices					-0.0015
					[-0.71]
District FE	N	Y	Y	Y	Y
Time dummies	N	Y	Y	Y	Y
Observable controls × year	N	N	Y	N	N
District-specific effects (unobservable × year)	N	N	N	Y	Y
Number of observations	2335	2335	2246	2335	1665
Number of districts	143	143	137	143	104

Notes: Sample period: 1920–1939. Corrected t-statistics are shown in brackets. Significance level at which the null hypothesis is rejected: ***, 1 percent; **, 5 percent; and *, 10 percent. Standard errors are clustered at the district level. We adjust standard errors for spatial dependency following Hoechle (2007). Given that observable characteristics are redundant once district-specific effects (DSE) are included, we present the results only after controlling for DSE. Including observable characteristics instead of DSE does not change the results.

In Table 3, we include the square term of $RainfallDeviation_{i,t}$ and find that the effect of weather shocks on imprisonment is curvilinear (U-shaped), meaning that both drought and excessive rainfall give rise to higher levels of conviction (columns 1-5). We also test for the symmetricity of the effect by including the ‘positive rainfall shock’ and ‘negative rainfall shock’ variables into the analysis. A standard deviation *increase* in rainfall beyond the mean causes a 0.33 standard deviation increase in imprisonment. Likewise, a standard deviation *decrease* in rainfall causes a 0.25 standard deviation increase in imprisonment. A possible explanation of this asymmetry is that in years of excessive rainfall farmers would lose their entire harvest in a relatively shorter time, whereas in years of drought farmers could hope for late rains.

Table 3. Curvilinear effect of weather shocks on social distress

Dependent variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Imprisonment deviation	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
Rainfall deviation	0.0189	0.0108	0.0140	0.0139	0.0081					
	[0.93]	[0.47]	[0.66]	[0.61]	[0.29]					
Rainfall deviation squared	0.1287	0.1223	0.1179	0.1103	0.0763					
	[8.41]***	[6.34]***	[6.06]***	[6.11]***	[3.63]***					
Positive rainfall shock						0.3905	0.3354	0.3156	0.3074	0.1937
						[7.21]***	[4.98]***	[4.90]***	[4.69]***	[2.39]**
Negative rainfall shock						0.2762	0.2595	0.2516	0.2375	0.1499
						[5.11]***	[4.15]***	[4.08]***	[4.08]***	[2.23]**
Population density					0.0047					0.0045
					[1.35]					[1.31]
Whites per 1000 of the population					0.0160					0.1141
					[0.58]					[0.42]
World market prices					-0.0012					-0.012
					[-0.57]					[-0.57]
District FE	N	Y	Y	Y	N	N	Y	Y	Y	Y
Time dummies	N	Y	Y	Y	N	N	Y	Y	Y	Y
Observable controls × year	N	N	Y	N	N	N	N	Y	N	N
District-specific effects (*unobservable* × year)	N	N	N	Y	Y	N	N	N	Y	Y
Number of observations	2335	2335	2246	2335	1665	2335	2335	2246	2335	1665
Number of districts	143	143	137	143	104	143	143	137	143	104

Notes: Sample period: 1920–1939. Corrected t-statistics are shown in brackets. Significance level at which the null hypothesis is rejected: ***, 1 percent; **, 5 percent; and *, 10 percent. Standard errors are clustered at the district level. We adjust standard errors for spatial dependency following Hoechle (2007).

The impact of a rainfall shock on distress may not be immediate but only felt the next year. Table 4 presents the results when we include lagged weather shocks as determinants of imprisonment. Column 1 shows that social distress is not associated with lags of rainfall shocks. In column 2, none of the interactions have a significant impact on imprisonment and they are jointly not statistically significant (with a p-value of 0.25). This suggests that the observed spikes in imprisonment in our data are caused by weather shocks in that same year (leading to immediate losses in agricultural income), rather than prolonged episodes of adverse weather.

Table 4. *The impact of Lagged Weather Conditions*

Dependent variable	(1)	(2)
Imprisonment deviation	OLS	OLS
Positive rainfall shock *t*	0.3404	0.3772
	[4.99]***	[5.25]***
Negative rainfall shock *t*	0.2422	0.2422
	[3.71]***	[3.58]***
Positive rainfall shock *t - 1*	0.0184	0.0563
	[0.36]	[1.04]
Negative rainfall shock *t - 1*	0.0700	0.0697
	[1.16]	[1.10]
Positive rainfall shock *t* × positive rainfall shock *t - 1*		-0.2407
		[-1.64]
Negative rainfall shock *t* × negative rainfall shock *t - 1*		-0.0128
		[-0.08]
District FE	Y	Y
Time dummies	Y	Y
Observable controls × year	N	N
District-specific effects (unobservable × year)	Y	Y
Number of observations	2178	2178
Number of districts	143	143

Notes: Sample period: 1920–1939. Corrected t-statistics are shown in brackets. Significance level at which the null hypothesis is rejected: ***, 1 percent; **, 5 percent; and *, 10 percent. Standard errors are clustered at the district level. We adjust standard errors for spatial dependency following Hoechle (2007).

In Table 5, we show the results after distinguishing among the different types of prisoners. As argued before (section 4.2), we expect short term imprisonments to be most responsive to weather shocks. This is confirmed by our estimation. The effect of weather shocks on convictions of maximum 3 months is almost twice as large as the effect for convictions above

3 months (columns 1-2). Debt is also statistically significant, which suggests that weather-induced loss of incomes resulted in higher levels of debt default (column 3).

Table 5. *Results with alternative dependent variables*

	(1)	(2)	(3)
Dependent variable:	Convictions <3 months	Convictions >3 months	Debt
Absolute rainfall deviation	0.2114	0.1281	0.1005
	[4.77]***	[2.99]***	[2.89]***
District FE	Y	Y	Y
Time dummies	Y	Y	Y
Observable controls × year	N	N	N
District-specific effects (unobservable × year)	Y	Y	Y
Number of observations	2250	2280	1797
Number of districts	142	144	109

Notes: OLS-FE estimator. Sample period: 1920–1939. Sample period: 1920–1939. Corrected t-statistics are shown in brackets. Significance level at which the null hypothesis is rejected: ***, 1 percent; **, 5 percent; and *, 10 percent. Standard errors are clustered at the district level. We adjust standard errors for spatial dependency following Hoechle (2007).

5.3. Robustness

We perform a range of robustness exercises reported in the Appendix. In Table A-1, we show that the results are largely unchanged when we replace rainfall anomalies obtained from meteorological stations with an alternative measure of rainfall obtained from the University of Delaware world rainfall dataset (Matsuura and Wilmott, 2009). In Table A-2, we distinguish between *limited* drought and excess rainfall (one standard deviation from the long-term rainfall mean) and *exceptional* drought and excess rainfall (one and a half standard deviation from the mean). The results show that the impact of *limited* drought and excess rainfall is smaller than the impact of *exceptional* drought and excess rainfall. The effect increases gradually as the deviation becomes larger, suggesting that the data on weather shocks make intuitive sense. In Table A-3 we include the lag of the dependent variable and run a dynamic panel data model (system-GMM). This specification gives nearly identical results. Table A-4, reports the impact of different combinations of the lags and leads. The effect remains unchanged when we control for the impact of lagged rainfall shocks at time *t - 1* and *t – 2*. Drought and excess rainfall in the lags and leads did not have any significant impact on distress. In Table A-5, we show that the results are robust to clustering standard errors at different levels; standard errors are clustered at the year level, country level as well as two-way clustered at both the year and the country level. Again results are similar to our baseline.

6. Results: The Mitigating Effect of Export Crops

6.1. Model

To test the mitigating effect of export crop cultivation on social distress, we estimate the following equation:

$$Y_{i,t} = \beta_1 \, AbsoluteRainfallDeviation_{i,t} + \pi \, (CashCropProduction \times AbsoluteRainfallDeviation)_{i,t} + \delta Z'_{i,t} + \nu_i + \mu_t + (observable \times time)_{i,t} + (unobservable \times time)_{i,t} + \varepsilon_{i,t} . \quad (2)$$

where $(CashCropProduction \times AbsoluteRainfallDeviation)_{i,t}$ denotes the interaction of above median export crop production with *absolute rainfall deviation (linear)*. The remainder of the variables in this specification is discussed in section 5.

6.2. Results

The results are presented in Table 6. They strongly suggest that access to export crops mitigated the effect of weather shocks on social distress (columns 1-3). We also examine whether the effect remains unchanged when we use the *export crop suitability index* (columns 4-6). Indeed, districts where export crop suitability was high (above median) were less severely affected in years of weather shocks. The lower coefficients of our suitability indicator may reflect the fact that not all areas *suitable* for export crop cultivation were actually *cultivating* export crops. These results conform with our finding that the overall treatment effect of export crops on local farmers was positive. Column 3, which is our preferred estimation, shows that export crops attenuated the effect of weather shocks on social distress by 24.5 per cent.

Table 6. *The Mitigating Effect of Export crops*

Dependent variable	(1)	(2)	(3)	(4)	(5)	(6)
Imprisonment deviation	OLS	OLS	OLS	OLS	OLS	OLS
Absolute rainfall deviation	0.3393 [7.21]***	0.3416 [7.41]***	0.3178 [7.22]***	0.3173 [6.66]***	0.3236 [6.93]***	0.2990 [6.75]***
Export crop *production* × absolute rainfall deviation	-0.2376 [-2.80]***	-0.2765 [-3.26]***	-0.2456 [-3.02]***			
Export crop *suitability* × absolute rainfall deviation				-0.1521 [-1.99]**	-0.2488 [-2.26]**	-0.1761 [-2.09]**
District FE	Y	Y	Y	Y	Y	Y
Time dummies	Y	Y	Y	Y	Y	Y
Observable controls × year	N	Y	N	N	Y	N
District-specific effects (*unobservable* × year)	N	N	Y	N	N	Y
Number of observations	2335	2246	2335	2335	2246	2335
Number of districts	143	137	143	141	135	141

Notes: Sample period: 1920–1939. Corrected t-statistics are shown in brackets. The standard errors are clustered at the district level. Significance level at which the null hypothesis is rejected: ***, 1 percent; **, 5 percent; and *, 10 percent. Standard errors are clustered at the district level.

6.3. Robustness

Before making any claims about causality, one would like to know more about the relationship between export crop production and other district specific characteristics. Was the cultivation of export crops endogenously determined by an underlying variable that may also explain our results? To put it differently, was the cultivation of export crops conditional upon institutional, geographical or economic district characteristics that may also have had a *direct* mitigating effect on weather-induced vulnerability? A strong overlap between centralized political institutions and export crop production, for example, may raise a concern that such institutions explain both higher levels of export crop production, and lower vulnerability to weather shocks. In these scenarios, our export crop indicator would capture the effect of an omitted variable. To mitigate such concerns, we provide a number of robustness tests. First, we provide a simple OLS estimation to see if the production of export crops is determined by any observable district characteristics. We proceed by estimating the following specification:

$$\textit{Exportcrop Production}_i = \text{Exportcrop Suitability}_i + \varphi V_i + \theta_i \qquad (3)$$

Where V_i is a vector including the different categories of district characteristics. The characteristics are divided in three categories: institutional, economic and demographic. *Institutional characteristics* include the colonial presence measured by whites per 1.000 of the population; pre-colonial centralization measured with data taken from Murdock's Ethnographic Atlas; the coercive capacity of the colonial state measured by a twenty year-average of prisoners per 1.000 of the population; and colonial investments measured by the existence of a railway (dummy). *Geographical characteristics* include controls for the length of the rainy season; degree of aridity/humidity of the climate, measured by the 20 year-average rainfall per district; the variability of rainfall using the coefficient of variation (CV) of rainfall for each district; direct access to international trade measured by a coastal dummy; and the suitability for food crops. *Economic characteristics* include alternative sources of income, including livestock measured per 1.000 of the population; rural wage labour measured by the presence of settlers (dummy); and population density as a proxy for land scarcity.[6]

The correlations are presented in Table 7. Column 1 demonstrates that our measure of cash crop production and crop suitability are highly correlated at the 1 per cent level of significance and with a coefficient greater than 0.95, which serves as validation of the empirical strategy. For robustness, instead of taking the average of all cash crops, we only include the single most suitable cash crop per district (results do not change and are not reported). Columns 2-4 present the results from the institutional, geographical and economic controls in turn. Column 5 presents the results when we jointly include the controls. The results suggest that there

[6] We have also controlled for, but not report, the possibility that, coincidentally, the growing season in export crop districts occurs later in the year than in food crop regions, which would imply that the expected effect of rainfall shocks in year t only shows up in these districts in year t+1. Although we find that the effect of rainfall shocks on imprisonment was indeed significantly lower in districts in which the rainy season spills over into the next year, we do not find that the timing of the rainy season and the production of export crops significantly overlap.

are no statistically significant correlations between the observed district characteristics and export crop production.

Table 7. *Correlations between export crops and district characteristics*

	Dependent variable: Export crop *Production*				
	(1)	(2)	(3)	(4)	(5)
	OLS	OLS	OLS	OLS	OLS
Export crop *suitability*	0.9583	0.9217	0.9283	0.9506	1.1992
	[6.63]***	[6.68]***	[5.74]***	[6.23]***	[6.14]***
Institutional controls					
Colonial Presence		-0.0011			-0.0014
		[-0.44]			[-0.39]
Pre-colonial chiefdom		0.2062			0.0259
		[0.87]			[0.18]
Coercive capacity		0.0169			0.0116
		[1.57]			[1.25]
Railway dummy		0.0738			0.0773
		[0.34]			[0.31]
Geographical controls					
Length of rainy season			0.1163		0.1018
			[1.59]		[1.22]
Rainfall long-term average			-0.0001		0.0031
			[-0.02]		[0.51]
Rainfall variability CV			-1.3015		-1.7054
			[-1.37]		[-1.01]
Coastal dummy			-0.3984		-0.5408
			[-1.21]		[-1.49]
Food crop *suitability*			0.1829		0.1515
			[0.76]		[0.61]
Economic controls					
Livestock per 10.000 population				-0.0001	-0.0002
				[-0.47]	[-0.76]
Settler farming dummy				-0.2642	-0.5392
				[-0.93]	[-1.61]
Population density				-0.0006	-0.0011
				[-0.16]	[-0.91]
Number of observations	159	151	139	156	133

Notes: Sample period: 1920–1939. Corrected t-statistics are shown in brackets. The standard errors are clustered at the district level. Significance level at which the null hypothesis is rejected: ***, 1 percent; **, 5 percent; and *, 10 percent. Standard errors are clustered at the district level.

Additionally, we interact alternative explanations with *absolute rainfall deviation* (linear) and include this term in the regression. The most important results are presented in Table 8. Since our export crop indicator is cross-sectional, we were concerned that the mitigating effect of export crops was concentrated either at the beginning or end of our period (1920-1939). To deal with this concern, we interact *absolute rainfall deviation* (linear) with a time trend and include this term in the regression (column 1). No statistically observable trend for the mitigating impact of export crops was found.

To reaffirm that our 'export crop effect' is not driven by overall agricultural suitability, we perform a so-called 'placebo test' with food crop suitability. We split our sample into two halves (above and below median food crop suitability), and interact both absolute rainfall deviation with food crop suitability (*FoodCropSuitability* × *AbsoluteRainfallDeviation*) and export crop production (*CashCropProduction* × *AbsoluteRainfallDeviation*). As shown in column 2, the regression results show that impact of food crop suitability on imprisonment deviation is close to 0. Hence, suitability to food crop cultivation does not explain export crop districts' greater resilience to social distress in the wake of weather shocks. This finding further enhances our confidence that the actual presence of export crops explains our heterogeneous results.

Additional 'horse race tests' are provided in Table A-6, which refute alternative institutional, geographical and income-related explanations that might (directly or indirectly) compete with export crop cultivation as an explanation for our heterogeneous results. The mitigating effect of export crops remain virtually unchanged.

Finally, we also check the robustness of our estimates to the use of alternative samples. A first concern is the possibility that higher spikes of imprisonment in our below-median export crop sample is not driven by the absence of export crops, but by the presence of settlers (all settler districts end up in the below-median export crop sample). A potential concern here would be that land alienation and extractive institutions in settler districts could potentially have an aggravating effect on social distress. We thus exclude the settler districts from the analysis (column 3) and find that our results remain robust. A second issue is that the mitigating effect of export crops is driven by districts with cocoa, which are sometimes portrayed as an exceptional case of successful export crop adoption. To rule out the possibility that our export crop interaction effect is driven by cocoa, we created a sub-sample excluding the cocoa districts from the analysis, and find that our results remain robust (column 4).

Table 8. *Robustness checks: Trends, Food Crops and Sub-Samples*

Dependent variable	(1)	(2)	(3)	(4)
Imprisonment deviation	OLS	OLS	OLS	OLS
Absolute rainfall deviation	0.4270	0.3158	0.3613	0.3179
	[5.22]***	[7.12]***	[7.57]***	[6.77]***
Export crop *production* × absolute rainfall deviation	-0.2355	-0.2445	-0.2290	-0.2482
	[-2.94]***	[-3.01]***	[-2.57]***	[-3.00]***
Absolute rainfall deviation × trend	-0.0103			
	[-1.52]			
Food crop *suitability* × absolute rainfall deviation		0.0475		
		[0.21]		
District FE	Y	Y	Y	Y
Time dummies	Y	Y	Y	Y
Observable controls × year	N	N	N	N
District-specific effects (*unobservable* × year)	Y	Y	Y	Y
Number of observations	2335	2335	1909	2199
Number of districts	141	141	115	133

Notes: Sample period: 1920–1939. Corrected t-statistics are shown in brackets. The standard errors are clustered at the district level. Significance level at which the null hypothesis is rejected: ***, 1 percent; **, 5 percent; and *, 10 percent.

7. Conclusion

This study has investigated two key questions. First, to what extent did weather shocks induce higher levels of social distress in colonial British Africa? Second, to what extent did the cultivation of export crops mitigate weather-induced distress? Building on newly collected data, it makes two contributions. First, our findings suggest that both annual drought and excessive rainfall are strongly associated with spikes in imprisonment. On the basis of previous literature and our reading of colonial administrative reports, we conclude that the key pathway linking rainfall shocks to spiking imprisonment rates is that of falling agricultural incomes. Second, we find that the production of export crops had a *mitigating* effect on weather-induced social distress. In the context of interwar British colonial Africa, districts with more export crops experienced less pronounced spikes of imprisonment in years of weather shocks than those districts with few or none at all. We argue that the presence of export crops drives our heterogeneous result, which holds up to a battery of performed robustness tests that effectively refute a wide range of plausible alternative explanations. Overall, our findings suggest that the surplus revenues generated by export crops partially alleviated negative rural income shocks.[7]

Our findings are set in the historical context of interwar British colonial Africa. Nevertheless, many African smallholders today still face agricultural and climatological conditions resembling those found in this historical setting. We posit therefore, that our highly significant and robust findings on the adverse effects of weather fluctuations, and the mitigating effect of agricultural commercialization bear great relevance for today's vulnerable rural societies, particularly in the contemporary context of accelerating climate change, which generates more severe and frequent weather extremes.

That *even in a colonial context*, smallholder-based export crop cultivation had a mitigating effect on weather-induced distress, suggests that a key policy priority should be to provide smallholders with the ability to produce for external markets. At the same time it would be unwarranted, even reckless, to claim that 'state sponsored' export crops are a 'magic bullet', or even that agricultural commercialization more generally is universally beneficial to mitigating rural societies' vulnerability to weather shocks. When interpreting our findings, it is particularly important to consider the fact that (i) most of colonial tropical Africa was *land abundant*, that (ii) African farmers combined cultivation of export and subsistence crops, and that (iii) smallholders

[7] Our findings are in line with Burgess and Donaldson (2010) for colonial India and with Papaioannou (2017) for colonial South and Southeast Asia; both arguing that openness to trade and crop diversification provide an alternative insurance mechanism to rural households in coping with adverse weather shocks.

generally did not have to incur debts to participate in cultivation for export, despite the fact that inputs were low and farming techniques basic. Moreover, in districts that were unsuitable for the cultivation of export crops, their introduction would not be a viable strategy to cope with climate extremes.

Our empirical strategy enabled us to tease out the *robust overall effect* export crops had in reducing weather-induced social distress. The scope of our analysis and the scarcity of reliable data prevented us from analyzing the complex, variegated set of mechanisms through which agricultural commercialization mitigates the vulnerability of African farmers. Our findings should, therefore, be interpreted in the light of the existing rich literature, in which such mechanisms are exposed in greater detail.

Three complementary sets of entangled mechanisms require particular consideration. Firstly, how does agricultural commercialization affect *food production* in years of abnormal weather? Previous literature has suggested that the (partial) substitution of food crops with export crops resulted in the disappearance of food buffers and, as a result, increased the degree of rural vulnerability after a disappointing harvest. This food-crop/export-crop substitution effect may be aggravated by the fact that some export crops, such as cotton or tobacco, are non-edible and highly labor intensive. Yet it still remains ill-understood how the cultivation of export crops could have enhanced resilience in the light of this substitution mechanism. The introduction of new, exportable crops may reduce the risk of *complete* harvest failure, as weather conditions often impact export crops and local food crops differently (Maxwell & Fernando 1989; Morton, 2007). Furthermore, 'state sponsored' export crops tend to include extension services, agricultural innovations and new technological inputs, all or any of which may boost the productivity of food crops as well (Goetz, 1993). Despite few high-yielding food crop varieties being brought to smallholders in colonial Africa, the adoption of export crops did coincide with a partial switch to less labor-intensive and more drought-resistant food crops, such as cassava which, although less nutritious, have enhanced food security (Tosh, 1980).

Secondly, how does agricultural commercialization affect *household incomes* in years of harvest failure? If the cultivation of export crops provokes food shortages in bad years, it may still enhance smallholders' abilities to smooth consumption and obtain food on the market. Commercial production enables households to convert (a part of) their harvest into storable wealth (such as cash or livestock), enabling the purchase of food in bad years. This 'consumption smoothing' is conditional upon smallholders actually receiving the income benefits from export crop cultivation, which is not self-evident. Structural indebtedness or excessive taxation may negatively impact storable wealth, preventing smallholders from utilizing their export crop income to alleviate distress (Bates, 1981; Scott, 1976). While the colonial tax burden on smallholder export crops could be excessive indeed, it was not high enough to completely annul the gains in purchasing power arising from export crop cultivation (De Haas, 2017).

Thirdly, how does agricultural commercialization affect *collective coping and relief mechanisms* in years of harvest failure? The adoption of export crops does not only have repercussions on the level of the individual smallholder, but also on the broader institutional and infrastructural context. While scholars have argued that rural commercialization erodes pre-capitalist, 'moral economy' insurance institutions (Fafchamps, 1992; Scott, 1976; Watts, 1983), the revenue-generating potential of export crop regions may also provide the state with the means to invest in technology diffusion, infrastructure and food security (Govereh & Jayne, 2003; Burgess and Donaldson, 2010; Papaioannou, 2017).

We find it plausible that each of the three channels described above contributes to explaining the *overall mitigating* effect of export crops found in this study, whilst reiterating that colonial occupation may – through excessive taxation, insufficient commitment to rural development or insistence on a limited set of 'state sponsored' export crops – have prevented smallholders from realizing maximum potential benefit from agricultural commercialization. Further disentangling the mechanisms suggested above should continue to be a top priority for scholars and policy makers.

We suggest a number of directions for future research. Firstly, in relation to the discussion above, it would be of particular interest to see if the effect of export crops is primarily channelled through higher *private income* or through *public investments* in infrastructure and food aid programs. Secondly, further study may uncover different results for aspects of distress not touched upon in this paper, such as malnutrition or uneven vulnerabilities across class and gender. Thirdly, it would be valuable to give focused attention to the actual adoption of different types of export crops and identify conditions determining successful adoption. Our finding that export crop suitability mattered for the adoption of export crops implies that areas unsuitable for such traditional export crops require different commercialization strategies; whether that being a higher reliance on drought-resistant food crops, such as cassava or sorghum, or alternative, non-agricultural 'roads to openness'. Fourthly, while this study finds a *short term* mitigating effect of export crops on social distress, it does not address the *long-term* effects, which may include the risk of overspecialization in a primary commodity or the adverse environmental impacts of agricultural commercialization. Thus, a more complete understanding of the impact of export crops would require further empirical study into the *long-run effects* of these crops.

8. References

Adano, W. R., Dietz, T., Witsenburg, K., & Zaal, F. (2012). 'Climate change, violent conflict and local institutions in Kenya's drylands'. *Journal of Peace Research*, 49(1): 65-80.

Adger, W. N. (2000). Social and ecological resilience: are they related? *Progress in human geography*, 24

Ahmed, S. A., Diffenbaugh, N. S., & Hertel, T. W. (2009). Climate volatility deepens poverty vulnerability in developing countries. *Environmental Research Letters*, 4(3), 034004.

Almer, C., & Boes, S. (2012). "Climate (change) and conflict: Resolving a puzzle of association and causation, " Discussion Papers, Department of Economics, University of Bern

Amin, S. (1972). Underdevelopment and Dependence in Black Africa-Origins and Contemporary Forms. *The Journal of Modern African Studies*, *10*(4), 503-524.

Auffhammer, M., Hsiang, S. M., Schlenker, W., & Sobel, A. (2013). Using weather data and climate model output in economic analyses of climate change. *Review of Environmental Economics and Policy*, 7(2), 181-198.

Austin, G. (2008). Resources, techniques, and strategies south of the Sahara: revising the factor endowments perspective on African economic development, 1500-2000. *The Economic History Review*, *61*(3), 587-624.

_______ (2014a). Explaining and evaluating the cash crop revolution in the "peasant" colonies of tropical Africa, ca. 1890-ca. 1930: beyond "vent for surplus". In E. Akyeampong, R. H. Bates, N. Nunn, & J. Robinson, A. (Eds.), *Africa's development in historical perspective* (pp. 295-320). Cambridge: Cambridge University Press.

_______ (2014b). Vent for surplus or productivity breakthrough? The Ghanaian cocoa take-off, c. 1890–1936. *The Economic History Review*, *67*(4), 1035-1064

Barrios, S, Bertinelli, L., & Strobl E. (2010). "Trends in Rainfall and Economic Growth in Africa: A Neglected Cause of the Growth Tragedy," *The Review of Economics and Statistics*, 92(2): 350-366.

Bates, R. H. (1981). *Markets and states in tropical Africa: the political basis of agricultural policies.* Berkeley, CA: University of California Press.

Benjaminsen, T. A., Alinon, K., Buhaug, H., & Buseth, J. T. (2012). 'Does climate change drive land-use conflicts in the Sahel?'. *Journal of Peace Research*, 49(1): 97-111.

Bernault, F. (2007). The Shadow of Rule: Colonial Power and Modern Punishment in Africa. *Cultures of Confinement: A History of the Prison in Africa, Asia and Latin America*, 55-94.

Binswanger, H. P., & McIntire, J. (1987). Behavioral and Material Determinants of Production Relations in Land-Abundant Tropical Agriculture. *Economic Development and Cultural Change, 36*(1),73-99

Blakeslee, D. S., & Fishman, R. (2014). Weather shocks, crime, and agriculture: evidence from India. *Social Science Research Network*.

Blattman, C., & Miguel, E. (2010). "Civil war," *Journal of Economic Literature*, 3-57.

Bowden, S., Chiripanhura, B., & Mosley, P. (2008). Measuring and explaining poverty in six African countries: a long-period approach. *Journal of International Development, 20*(8), 1049-1079.

Branch, D. (2005). Imprisonment and Colonialism in Kenya, c.1930-1952: Escaping the Carceral Archipelago. *The International Journal of African Historical Studies*, 38(2), 239-265

Braun, J. V., & Kennedy, E. (1994). *Agricultural commercialization, economic development, and nutrition*. Johns Hopkins University Press.

Brückner, M., & Ciccone, A. (2011). 'Rain and the democratic window of opportunity'. *Econometrica*, 79(3): 923-947.

Bryceson, D. F. (1990). *Food insecurity and the social division of labour in Tanzania, 1919-85*. Springer.

___________ (2002). The scramble in Africa: reorienting rural livelihoods.*World development*, *30*(5), 725-739.

Buhaug, H., Nordkvelle, J., Bernauer, T., Böhmelt, T., Brzoska, M., Busby, J. W., ... & Goldstone, J. A. (2014). One effect to rule them all? A comment on climate and conflict. *Climatic Change*, *127*(3-4), 391-397.Fjelde, H., & von Uexkull, N. (2012). 'Climate triggers: Rainfall anomalies, vulnerability and communal conflict in sub-Saharan Africa'. *Political Geography*, 31(7): 444-453.

Burgess, R., & Donaldson, D. (2010). Can openness mitigate the effects of weather shocks? Evidence from India's famine era. *The American Economic Review*, 449-453.

Burke, M., Hsiang, S. M., & Miguel, E. (2014). *Climate and conflict* (No. w20598). National Bureau of Economic Research.

Carswell, G. (2003). Food crops as cash crops: the case of colonial Kigezi, Uganda. *Journal of Agrarian Change*, *3*(4), 521-551.

Chambers, R., & Conway, G. (1992). *Sustainable rural livelihoods: practical concepts for the 21st century*. Institute of Development Studies (UK).

Christian, C., & Fenske, J. (2015). Economic shocks and unrest in French West Africa. *CSAE Working Paper WPS/2015-01*.

Collier, P., & Dercon, S. (2014). African Agriculture in 50Years: Smallholders in a Rapidly Changing World?. *World development*, *63*, 92-101.

Couttenier, M., & Soubeyran, R. (2011). Drought and civil war in Sub-Saharan Africa. *FEEM Working Paper No. 150*.

Daly, C., Gibson, W. P., Taylor, G. H., Doggett, M. K., & Smith, J. I. (2007). Observer bias in daily precipitation measurements at United States cooperative network stations. *Bulletin of the American Meteorological Society*, *88*(6), 899.

De Haas, M. (2017). Measuring rural welfare in colonial Africa: did Uganda's smallholders thrive? *The Economic History Review, Forthcoming*.

De Janvry, A., Fafchamps, M., & Sadoulet, E. (1991). Peasant household behavior with missing markets: Some paradoxes explained. *Economic Journal, 101*(409), 1400-1417.

Dell, M., Jones, F. B. & Olken, B. (2014) "What do we learn from the weather? The new climate-economy literature", *Journal of Economic Literature* 52(3), 740-798

Deschenes, O. (2014). Temperature, human health, and adaptation: A review of the empirical literature. *Energy Economics*, 46, 606-619.

Ellis, F. (2000). The determinants of rural livelihood diversification in developing countries. *Journal of Agricultural Economics*, *51*(2), 289-302.

Ember, C. R., Adem, T. A., Skoggard, I., & Jones, E. C. (2012). Livestock raiding and rainfall variability in Northwestern Kenya. *Civil Wars, 14*(2), 159-181.

Fafchamps, M. (1992). 'Solidarity networks in preindustrial societies: Rational peasants with a moral economy'. *Economic Development and Cultural Change*: 147-174.

___________ (2003). *Rural poverty, risk and development*. Edward Elgar Publishing.

Fenske, J., & Kala, N. (2015). Climate and the slave trade. *Journal of Development Economics*, 112, 19-32.

Folke, C. (2006). Resilience: the emergence of a perspective for social–ecological systems analyses. *Global Environmental Change*, 16(3), 253-267.

Frankema, E., Williamson, J., & Woltjer, P. (2015). *An economic rationale for the African scramble: the commercial transition and the commodity price boom of 1845-1885* (No. w21213). National Bureau of Economic Research.

Gallopín, G. C. (2006). Linkages between vulnerability, resilience, and adaptive capacity. *Global environmental change*, 16(3), 293-303

Giller, K. E., Witter, E., Corbeels, M., & Tittonell, P. (2009). Conservation agriculture and smallholder farming in Africa: the heretics' view. *Field crops research*, *114*(1), 23-34.

Goetz, S. J. (1993). Interlinked Markets and the Cash Crop: Food Crop Debate in Land-Abundant Tropical Agriculture. *Economic Development and Cultural Change*, *41*(2), 343-361.

Govereh, J., & Jayne, T. S. (2003). Cash cropping and food crop productivity: synergies or trade-offs?. *Agricultural economics*, *28*(1), 39-50.

Gray, J. P. (1999). A corrected ethnographic atlas. *World Cultures*, 10(1), 24-85.

Harari, M., & La Ferrara, E. (2013). Conflict, Climate and Cells: A disaggregated analysis.

Heldring, L., & Robinson, J. A. (2012). *Colonialism and economic development in Africa* (No. w18566). National Bureau of Economic Research.

Hendrix, C. S., & Salehyan, I. (2012). Climate change, rainfall, and social conflict in Africa. *Journal of Peace Research*, *49*(1), 35-50.

Hoechle, D. (2007). Robust standard errors for panel regressions with cross-sectional dependence. Stata

Hogendorn, J. S. (1978). *Nigerian groundnut exports : origins and early development*. Zaria: Ahmadu Bello University Press.

Hsiang, S. M. (2016). *Climate Econometrics* (No. w22181). National Bureau of Economic Research.

Hsiang, S. M., Burke, M., & Miguel, E. (2013). 'Quantifying the influence of climate on human conflict'. *Science*, 341(6151): 53-67.

Hynd, S. (2011). "Law, Violence and Penal Reform: State Responses to Crime and Disorder in Colonial Malawi, c. 1900–1959." *Journal of Southern African Studies* 37(3), 431-447.

Isaacman, A. (1996). *"Cotton is the mother of poverty": peasant resistance to forced cotton production in Mozambique, 1938-1961*. London: James Currey.

Iyer, L., & Topalova, P. B. (2014). Poverty and crime: evidence from rainfall and trade shocks in India. *Harvard Business School BGIE Unit Working Paper*, (14-067).

Jia. R. (2014). "Weather shocks, sweet potatoes and peasant revolts in historical China", *The Economic Journal*, *124*(575), 92-118.

Killingray, D. (1986). The Maintenance of Law and Order in British Colonial Africa. *African Affairs*, *85*(340), 411-437

Klomp, J., & Bulte, E. (2013). 'Climate change, weather shocks, and violent conflict: a critical look at the evidence'. *Agricultural Economics*, 44(s1): 63-78.

Likaka, O. (1997). *Rural Society and Cotton in Colonial Zaire*. Univ of Wisconsin Press.

MacKenzie, A. F. D. (1999). Betterment and the gendered politics of maize production, Murang'a district, Central Province, Kenya, 1880-1952. *Canadian Journal of African Studies*, 33(1), 64-97.

Mandala, E. C. (1990). *Work and Control in a Peasant Economy: A History of the Lower Tchiri Valley in Malawi,1859-1960*. Madison: University of Wisconsin Press.

Matsuura, K. and Willmott, C. J. (2009). *Terrestrial precipitation: 1900–2008 gridded monthly time series.* Centre for Climatic Research Department of Geography, Centre for Climatic Research, University of Delaware.

Maxwell, S., & Fernando, A. (1989). Export crops in developing countries: The issues, the facts, the policies. *World Development*, 17(11), 1677-1708

Maystadt, J. F., & Ecker, O. (2014). Extreme weather and civil war: does drought fuel conflict in Somalia through livestock price shocks?. *American Journal of Agricultural Economics*, 96(4), 1157-1182.

Miguel, E., Satyanath, S., & Sergenti, E. (2004). ‘Economic shocks and civil conflict: An instrumental variables approach’. *Journal of Political Economy*, 112(4): 725-753.

Moradi, A., & Baten, J. (2005). Inequality in Sub-Saharan Africa: new data and new insights from anthropometric estimates. *World Development, 33*(8), 1233-1265.

Morton, J. F. (2007). The impact of climate change on smallholder and subsistence agriculture. *Proceedings of the National Academy of Sciences*, 104(50), 19680-19685.

Mosley, P. (1983). *The settler economies: studies in the economic history of Kenya and Southern Rhodesia, 1900-1963*. Cambridge; New York, N.Y.: Cambridge University Press.

Myint, H. (1958). The classical theory of international trade and the underdeveloped countries. *Economic Journal, 68,* 317-337.

Nunn, N., & Qian, N. (2014). US food aid and civil conflict. *The American Economic Review*, *104*(6), 1630-1666.

Papaioannou, K. J. (2016). ‘Climate Shocks and Conflict: Evidence from colonial Nigeria’. *Political Geography*, 50(1): 33-47

Papaioannou, K. J. (2017). 'Hunger Makes a Thief of Any Man': Poverty and Crime in British Colonial Asia. *European Review of Economic History* 21(1), 1-28.

Papaioannou, K. J., & Van Zanden, J. L. (2015). The dictator effect: how long years in office affect economic development. *Journal of Institutional Economics, 11*(01), 111-139.

Papaioannou, K. J. & Frankema, E. (2017). Rainfall Patterns and Human Settlement in Tropical Africa and Asia Compared. Did African Farmers Face Greater Insecurity?” Discussion paper DP 11795: Centre for Economic Policy Research (CEPR).

Polly Hill. (1997). *The migrant cocoa-farmers of southern Ghana: A study in rural capitalism*. LIT Verlag Münster.

Raikes, P., & Gibbon, P. (2000). ‘Globalisation’ and African export crop agriculture. *The Journal of Peasant Studies*, *27*(2), 50-93.

Raleigh, C., & Urdal, H. (2007). 'Climate change, environmental degradation and armed conflict'. *Political Geography*, 26(6): 674-694.

Roberts, R. L. (1996). Two worlds of cotton : colonialism and the regional economy in the French Soudan, 1800-1946. Stanford, Calif.: Stanford University Press.

Schlenker, W., & Lobell, D. B. (2010). Robust negative impacts of climate change on African agriculture. *Environmental Research Letters*, *5*(1), 014010.Buhaug, H. (2010). Climate not to blame for African civil wars. *Proceedings of the National Academy of Sciences, 107*(38), 16477-16482.

Scoones, I. (2009). Livelihoods perspectives and rural development. *The Journal of Peasant Studies*, *36*(1), 171-196.

Scott, J. C. (1976). The moral economy of the peasant: Subsistence and rebellion in Southeast Asia. *Yale UP (New Haven).*

Sen, A. (1981). *Poverty and famines: an essay on entitlement and deprivation*. Oxford university press.

Swindell, K., & Jeng, A. (2006). *Migrants, credit and climate: the Gambian groundnut trade, 1834-1934* (Vol. 12). Leiden-Boston: Brill.

Theisen, O. M. (2012). 'Climate clashes? Weather variability, land pressure, and organized violence in Kenya, 1989–2004'. Journal of Peace Research, 49(1): 81-96.

Thompson, E. P. (1971). The moral economy of the English crowd in the eighteenth century. *Past & present*, (50), 76-136.

Tosh, J. (1980). The cash-crop revolution in tropical Africa: an agricultural reappraisal. *African Affairs*, 79(314), 79-94.

Vaughan, M. (1987). The story of an African famine: Gender and famine in twentieth-century Malawi: Cambridge University Press.

Watts, M. J. (1983). Silent Violence: Food, Famine and Peasantry in Northern Nigeria (Vol. 18). Berkeley. Cal.: University of California Press

Watts, M. J., & Bohle, H. G. (1993). The space of vulnerability: the causal structure of hunger and famine. *Progress in human geography, 17*(1), 43-67.

Witsenburg, K. M., & Adano, W. R. (2009). 'Of rain and raids: Violent livestock raiding in northern Kenya'. *Civil Wars*, 11(4): 514-538.

Wrigley, C. C. (1970). Crops and wealth in Uganda: a short agrarian history.*Crops and wealth in Uganda: a short agrarian history.*

Primary data from *The National Archives of the UK* (TNA), housed in 'Kew', London:
Bechuanaland Protectorate *Blue Books of Statistics*, DO 26
_____________________ *Annual Departmental Reports*, DO 102
The Gambia *Blue Books of Statistics,* CO 90
__________ *Annual Departmental Reports*, CO 89
Gold Coast *Blue Books of Statistics*, CO 100
_________ *Annual Departmental Reports*, CO 98
Kenya *Blue Books of Statistics*, CO 543
_____ *Annual Departmental Reports,* CO 544
Nigeria *Blue Books of Statistics*, CO 660
______ *Annual Departmental Reports*, CO 657
Southern Nigeria Protectorate, *Blue Books of Statistics*, CO 473
_______________________, *Annual Departmental Reports,* CO 592
Northern Rhodesia *Blue Books*, CO 798
_______________ *Annual Departmental Reports*, CO 795
Nyasaland Protectorate *Blue Books*, CO 452
__________________ *Annual Departmental Reports,* CO 626
Sierra Leone *Blue Books*, CO 267
__________ *Annual Departmental Reports*, CO 270
Tanganyika Territory *Blue Books*, CO 726
_________________ *Annual Departmental Reports*, CO 736
Zanzibar *Blue Books*, CO 690
_______ *Annual Departmental Reports*, CO 688
Uganda Protectorate *Blue Books*, CO 613
______ *Annual Departmental Reports*, CO 685

Appendix A. Robustness Tests

Table A-1. *Main results with absolute rainfall deviation, Grids*

Dependent variable	(1)	(2)	(3)	(4)	(5)
Imprisonment deviation	OLS	OLS	OLS	OLS	OLS
Absolute rainfall deviation (Grids)	0.1632	0.1794	0.1636	0.1689	0.1667
	[4.95]***	[4.89]***	[4.63]***	[5.07]***	[3.85]***
Population density					0.0045
					[1.35]
Whites per 1000 of the population					0.0117
					[0.45]
World market prices					-0.0010
					[-0.52]
District FE	N	Y	Y	Y	Y
Time dummies	N	Y	Y	Y	Y
Observable controls × year	N	N	Y	N	N
District-specific effects (unobservable × year)	N	N	N	Y	Y
Number of observations	2680	2680	2422	2680	1827
Number of districts	156	156	137	156	105

Notes: Sample period: 1920–1939. Corrected t-statistics are shown in brackets. Significance level at which the null hypothesis is rejected: ***, 1 percent; **, 5 percent; and *, 10 percent. Standard errors are clustered at the district level.

Table A-2. *The Impact of Limited and Exceptional Droughts & Excessive rainfall on Social Distress*

Dependent variable:	Imprisonment deviation			
	(1)	(2)	(3)	(4)
Exceptional positive rainfall shock	0.3256	0.3566	0.3627	0.3540
	[3.38]***	[3.79]***	[3.84]***	[3.69]***
Exceptional negative rainfall shock	0.3259	0.2955	0.2461	0.2204
	[3.32]***	[2.78]***	[2.37]**	[2.26]**
Limited positive rainfall shock	0.2523	0.1799	0.1573	0.1558
	[3.73]***	[2.36]**	[2.12]**	[2.07]**
Limited negative rainfall shock	0.1522	0.1448	0.1585	0.1540
	[2.32]**	[2.06]**	[2.38]**	[2.55]**
District FE	N	Y	Y	Y
Time dummies	N	Y	Y	Y
Observable controls × year	N	N	Y	N
District-specific effects (unobservable × year)	N	N	N	Y
Number of observations	2335	2335	2246	2335
Number of districts	143	143	137	143

Notes: OLS estimator. Sample period: 1920–1939. Sample period: 1920–1939. Corrected t-statistics are shown in brackets. Significance level at which the null hypothesis is rejected: ***, 1 percent; **, 5 percent; and *, 10 percent. Standard errors are clustered at the district level.

Table A-3. *The impact of Lagged Imprisonment and Absolute Rainfall Deviation*

Dependent variable	(1)	(2)	(3)
Imprisonment deviation	GMM	GMM	GMM
Imprisonment deviation, lagged *t - 1*	0.4273	0.6906	
	[10.71]***	[14.99]***	
Absolute rainfall deviation	0.1926	0.2361	0.2073
	[4.15]***	[2.79]***	[3.29]***
Absolute rainfall deviation, *t - 1*			-0.0089
			[-0.04]
Absolute rainfall deviation, *t - 2*			0.0472
			[0.92]
District FE	Y	Y	Y
Time dummies	Y	Y	Y
Observable controls × year	N	N	N
District-specific effects (unobservable × year)	N	Y	Y
Number of observations	2216	2216	1995
Number of districts	143	137	143
Number of instruments	169	309	168
AR1 statistics (p-value)	0.000	0.000	0.000
AR2 statistics (p-value)	0.216	0.638	0.220
Hansen test (p-value)	0.987	0.942	0.299

Notes: System-GMM estimation for dynamic panel data-model. Sample period: 1920–1939. Corrected t-statistics are shown in brackets. Significance level at which the null hypothesis is rejected: ***, 1 percent; **, 5 percent; and *, 10 percent. Second (and latter) lags were used as instruments in the first-differenced equations, and their once-lagged first differences were used in the levels equation. Two-step results using robust standard errors corrected for finite samples using correction. We adjust standard errors for spatial dependency following Conley (1999).

Table A-4. *The Impact of Limited and Exceptional Droughts & Excessive rainfall on Social Distress*

	Dependent variable: Imprisonment deviation				
	(1)	(2)	(3)	(4)	(5)
Positive rainfall shock $t+2$	-0.0062				
	[-0.12]				
Negative rainfall shock $t+2$	0.0587				
	[-1.16]				
Positive rainfall shock $t+1$		0.0834			
		[1.63]			
Negative rainfall shock $t+1$		0.0170			
		[0.33]			
Positive rainfall shock t			0.3354		
			[4.98]***		
Negative rainfall shock t			0.2595		
			[4.15]***		
Positive rainfall shock $t-1$				-0.0006	
				[-0.01]	
Negative rainfall shock $t-1$				0.0560	
				[0.95]	
Positive rainfall shock t - 2					-0.0210
					[-0.37]
Negative rainfall shock t - 2					0.0412
					[0.72]
District FE	Y	Y	Y	Y	Y
Time dummies	Y	Y	Y	Y	Y
Observable controls × year	N	N	N	N	N
District-specific effects (unobservable × year)	Y	Y	Y	Y	Y
Number of observations	2166	2286	2335	2211	2077
Number of districts	143	143	143	143	143

Notes: OLS estimator. Sample period: 1920–1939. Corrected t-statistics are shown in brackets. Significance level at which the null hypothesis is rejected: ***, 1 percent; **, 5 percent; and *, 10 percent. Standard errors are clustered at the district level. Column (3) replicates the results in column 7 of Table 3.

Table A-5. *Clustering Standard Errors at Different Levels*

	Dependent variable: Imprisonment deviation			
	(1)	(2)	(3)	(4)
	OLS	OLS	OLS	OLS
Rainfall Deviation Stations	0.2919	0.2744	0.2700	0.2509
	(0.0437)	(0.0408)	(0.0405)	(0.0391)
		<0.0930>	<0.0854>	<0.0834>
		[0.0905]	[0.0825]	[0.0759]
Rainfall Deviation Grids	0.1632	0.1739	0.1636	0.1695
	(0.0371)	(0.0355)	(0.0353)	(0.0336)
		<0.0865>	<0.0752>	<0.0725>
		[0.0793]	[0.0716]	[0.0667]
District FE	N	Y	Y	Y
Time dummies	N	Y	Y	Y
Observable controls x year	N	N	Y	N
District-specific effects (unobservable x year)	N	N	N	Y
Number of observations	2335	2680	2422	2680

Notes. The specifications and the estimated coefficients in this Table are the same as in Table A-5. The standard errors in columns 2–4 are clustered at the district level (in parentheses), the country level (in angle brackets) as well as two-way clustered both the country and the year level (in square brackets).

Table A-6. *Alternative explanations*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable	Institutions			Geography			Income	
Imprisonment deviation	Whites per 100	Pre-colonial chiefdoms	Coercive capacity	Length of rainy season	Rainfall Zones	Rainfall variability	Livestock	Settler Farming
Absolute rainfall deviation	0.3393	0.3416	0.3178	0.3393	0.3416	0.3178	0.3173	0.3236
	[7.21]***	[7.41]***	[7.22]***	[7.21]***	[7.41]***	[7.22]***	[6.66]***	[6.93]***
Export crop *production* × absolute rainfall deviation	-0.2376	-0.2765	-0.2456	-0.2376	-0.2765	-0.2456	-0.2765	-0.2765
	[-2.80]***	[-3.26]***	[-3.02]***	[-2.80]***	[-3.26]***	[-3.02]***	[-3.26]***	[-3.26]***
Alternative explanation x absolute rainfall deviation	-0.0002	0.0063	-0.0008	0.0151	0.0001	-0.0631	0.0061	-0.0156
	[-0.76]	[0.18]	[-1.00]	[1.34]	[0.28]	[-0.56]	[0.56]	[-0.65]
District FE	Y	Y	Y	Y	Y	Y	Y	Y
Time dummies	Y	Y	Y	Y	Y	Y	Y	Y
Observable controls x year	Y	Y	Y	Y	Y	Y	Y	Y
District-specific effects (*unobservable* x year)								
Number of observations	2335	2246	2335	2335	2246	2335	2246	2335
Number of districts	143	139	143	143	137	143	137	143

Notes: Sample period: 1920–1939. Corrected t-statistics are shown in brackets. Significance level at which the null hypothesis is rejected: ***, 1 percent; **, 5 percent; and *, 10 percent. Standard errors are clustered at the district level.

Appendix B. Export crop production calculation (for online Appendix)

We proceed in the following steps:

(i) We obtain *annual, crop-specific, country-level export crop export values*, compiled in the *Wageningen African Commodity Trade Database* (henceforth WTD) (Frankema et al., 2015), for the years 1920 to 1939;

(ii) We collect *annual, crop-specific, district-level, smallholder export crop production estimates* for the years 1920 to 1939. We use a range of sources, including colonial maps, annual statistics and agricultural censuses. We inter-/extrapolate if production data is not available for all years. Whenever part of export crop production happens on expatriate farms, we deduct their share. The data is rough but suffices to estimate the shares of different districts in total country production.

(iii) We use (ii) to distribute (i) over the individual districts, for each of the countries in our dataset.

(iv) We add up the value of all smallholder grown export crops in a district to arrive at an indicator of *annual, district-level export crop export values per district*.

(v) We divide (iv) over *annual, district-level population figures* to arrive at an indicator of *annual, district-level, smallholder export crop export value per capita*. We inter-/extrapolate if population data is not available for all years.

(vi) We take the average of (v) for the years 1920-1939 to arrive our indicator of *export crop production (average annual value of export crops in pounds per capita).*

A simple example is given below. We have followed a similar procedure for all the districts in our dataset.

(i) The total value of Nyasaland's cotton production in the years 1920-1939, following the Wageningen African Trade Database, fluctuated between a minimum of £35 thousand in 1932 and a maximum of £205 thousand in 1935.

(ii) The colonial Bluebooks of Nyasaland report annual estimates of district-level native cotton production. The *Lower Shire District*'s contribution, according to these estimates, fluctuated between 21 and 65 per cent of the country's total cotton production between 1920 and 1939.

(iii) By multiplying the annual value (i) with the Lower Shire's production share (ii), we find that the value of cotton produced in the Lower Shire district fluctuated between a minimum of £14 thousand and a maximum of £67 thousand.

(iv) The Lower Shire District only produces cotton so we can use the cotton figures, without having to add up values of different export crops.

(v) We deflate these annual district-level values with district-level population numbers to obtain an estimate of *gross-export-crop-income per capita*, which in the case of the Lower Shire varies between £0.2 (during the depression years), and £0.8 per capita.

(vi) Because both the district-level production estimates and population figures need to be treated as rough proxies of reality, we discard annual fluctuations and take the average of the entire 20-year period as our indicator for export crop intensity. The average gross annual per capital export income for the Lower Shire district is £0.4.

Gold Coast

District borders are the administrative borders from 1930 reported in Gold Coast 'Administration Report 1930'. District-level, smallholder production shares for cocoa, cola nuts, copra and palm oil are estimated using maps in Cardinall (1932) and Kaplan et al. (1971). No panel data on export crop production is used. The 1931 map-based production shares are used for the entire period (1920-1939). District-level, export crop production shares are obtained by dividing the district's production estimates by the country-sum of production estimates. Annual, district-level smallholder export crop production values are obtained by multiplying the 1931 production shares with annual country-level, crop-specific exports from the WTD. All crops are added up and the resulting total is divided by the district population. Annual population figures are obtained from Gold Coast Blue Books (1920-1939). For some districts, only data for 1930 is available. Missing years are extrapolated using a nearby district. Note that the maps only indicate the area in which export crops were produced, and do not indicate the intensity of production or yields. Hence, the assigned shares are a rough approximation.

Nigeria

District level data for Nigeria is not available. Instead, we use provinces. Borders are obtained from Papaioannou (2016). Province-level, smallholder production shares for cocoa, cotton, groundnuts and palm oil are estimated using maps cited in Papaioannou (2016). No panel data on export crop production is used. The map-based production shares are used for the entire period (1920-1939). District-level, export crop production shares are obtained by dividing the district's production estimates by the country-sum of production estimates. Annual, district-level smallholder export crop production values are obtained by multiplying the map-based production shares with annual country-level, crop-specific exports from the WTD. All crops are added up and the resulting total is divided by the district population. Annual population figures are obtained from Nigeria Blue Books (1920-1939). Note that the maps only indicate the area in which export crops were produced, and do not indicate the intensity of production or yields. Hence, the assigned shares are a rough approximation.

Sierra Leone

District borders are administrative borders from 1920-30, reported in Abraham (1978). District-level, smallholder production shares for ginger and palm oil are estimated using production estimates for 1938, reported on a map in Sierra Leone 'Administration Reports'. No panel data on export crop production is used. The 1938 production shares are used for the entire period (1920-1939). District-level, export crop production shares are obtained by dividing the district's production estimates by the country-sum of production estimates. Annual, district-level smallholder export crop production values are obtained by multiplying the 1938 production shares with annual country-level, crop-specific exports from the WTD. All crops are added up and the resulting total is divided by the district population. Annual population figures are obtained from Sierra Leone Blue Books (1920-1939). Note that the districts in Sierra Leone shifted somewhat between the interwar period and today. The graphical representation on the map, hence, is not fully accurate.

Gambia

Gambia is treated as one district. Export crop production (groundnuts) in that district can be equated to the total annual export figure in the WTD. Population figures from Gambia Blue Books (1920-1939). Note that considerable numbers of migrants ('strange farmers') came annually to the Gambia to produce groundnuts (Swindell, 1980). Since these migrants are not counted in the population figures, the export crop intensity may be biased slightly upwards.

Tanganyika

District borders are the administrative borders from 1933 reported in Berry (1972). District-level, smallholder production estimates for coffee, copra, cotton, groundnuts, sesame and tobacco are obtained from the Tanganyika Blue Books (1926, 1927, 1929, 1930, 1932, 1933, 1935, 1937, 1938 and 1939). District-level, smallholder export crop production shares are obtained by dividing each district's production estimates by the country-sum of district production estimates. Expatriate-cultivated coffee is excluded from these shares, and subtracted from the country-level export value before values are assigned to the districts. Production shares for missing years are interpolated. The shares for 1920-1925 are set equal to the average share of 1926 and 1927. Annual, district-level smallholder export crop production values are obtained by multiplying the annual production shares with annual country-level, crop-specific exports from the WTD. All crops are added up and the resulting total is divided by the district population. Annual population figures are obtained from Tanganyika Blue Books (1928, 1931, 1939). Missing years are inter-/extrapolated using the same procedure as for the production estimates. Note that some of the crops included (copra, groundnuts and sesame) were both consumed locally and exported. We are forced to assume that export/local consumption shares are equally divided over the producing districts. This assumption has only a minor effect on the eventual export crop intensity estimates.

Zanzibar

District borders coincide with Pemba Island and Zanzibar Island. District-level, smallholder production estimates for cloves and copra are obtained by estimating the relative contribution of the two Islands based on production figures in Zanzibar 'Administration Reports'. District-level, export crop production shares are obtained by dividing the district's production estimates by the country-sum of production estimates. As the country export data does not distinguish between smallholder- and expatriate-produced export crops, we roughly estimate expatriate-plantation clove production at 50% and copra production at 20% and subtract the share of crops produced by expatriate farmers from the country sum before assigning values to districts. Annual, district-level smallholder export crop production values are obtained by multiplying the annual production shares with annual country-level, crop-specific exports from the WTD. All crops are added up and the resulting total is divided by the district population. Annual population figures are obtained from Zanzibar Blue Books (1920-1939).

Kenya

District borders are from Kenya 'Administration Reports 1931'. District-level, smallholder production estimates for cotton, wattle, sesame, groundnuts and coconuts are obtained from Kenya 'Agricultural Census 1930'. No panel data on export crop production is used. The 1930 production shares are used for the entire period (1920-1939). District-level, export crop production shares are obtained by dividing the district's production estimates by the country-sum of production estimates. Expatriate-cultivated maize and wattle is excluded from these shares, and subtracted from the country-level export value before values are assigned to the districts. Annual, district-level smallholder export crop production values are obtained by multiplying the 1930 production shares with annual country-level, crop-specific exports from the WTD. All crops are added up and the resulting total is divided by the district population. Annual population figures are obtained from Kenya Colony Blue Books (1927, 1929, 1934, 1938). Missing years are inter-/extrapolated using a procedure analogous to the production estimates under 'Tanganyika'. Note that the district-level production figures are based on sales rather than production. Note that some of the crops included (maize, sesame, groundnuts, coconuts) were both consumed locally and exported. We are forced to assume that exports are equally divided over the producing districts, but this assumption has only a minor effect on the eventual export crop intensity estimates.

Uganda

District borders are from Uganda 'Administration Reports 1948', with some modifications based on Wrigley (1959). District-level, smallholder production estimates for coffee and cotton are obtained from the Uganda Blue Books (1920, 1923, 1926, 1929, 1932, 1935 and 1938). District-level, export crop production shares are obtained by dividing the district's production estimates by the country-sum of production estimates. Expatriate-cultivated coffee is excluded from these shares, and subtracted from the country-level export value before values are assigned to the districts. Production shares for missing years are set equal to the closest available year. Annual, district-level smallholder export crop production values are obtained by multiplying the annual production shares with annual country-level, crop-specific exports from the Uganda Bluebooks (the WTD does not break down export data for Kenya and Uganda). All crops are added up and the resulting total is divided by the district population. Annual population figures are obtained from Uganda Blue Books (1920, 1923, 1926, 1929, 1932, 1935 and 1938). Missing years are inter-/extrapolated using the same procedure as for the production estimates. Note that the district shares, as well as the smallholder versus expatriate shares are based on acreage rather than production, meaning that yield differences between provinces is not taken into account. This may slightly diminish the accuracy of the export crop intensity estimates.

Nyasaland

District borders are from Nyasaland 'Administration Reports 1933'. District-level, smallholder production estimates for cotton and tobacco are obtained from the Nyasaland Blue Books (1923, 1925, 1927, 1929, 1931, 1933, 1935, 1937 and 1939). District-level, export crop production shares are obtained by dividing the district's production estimates by the country-sum of production estimates. As the country export data does not distinguish between smallholder- and expatriate-produced export crops, crops (both cotton and tobacco) produced by expatriate farmers are included into this country-sum. Production shares for missing years are inter-/extrapolated (analogous to procedure described under 'Tanganyika' above). Annual, district-level smallholder export crop production values are obtained by multiplying the annual production shares with annual country-level, crop-specific exports from the WTD. All crops are added up and the resulting total is divided by the district population. Annual population figures are obtained from Nyasaland Blue Books (1920-1938). Missing years are inter-/extrapolated using the same procedure as for the production estimates. Note that the district-level production figures are based on sales rather than production. The Blue Books explicitly note that this way of measuring diminishes the accuracy of production estimates, as 'many natives grow their tobacco and cotton in one district and sell in another'.

Bechuanaland

Districts borders based on a map kindly provided by Ellen Hillbom. No smallholder export crops were exported from Bechuanaland. All districts are set at 0.

Northern Rhodesia

No map from the interwar period was available. Instead we used district borders based Northern Rhodesia 'Administration Reports 1948'. No smallholder export crops were exported from Northern Rhodesia. All districts are set at 0.

General notes

Population figures are obtained from the Blue Books. These official population figures are generally considered to be much too low (see Frankema and Jerven (2014). However, we are still very far from revising these official colonial population figures on the district level. Hence, we consistently use the colonial figures, taking stock of the possibility that our per capita estimates are too high all across the board and that some inaccuracy may enter the dataset as some districts may have been more accurately counted than others.

Country-level exports of each of the crops are obtained from Wageningen Trade Database (WTD). These figures are generally considered highly accurate and hence serve as the basis of our estimates. However, we do not account for the possibility that a share of the export value did not accrue to others in the production chain.

Additional references

Abraham, A. (1978). *Mende government and politics under colonial rule : a historical study of political change in Sierra Leone, 1890-1937.* Freetown, Sierra Leone; Oxford: Sierra Leone University Press ; Distributed by Oxford University Press.

Berry, L. (1972). *Tanzania in maps: graphic perspectives of a developing country.* New York, Africana Pub. Corp

Cardinall, A. W. (1932). *The Gold Coast, 1931 : a review of conditions in the Gold Coast in 1931 as compared with those of 1921, based on figures and facts collected by the chief census officer of 1931, together with a historical, ethnographical, and sociological survey of the people of that country.* Accra, Government Printer.

Frankema, E., Williamson, J., & Woltjer, P. (2015). *An economic rationale for the African scramble: the commercial transition and the commodity price boom of 1845-1885* (No. w21213). National Bureau of Economic Research.

Kaplan, I. (ed.) (1971). *Area handbook of Ghana.* Washington, D.C., U.S. Government Printing Office.