

“Hunger makes a thief of any man”:

Poverty and Crime in British colonial Asia

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Abstract. This study uses rainfall variation as an instrumental variable for padi-rice production to estimate the impact of poverty on different types of crime across British colonies in South and South East Asia (1910-1940). Using original primary sources retrieved from annual administrative and statistical reports, it provides some of the first evidence in a historical setting on the *causal* relationship between poverty and crime. Extreme rainfall, both droughts & floods, lead to a large increase in property crimes (such as robbery, petty theft and cattle raiding) but not to an increase in interpersonal violent crimes (such as murder, homicides and assault). In line with a growing body of literature on the climate-economy nexus, we offer evidence that loss of agricultural income is one of the main causal channels leading to property crime. Additional historical information on food shortages, poverty and crime is used to explore the connection in greater detail.

Keywords: subsistence crisis; poverty; crime; climate shocks; British colonialism; rural livelihoods; rice economies; agrarian societies

JEL Codes: C26; N55; Q15; O13; I3; F54

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1. Introduction

Climate change and its potential threatening impacts have spurred a growing body of literature examining how extreme weather conditions influence human behaviour. This literature suggests that deviations from average rainfall and temperature levels increase the likelihood of intergroup conflict (Hsiang et al., 2013; Fjelde & von Uexkull 2012), inter-communal conflict (Bai & Kai-sing Kung 2011; Papaioannou 2016), the onset of civil war (Miguel et al. 2004; Blattman & Miguel 2010), property crime (Mehlum et al. 2006; Iyer & Topalova 2014; Blakeslee & Fishman 2015), civil unrest and disobedience (Christian & Fenske 2015; Papaioannou & de Haas 2015) and even complete institutional breakdowns (Bruckner & Ciccone 2011). However, some of this evidence has been contested on both theoretical (Buhaug et al. 2014) and methodological grounds (Sarsons 2015; Klomp & Bulte 2013), leaving the debate far from settled.¹

The societal impact of weather variability seems to be stronger and less ambiguous in developing regions, where the majority of cultivated crops are rain-fed and an insignificant share of cultivated areas are equipped with irrigation (Burke et al. 2015), but we still do not fully understand the underlying mechanisms. The most commonly hypothesized channel is that of falling incomes, and by extension poverty (Hsiang et al. 2013; Dell et al. 2014; Miguel et al. 2004). Extreme weather conditions –resulting in drought or flood– are associated with poor harvests and complete crop failures. In a predominantly agrarian society –being primarily rain-fed economy without irrigation– economic prosperity is intimately tied to agricultural output. Consequently, loss of a year’s harvest, besides bringing about near-famine conditions, can easily push farmers into extreme poverty.

Poverty has long been a question of great interest in a wide range of fields. Multiple scholarly disciplines, including economics, political science, history and anthropology, have observed and documented that poverty and crime go hand in hand. The literature distinguishes between absolute poverty (i.e. lack of the minimal material necessities for survival) and relative poverty (i.e. income inequality). A great deal of previous research has demonstrated that absolute poverty is associated with higher property crime rates (Patterson 1991; Miguel 2004; Mehlum et al 2006; Iyer & Topalova 2015), while relative poverty has been linked with the surge of aggression and violent crime (Blau & Blau 1982; Kelly 2000; Fajnzylber et al

¹ A special issue of the *Journal of Peace Research* (January 2012) and more recently of *Political Geography* (March 2015) examine the relation between climatic variability and conflict in great detail. The robustness of the effect varies with the type of conflict (inter-communal conflict, civil war, property crimes etc.), the time horizon (daily, monthly, annual, decadal etc.) and the scale (household, district, province, country etc.) of these studies. The general conclusion emerging from these efforts is, at best, ambiguous.

2002). Throughout this study, the term ‘poverty’ will be used in its broadest definition to encompass a wide range of conditions such as abrupt food shortages, starvation, hunger, subsistence crises and near-famine conditions.

In simple economic theory of crime, originally introduced by Becker (1974), individuals are more likely to become involved in criminal activity when they experience a negative income shock. This reasoning is framed in terms of an *opportunity cost model*; as income levels decline as a result of unfavourable conditions, engaging in crime becomes more opportune relative to participating in more ‘peaceful’ economic activities (Grossman 1991; Seter 2016). While the theoretical foundations of poverty and crime have been well-established, the empirical basis for such an argumentation is considered speculative at best (Dell et al. 2014; Burke et al. 2015). One plausible explanation for this omission is the endogenous relationship between poverty and crime: deteriorating economic conditions may favour criminal activity, since more people are likely to engage into crime as an alternative source of income, while at the same time, higher levels of crime may undermine economic stability, investment and productivity. In other words, does poverty generate crime –or does crime lead to more poverty? Or does some third factor, for example state’s institutional capacity or certain food policy reform, affect both simultaneously?

Previous studies have been unable to resolve the key econometric identification issues and have been potentially subject to bias due to reverse causality and omitted variables, both of which distort simple ordinary least squares (OLS) estimates either downward or upward. For instance, OLS estimates of the effect may be biased downwards if colonial governments are more likely to invest in food relief programs in districts that experience high crime rates. These investments will underestimate the poverty-effect. On the other hand, OLS estimates of poverty on crime would be biased upwards if, for example, high crime rates bring about higher poverty. Likewise, an upward bias may result from third factors, such as the occurrences of political and economic crises, that tend to increase both crime and poverty simultaneously. In our findings we show that simple OLS estimates are, indeed, biased downward and underestimate the impact of poverty on crime to a substantial degree. The main innovation of this study lies in using rainfall shocks as an exogenous source of variation in food production to identify the relationship between poverty and crime. Although this article’s aim is to apply this approach in economic history, it may also be extended to more present day developing countries.

Ideally, one would need to pool reliable data from a comparable set of countries or administrative units within a similar agro-ecological setting (e.g. tropical agrarian economy),

that rely on the same staple crop (e.g. padi-rice), and share a rather uniform institutional framework (e.g. British colonial rule) over a significant period of time (1910-1940). The colonial states in South and South East Asia suit these conditions (Figure 1).² Regardless of their multifarious differences, the unity we attribute to these states is their shared reliance on the same staple crop, rice, which was indisputably the most important food-grain in the economy (Lim 1977; Hill 1977; Bray 1986; Farmer 1977; Elson 1997). And since we are mainly interested in states that are located within a similar agro-ecological setting, our scope will be confined to Asian countries that entirely lie within the tropics.³ To that end, we retrieve uniquely rich data from primary sources to create a novel district by year panel dataset. Our analysis exploits high-frequency (e.g. year to year) changes in rainfall levels, rice production and several categories of crime.

Figure 1. *British Imperialism in South and South East Asia, c. 1914.*



Source: Created by the authors in ArcGIS.

Our key hypothesis is twofold: (a) if weather shocks lead to crime through subsistence crises, then these shocks should primarily affect the kinds of crime that alleviate loss of income. We argue that this may very well be the case in both rural and urban areas but for different reasons. In rural areas, farmers are *directly* affected by the deficient harvest and resort to illicit activities, whereas in urban areas, waged labourers had to cope with food price spikes, since they were much more dependent on the market for their daily calories. (b) if

² Twenty seven states and districts were included in the analysis. The states include, the three Straits Settlements of Singapore, Penang, and Malacca; the four Malay states of Selangor, Perak, Negri Sembilan, and Pahang which form the Federated Malay States (F.M.S.); Johore, Kedah, Perlis, Kelantan and Trengganu which collectively are known as the Unfederated Malay States (U.M.S.); North Borneo with its five administrative districts; the protectorate of Brunei; and Ceylon with its nine administrative districts. Sarawak had to be dropped due to lack of consistent data.

³ India, for example, was not included since rice was largely competing with wheat as the main staple crop and almost half of its land lies outside the tropics.

weather-induced harvest failures are causing sharp increases in income inequality (relative poverty), for instance because some farmers or merchants benefit from exceptional market power during a period of food scarcity and food price hikes, we would expect more violent uprisings and grievances against people who were making money by exploiting the needs and misery of others. In other words, on the one hand, income losses caused by weather shocks should primarily increase petty theft and cattle raiding, and, on the other hand, perceptions of ‘injustice’, ‘exploitation’ or ‘abuse’ of miserable circumstances may induce a rise in violent crime such as homicides, murders and assaults.

We investigate this possibility by distinguishing between these two broad crime categories; i.e. property and violent crimes. We find that a one standard deviation *decrease* in annual rice production increases property crime by 21.2%. These effects are considerably higher in magnitude to accumulated evidence from other studies reviewed by Hsiang et al. (2013). One explanation for that may be the fact that we are dealing with a non-industrial part of the world, where the vast majority of the total income is derived from agricultural practises such as livestock herding and (food and cash crop) farming, and where urban labour was limited (Drabble 1973; Lim 1976; Farmer 1977; Bray 1994; Elson 1997; Booth 1999). As expected, the effect of poverty on violent crimes was insignificant and nearly zero, suggesting that income inequality was not (as) crucial in inciting crime. Additionally, we show that a standard deviation decrease in rice yields increased begging and vagrancy by 13.8%. This finding suggests that rice production was a key determinant of poverty during this period.

This study yields three contributions. *First*, we find strong evidence that both drought and excessive rainfall cause substantial increases in property crime. The results are robust to using alternative econometric specifications, to using lagged dependent and independent variables, to cross-sectional spill-overs, and finally, to clustering standard errors at the country level, the year level as well as two-way clustered at both the country and the year level. These results are in accord with recent studies indicating that property crimes are more likely to increase in years of depressed incomes than violent crimes (Blakeslee & Fishman 2015; Iyer & Topalova 2015; Melhum et al. 2006; Miguel 2005), as well as with simple economic theory of crime (Becker 1974; Grossman 1991).

Second, we are the first to establish a causal relationship between poverty and property crime in an agrarian historical setting, and identify the channel of causality by using rainfall as a source of exogenous variation in food production. While it is intuitively plausible that the rainfall instruments are exogenous, we have to evaluate whether they satisfy the exclusion restriction: rainfall shocks should affect property crime only through reduced agricultural

production. One potential concern may be a direct causal link (without any changes to real income) between high temperatures and aggressive and/or violent behaviour, as several psychological and empirical studies have documented (Anderson 1989; Anderson et al 2000; Ranson 2014; Iyer & Topalova 2014; Blakeslee and Fishman 2015). Our results confirm this direct extra-economic channel, since high temperature shocks are associated with more violent crimes (coeff. 0.043, standard error 0.018). However, temperature shocks yield no association with property crimes nor with adverse effects on food production. This serves as an important validation of the empirical strategy and highlights the importance of looking beyond aggregate crime measures in this climate-crime literature, since they may shadow heterogeneous patterns across crime categories.

Another potential violation of the exclusion restriction is the possibility that rainfall deviation may have a direct effect on crime; if heavy rains, due to flooded roads for instance, reduce criminals' likelihood of being detained by the police or hamper police's capacity to report crimes. Therefore, if such channels are present, IV estimates could misattribute the direct effects of rainfall to crime. Note that such channels are not serious threats to our estimation strategy, since excessive rainfall is empirically associated with significantly more (not less) crime in the reduced-form regressions. Thus to the extent that a bias exists, our estimates would be lower bounds on the true impact of poverty on property crime.

A critical assumption underlying the use of rainfall as an IV is that rainfall shocks affect property crime only through their impact on *rural income*. The most prominent critique put forward for such an assumption is that rainfall shocks could also potentially operate through non-agricultural urban channels (manufacturing and non-agricultural wages). However, these channels are unlikely to be important in the agrarian and largely non-industrial context we study, where rain-fed agriculture dominates aggregate production and a relatively small amount of urban labourers existed (Parmer 1960; Tregonning 1965; Drabble 1973; Bruton et al. 1992). We acknowledge that our identification strategy may be inappropriate for other more developed regions of the world, where rainfall shocks are not sufficiently related to depressing rural income, for instance, due to substantial investment in irrigation infrastructure (Sarsons 2015). Nevertheless, this strategy is likely to be of interest to both economic historians and policy makers, since it is highly viable for poor agrarian societies, like pre-industrial Europe or contemporary less developed countries.

Third, we make use of additional historical information on food shortages and crime as reported in the colonial sources. This is a substantial contribution since most studies in this field are solely based on econometric correlations and make no attempt to contextualize their

findings using qualitative evidence. Using a systematic approach, we were not only able to confirm the empirical findings of this study but to find support in favour of the theoretical foundations of the opportunity cost model. We observe that as foodstuffs become scarcer and distress levels rise, property crimes and vagrancy inflate substantially –while violent crimes remain unaffected.

Our work also relates to the emerging literature on the effects of weather shocks on crime and conflict. Interestingly, the vast majority of the studies published on the climate-economy nexus has been mostly restricted to limited comparisons in the post-1960 period, mainly due to data availability (see Hsiang et al. 2013; Dell et al 2014). Only very recently scholars have begun expanding the temporal scope in the pre-1960 period (for example Bai & Kai-sing Kung (2011) and Jia (2014) for premodern China; Anderson et al. (2015) and Bignon et al. (2016) for premodern Europe; Papaioannou (2016); Christian and Fenske (2016) Papaioannou & de Haas (2016) for colonial Africa). This study thus expands both the geographical as well as temporal scope of studies on the climate-economy nexus.

The remainder of the paper proceeds as follows. Section 2 reviews the historical context and the colonial reports. Section 3 describes our data sources and the construction of variables used in the analysis, and Section 4 lays out the empirical strategy. Sections 5 presents our empirical findings and Section 6 concludes.

2. Historical Context

In thinking about the possible mechanisms underpinning the relationship between food shortages, poverty and crime in British colonial Asia, it is important to consider some of the underlying agricultural, economic and political conditions. We begin by providing a brief historical background, including a discussion of the importance of rice production and various aspects of the British colonial rule. We then proceed by reviewing the colonial reports to offer further contextualization, shed light on the underlying mechanisms and validate the theoretical foundations of the *opportunity cost model*.

2.1 Historical Background

Agricultural practises. During their long history as agrarian societies, South and South East Asian states were very vulnerable to unfavourable climatological conditions (Lim 1976; Hill 1977; Bray 1994). Peasant agriculture failed to rise above subsistence level during the period of British rule (Tregonning 1965; Bruton et al. 1992). The crops continued to be adversely affected by natural enemies and there were limited agricultural advances to increase

yields as the peasant's technology had changed only slightly over the years and the growth of agricultural production was further impeded by the rapid expansion of rubber cultivation in the early twentieth century (Drabble 1974; Elson 1997; Bray 1994). Even though padi rice was the traditional staple crop in this part of the world, the quantities of padi produced were sometimes described as being inadequate to meet the wants of the people who grow it and several states were, to various degrees, dependent on imported agricultural produce (Farmer 1977; Butcher 1979). However, padi rice production formed the principal occupation of the peasant, and was the chief source of general prosperity (Lim 1976; Elson 1997).

Many historians have observed that deep in the peasant's ethos was the understanding that padi-rice was the foundation of life and its cultivation the proper and most honoured sphere of toil. To be a cultivator very nearly meant to be a padi cultivator (Farmer 1977; Bray 1994). As Hill (1977, p. 59) puts it "*the Malaya states were predominantly agricultural and rice-growing was so prevalent that had led to the virtual exclusion of any other food crop*". For most Malaya states the proportion of rice growers to total economically active persons was above 80 per cent. Nevertheless, the Malays did not attempt double-cropping as wet land rice required so long a period to reach maturity, that there would have been a deficiency of water for a second crop. In cases where a second, light crop was attempted, "*it often scarcely repaid the trouble of cultivation; so poor was its yield*" (Hill 1977, p. 111).

A similar story can be deduced from Mills (1964) and Bruton et al. (1992) for Ceylon, and from Tregonning (1965) for North Borneo. Tregonning (1965; p. 93) points out that '*although the area devoted to rice cultivation was greater than that given to any other crop and its culture was the chief industry of the native people, there was never enough rice produced for the territory to be self-sufficient, and large quantities were always imported*'. Tropical climate, with the erratic rainfall patterns that accompany it, was aggravating the already distressed conditions of local livelihoods, since with few stocks in hand one year's weather shortfall could be easily translated into a subsistence crisis.

The significance of padi-rice cultivation for the overall well-being of the native population was also documented in the colonial sources. As we will see in more detailed in the next section, the agricultural commissioners had to report whether food supply was sufficient and well maintained to cover local needs. If rice production was scarce, they were requested to provide plausible explanations. Time and again, they pointed to climatological conditions in explaining the deficiency or failure of the annual padi-rice harvest and its consequential distress among smallholders.

British colonialism. The basic function of British colonisation in the Asian states covered by this study, whatever its form and origin, was to establish and maintain the conditions under which the dynamic forces of trade could flourish (Lange 2004; Mills 1964; Parmer 1960; Butcher 1979; Wade 1990). It is worth noting that the Colonial office wished to keep British involvement as limited and as free from conflict as possible. Butcher (1978, p. 20) notes that “*the most striking feature of the political situation in Malaya during the first decades of the 20th century was the absence of any challenge to British rule*”. Although the British rule was intended to be indirect, direct rule was the practice and it increased in scope and effectiveness as the years passed. The new structure was purely British in conception and operation. British interests dominated the vast majority of commercial activities as the British owned most of the plantations, the estate factories that processed the rubber, tea, and coconuts, the import-export trade, and other service activities.

In the minds of the British officials, as summarized by Parmer (1960, p.3), quite popular was the idea that “*prospective capitalists should be encouraged by spending government revenue to develop public works and railway, to promote research and experimentation, to provide loans at low rates of interest, and to give easy terms in respect to alienation of land and taxes on new enterprises*”. In areas with favourable soils and climates, cash crop export economies (such as coffee, tea, rubber etc.) were encouraged and promoted as they provided the colonial authorities with much needed revenue from customs duties and other forms of indirect taxation (Drabble 1974; Booth 1999).

While the British rule in South and South East Asia can be traced back to the turn of the nineteenth century, it is important to briefly consider the institutional and temporal framework of the particular states covered by this study. The Malay Peninsula was divided politically in three parts. In 1867, the three Settlements of Singapore, Malacca and Penang became a crown colony administered by a Governor. Between 1874 and 1888, the four Malay states of Perak, Negri Sembilan, Pahang and Selangor became British protectorates, forming the Federated Malay States. By the first decade of the twentieth century, the States of Johore, Kedah, Perlis, Trengganu and Kelantan had also come under colonial rule but were not added to the federation. They were commonly known as the Unfederated Malay States. Ceylon was a crown colony the longest, with its origins going back around the turn of the nineteenth century. In 1802, following the unsuccessful experiment of joint control by the crown and the East India Company, the Colonial office took full control. By the first decades of the twentieth century, Ceylon was sub-divided into nine administration units, which were consistent until after WWII.

Similarly, in 1902 the Sultan of Brunei, whose relations with the British had been already regulated by the 1888 ‘Treaty of Protection’, agreed on a more definite form of British rule. A new treaty was drawn up on lines similar to those in force with the rulers of the F.M.S.. Lastly, North Borneo was under the sovereign North Borneo Chartered Company from 1882 to 1941 and it was sub-divided into five residencies. Overall, uniformity in legislation and administration across each of the colonies was obtained by the enactment of similar statutes, allowing meaningful comparisons.

2.2 Qualitative evidence: Climate, poverty and crime

The sources we use are the annual reports filed by the colonial administration. The British colonizers set up an extensive system of administration, where elaborate administrative accounts were kept. These accounts make regular notice of weather-induced agricultural failure resulting in higher levels of social distress, and in more extreme cases, subsistence crises and near-famine conditions. In practice, each department filed reports to provide information and explanations of various incidences along with what was considered to be their causes. The goal of this section is not to systematically record all incidences of food shortages, subsistence crises, and crime, but rather to give a detailed contextual overview about the reasons, mechanisms and channels that appear to be the most relevant ones.

(a) Rainfall extremes: Flood & Drought

In thinking about the impact that unfavourable weather conditions have on annual food production, it is important to stress the non-linear nature of the relationship. Based on primary sources, we argue that both *excessive rainfall* and *droughts* have been responsible for bringing about deficient padi rice harvests. The examples in the sources about the curvilinear nature of the effect abound. For instance, the agricultural commissioner of Kedah, in his 1925 report, emphasises both types of environmental hazards in reducing farmers’ welfare:

a drought at the wrong season or a flood will cause great loss to the country and to the padi planters. It was at one time roughly estimated that the present year’s padi crop would, owing to drought, be some 25.000.000 gantangs of padi short of the previous year’s gantang. As a result it would involve a prospective loss of \$2.500.000 to padi planters. (Kedah Annual Report,1925).

In 1934, the same commissioner reported a severe crop failure, owing this time to excessive rainfall: “*serious flooding was experienced during November and early December, doing extensive damage in several districts, and it is believed that the harvest will be less abundant than that of the previous year*”. His speculation came true by the end of that year when “*the total yield was just about 33 million gantangs, showing a decrease of 17 million gantangs as compared with 1933*” (Kedah, *Annual Report*, 1934).

Likewise, in 1924, the Kelantan colonial official recorded both types of unfavourable weather conditions within the State and remarked that “*the high variability of yields has been connected chiefly with droughts and floods. As one reads back through the annual reports, one constantly comes across reports of disastrous droughts. At other times it is an early flood which has drowned the padi before it has become sufficiently established.*” The rice returns reveal that “*the total production of rice has fluctuated rather more violently than the area planted, and sometimes in an opposite direction. Thus in the 1924 season the 148,000 acres yielded only 55,359 tons, whereas last year the 139,000 acres yielded 74,008 tons*—a decrease in production of ca 25%. The reason for such a decrease was the “*serious flooding during the early part of the season made it impossible for peasants to cultivate their land*”. Thus, overall, our qualitative evidence supports a U-shaped parameterization of the link between weather and agricultural incomes.

(b) Food Scarcity & Price Spikes

The annual reports are very extensive and meticulous in the way they describe local agricultural conditions. These reports frequently mention the adverse consequences of weather conditions in inducing food shortages, food price hikes and resultant social distress. Shortages of rice and other foodstuffs and their subsequent increases in their prices were greatly felt by the people. Local padi-rice was sold for high prices, which were beyond the means of the poor.

An illustrative example is taken from the annual report of Trengganu in 1914 where the padi harvest was a very poor one, especially in the large plain drained by the main Trengganu river. An episode of abnormally high rainfall resulted in crop damage and shortage of food supply. It is important to note that such adverse conditions should be viewed in a context where “*the rice grown in Trengganu is far from sufficient for the support of the population*”. A shortage of rice resulted in a “*sudden panic in the market inciting food-price spikes and thus making food inaccessible to most farmers*”. That year the price of rice had risen from \$14 to \$27 a bag—an increase of about 100%. The colonial official 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 social consequences of such conditions can be depicted best through the annual police report of 1914, which recognized:

that there was a large increase in the number of offences against property. A number of causes are given for this increase...among them the most probable seem to be economic due to unfavourable weather conditions. The last reason applies more particularly to the surrounding plain, where thieves and house-breakers, when detected, are usually found to be young padi planters (Trengganu, Annual Report, 1914).

Similarly, the agricultural commissioner of Central province in Ceylon recounted in 1927 that “the padi-planters are going through a year of almost unprecedented misfortune” and that “the abnormal rainfall in January did considerable damage. That was a truly phenomenal rainfall. Paddy cultivation has been a failure —one of the lowest crops on record, and it was followed by the usual food shortage. This is also shown by the fact that burglars take away foodstuffs, which formerly were left behind. Owing to the shortage of paddy crops the price of paddy has risen dramatically. Deaths from starvation are occasionally reported”. Indeed, the rice crop was a poor one and totalled 300.000 gantangs as compared to 1.200.000 the year before –a decrease of ca 75%(Ceylon, Annual Report, 1927).

(c) Poverty & Property Crime

Poverty has been put forward as a decisive motive for crime. Individuals lacking the basic means of subsistence are more likely to become involved in criminal activity when they experience a negative income shock. As income levels decline, engaging in property crime becomes more opportune relative to participating in more ‘peaceful’ economic activities and the stolen property might be regarded as a buffer in alleviating distress. This kind of criminal behaviour was frequently stated in the annual reports and can be illustrated best in the words of the colonial Administrator of Southern Galle of Ceylon, who in 1931 observed that:

there is a great temptation to them to commit crime in order to live; and reports received indicate that there has been an increase of cattle-stealing and theft of foodstuffs. Thefts of foodstuffs have not been common in the past, and the increase in this type of crime and in

cattle-stealing is due to real poverty and difficulty in obtaining food
(Ceylon, *Annual Report*, 1931).

A similar conclusion was reached by the chief Commissioner of North Borneo in 1919, who stated that:

the year was probably the worst ever experienced in the State. The difficulties to be faced were great. Crop after crop was destroyed and by June the shortage of food was becoming very serious. Theft was rife and increased as food became short (North Borneo *Native Affairs*, 1919).

These two examples serve to highlight the idea that when farmers realize that their food yields are going to be deficient or entirely failed, the opportunity cost of crime is reduced and thereby increase its incidence. The more one reads into the reports the better insights he gets regarding the reasons behind the steep increases in property crimes. When the harvest fails and food becomes scarce, local farmers, in need of food, may resort to plundering and stealing either in the form of cash or kind on condition that it could alleviate distress. The Chief of the Police of the Malacca settlement, in 1936, summarized that:

The number of offences against property –cattle lifting, burglary, and petty thefts–has shown a most unsatisfactory tendency. This is doubtless due to the scarcity of food. I have heard it said that the way in which private gardens are rifled is a real deterrent to enterprise in their cultivation. This may be an exaggeration, but the evil is rampant, and in some cases is caused by real starvation (Straits Settlements, *Police Report*, 1936)

His counterpart in the Malay Peninsula, in his 1932 report, also associated the steep increase in property crimes of that year with the widespread shortage of food, stressing that when house breakers and thieves were detected, they were usually found to be young padi planters. In one of his journeys up country, the chief of Police recounted that:

it was impossible to obtain padi in the villages...The harvest was late, the crops were entirely ruined...rice crops were everywhere poor and

in many places destroyed by the phenomenal drought...The presence of property crime is undoubtedly due in no small measure to a shortage of rice (F.M.S., Judicial Report, 1932).

Few would dispute that livestock breeding broadens the opportunities to store wealth, mediate risks and raise land productivity in pre-industrial societies. However, livestock was also seen as an object of looting, since by stealing few cattle in times of hardship the perpetrator gains either income by marketing the cattle and exchanging it for other goods, or gains calories by simply consuming it. This is exemplified best in the report undertaken by the colonial officer of Trengganu state in 1931, who related the unfavourable weather conditions of that year with a considerable rise in arrests, stressing that in many parts of the central plain were “*so infested with thieves that poultry and cattle could not be kept and was stolen by night*”. In many instances the colonial officials associated food shortages directly to cattle-raiding noting that “*there was an increase of cattle theft, perhaps due to the shortage of food. Most cattle stolen are slaughtered*” or that “*cattle stealing was rife in North Kedah during the first nine months of the year owing to the unfavourable weather conditions of the country in certain localities.*”

Simple theoretical considerations suggest that income shocks should have a larger impact on property crimes as compared to violent ones. Our qualitative material confirms that logic, as the colonial officials reported sizable differences between the amount of property and violent crimes within the same year. We observe many instances where increases in property crime did not yield concurrent increases in violent crimes. According to the 1919 Annual Report, Kedah had “*experienced in succession the two driest years since rainfalls were first recorded in 1906*” and as is anticipated, the padi crop reaped at the beginning of 1919 was poor. Theft returns that year more than doubled; from 403 up to 812 cases –an increase of more than 100%, whereas the violent offences against the person declined substantially. The Commissioner reports that “*there is a large amount of petty thieving but there are remarkably few crimes of violence.*”

The evidence presented thus far supports the idea that scarcity of food and loss of income had led to substantially more property crime. However, unlike years of extreme weather fluctuations, there have also been seasons with exceptionally good yields. The impact of ‘feast’ seasons on reducing crime levels was noted by the colonial administrators as well. In years where the precipitation patterns were smooth, the rice-harvest was bountiful, and as a result crime rates plummeted. According to the 1930 Agriculture report of Kelantan: “*the*

crop was harvested under ideal weather conditions and proved to be one of the best secured for a number of years. A surplus over the requirements of the indigenous population was obtained.” According to the Police report of that same year “*there has been little serious crime, owing to prosperous favourable weather conditions*” and “*as regards criminal litigation, increased prosperity has led to diminution of crime*”(Kelantan, Police Report, 1930).

3. Data

The data were obtained from colonial administrative accounts (Annual Reports and Blue Books of Statistics) collected over a long research visit at The National Archives (TNA) in London. All variables are original and obtained directly from colonial sources, except if stated otherwise. The summary statistics are presented in Table 1 below. Panel (a) include the main dependent variables of crime. Panel (b) include the weather measures and their multiple modifications. Panel (c) reports padi-rice production and panel (d) include few time-varying controls. All variables are available annually at the district level between 1910 and 1939.

Table 1. Summary Statistics: District by Year

Variable	Obs.	Mean	Std. Dev.	Min	Max
<i>Panel (a): Crime measures per 100,000 population</i>					
Ln(Property crime)	659	2.41	0.40	0.50	3.69
Ln(Violent crime)	683	2.14	0.46	0.90	3.25
Ln(Theft)	610	2.30	0.45	0.42	3.69
Ln(Cattle-raiding)	417	1.99	0.39	0.88	3.02
Ln(Assault)	682	2.09	0.50	0.42	3.21
Ln(Homicides)	695	0.89	0.49	-0.68	2.33
Ln(Vagrancy)	339	0.69	0.57	-0.39	2.22
<i>Panel (b): Weather measures</i>					
Rainfall deviation Stations (z-score)	627	0.00	1.00	-2.42	3.19
Rainfall deviation squared Stations	627	1.00	1.44	0.00	10.23
Rainfall <i>absolute</i> deviation Stations (linear)	627	0.79	0.63	0.00	3.19
Positive rainfall shock (1 std dev)	627	0.17	0.37	0.00	1.00
Negative rainfall shock (1 std dev)	627	0.15	0.36	0.00	1.00
Rainfall deviation Grids (z-score)	780	0.00	1.00	-2.87	3.38
Rainfall deviation squared Grids	780	1.00	1.40	0.00	11.47
Rainfall <i>absolute</i> deviation Grids (linear)	780	0.80	0.59	0.00	3.38
Temperature deviation (z-score)	780	0.00	1.00	-2.25	3.05
<i>Panel (c): Food measure</i>					
Padi rice production (z-score)	682	0.00	1.00	-3.26	3.62
<i>Panel (d): Controls (time-varying)</i>					
Ln(Population density)	810	4.25	1.56	-0.33	8.09
Ln(Road density)	810	-2.12	2.60	-8.61	4.75
Ln(Police staff density) per 100,000 population	797	5.06	0.51	3.81	6.25

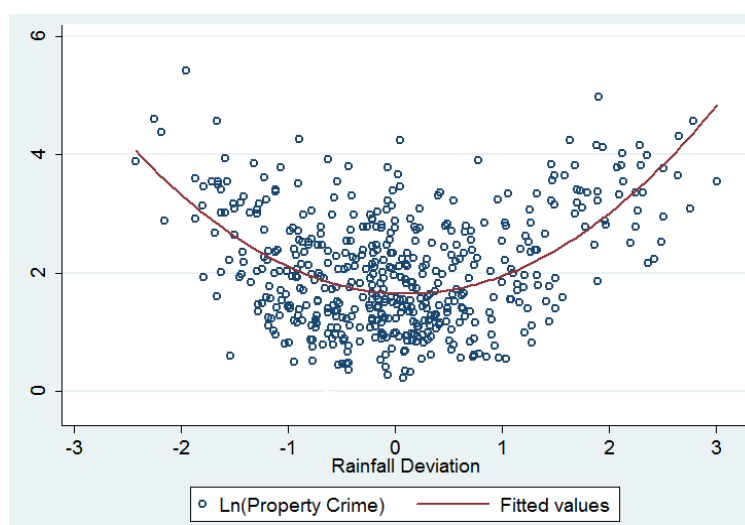
3.1 Crime data

Among the crimes included are theft, cattle-raiding, assault and homicide. Of the crimes included in the data, we combine individual crime categories into two broad categories: theft and cattle raiding as *property crimes*, and assault and homicide as *violent crimes*. We present results for both individual and aggregate crimes. Additionally, we obtain data for vagrancy for each state they were available. All variables exhibit a high year-to-year variation. Table A-1 presents the pairwise correlation matrix among the dependent variables. In thinking about issues of differential crime reporting over time, it is important to note that we have no evidence to believe that weather shocks would affect the incentive of crime victims to report crime or the incentive of colonial officials to record more or less criminal incidences. Even though it is not implausible that local authorities would in fact increase the level of under-reporting at precisely those times when crime is rife —i.e. after an adverse weather shock— we argue that this tendency would, if anything, downward our results. The summary statistics for the types of crime are presented in panel (a) of Table 1.

3.2 Weather shocks

Historical precipitation data come from meteorological stations, which were first introduced by the British in the late nineteenth century. The data were consistent throughout the period of interest. Since all districts had at least one meteorological station within its borders, we managed to include all colonial districts and states. If more than one station was in place, we took the average of them. Our measure of weather shocks is the annual standardized *rainfall deviation* from the long-term panel mean of rainfall for a given district. Values for standardized *rainfall deviation* have a mean of 0.00, a standard deviation of 1, and range from -2.42 to 3.19. Figure 2 shows how the relationship looks like when we scatter plot property crime (*fitted values in purple*) against rainfall deviation (*x-axis*).

Figure 2. *Rainfall shocks & Property Crime*



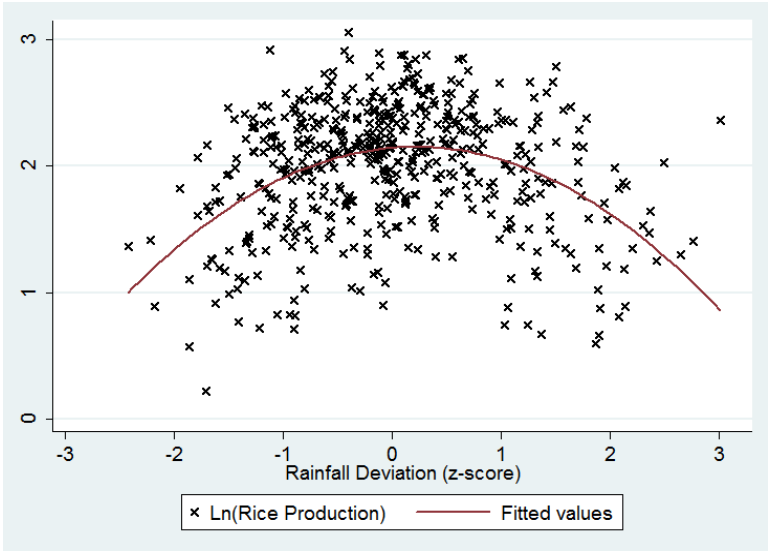
Since there are many ways to parameterize rainfall, we also transformed our main explanatory variable, and defined a “negative rainfall shock” as a dummy which takes the value of 1 when annual rainfall in a district i is one standard deviation below the long-run mean of panel i , and a “positive rainfall shock” as a dummy being one standard deviation above the panel’s mean. We also use an alternative measure of rainfall taken from the Willmott and Matsuura (2005) database. The data have 0.5° latitude by 0.5° longitude grids. Values for standardized *grid rainfall deviation* have a mean of 0.00, a standard deviation of 1, and range from -2.87 to 3.38. Although this measure give nearly identical results, it reduces (a) our sample size considerably (Singapore, Perlis and few district in North Borneo had to be dropped due to lack of observations) and (b) the accuracy of the observations as the data compiled in this dataset is mostly based on extrapolation. Lastly, we construct a variable of temperature deviation to account for the extra-economic direct impact of extreme heat on crime. The summary statistics of the weather conditions are presented in panel (b) of Table 1.

3.3 Rice production

District level agricultural data on padi rice yields were obtained from the *Agricultural Annual Reports* for each state. We create a consistent indicator of gantangs of rice per capita for each district in our sample. As discussed above, peasant agriculture failed to rise above subsistence level during this period of British rule (Tregonning 1965; Drabble 1973; Bray 1994; Mills 2012). Padi-rice yielded only one harvest a year in this part of the world at the time and peasants did not attempt double-cropping (Elson 1997; Lim 1973; Bruton 1992). Therefore, tying annual rainfall deviations with padi-rice production becomes straightforward. Figure 3 graphically presents the strong negative correlation between rainfall shocks and rice

production between 1910 and 1939. It is evident that as rainfall deviates from the long-term average in either direction, food production is shrinking.

Figure 3. *Weather shocks & Food Production*



3.4 Controls

While omitted variables should not be of great concern, we include a number of additional time-varying controls to address potential bias stemming from unobserved factors. We control for differences in (a) state capacity by constructing a measure of road density following Herbst (2000), (b) policing capacity by constructing a measure of police staff density (Papaioannou 2016), and (c) demographic pressures by constructing a measure of population density. Lastly, we control for the interaction of a few spatial characteristics of districts with a linear time trend to take into account their impacts over time. We construct a battery of district-specific effects to control for the possibility that some districts would react differently over time. For instance, a spike in property crimes in district i , may have urged the colonial authorities to invest more in those crime-stricken places and as a result the following years the capacity of police in inhibiting future crime would have been increased.

4. Empirical Strategy

We first establish that rainfall shocks significantly affect crime rates (reduced form specifications) and then proceed by focusing on identifying the causal channel linking poverty and crime (first-stage and IV-2SLS results).

To achieve our first goal, the regression specification (reduced form) is as follows:

$$\begin{aligned} \text{Ln}(\text{Crime})_{i,t} = & \beta_0 + \beta_1 \text{AbsoluteRainfallDeviation}_{i,t} + \delta Z'_{i,t} + v_i + \mu_t \\ & + (\text{District dummy} \times \text{Year})_{i,t} + \varepsilon_{i,t}. \end{aligned} \quad (1)$$

where $\text{Ln}(\text{Crime})_{i,t}$ denotes the natural log of the incidence of the various types of crime (per 100,000 population) in district i and year t . $\text{AbsoluteRainfallDeviation}_{i,t}$ denotes the annual *absolute* rainfall deviation of each district i from the historical long-term mean of the same district. $Z'_{i,t}$ denotes a vector of controls to avoid any potential omitted variable bias. v_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 quite crucial in controlling for unobservable time-invariant district heterogeneity and for factors that may affect the levels of crime across all districts in the same year (such as during the Great Depression). Moreover, $(\text{District dummy} \times \text{Year})_{i,t}$ denotes the unobservable district characteristics (v_i) when interacted with a linear time trend (t). In practice, we control for district-specific characteristics to capture district-specific changes in crime activity over time. A good example here, is changes in district capacity to report and restrain crime over time, since police authorities in highly criminal districts may become more efficient in preventing crimes over time.

The coefficient of interest, β_1 , is the estimated effect of a one standard deviation change (either positive or negative) in rainfall on crime. A positive sign, $\beta_1 > 0$, indicates that, on average, extreme rainfall shocks are associated with more crime. In all estimations we cluster standard errors at the district level to avoid any autocorrelation concerns of weather shocks and the possibility of measurement errors, which are more likely to be correlated within districts across time. For robustness, we cluster standard errors at the country and at the year level as well as both country-year level by two-way clustering. This way we avoid concerns about country-year unobservable characteristics that vary across time, such as levels of expenditures on law enforcement, or country's capacity to record crime rates. In addition, we control for spatial correlation (cross-sectional dependence) by adjusting standard errors following Hoechle (2007). To assess the importance of omitted variable bias we build on the method recently developed by Oster (2015) and Gonzalez & Miguel (2015), by estimating the

reliability ratios. In practice, we show that the coefficient estimates on property crime change little across regression specifications with and without additional covariates.

In achieving our second goal and identifying the causal effect of poverty on crime, we present the OLS first-stage relationship results between rainfall and food production, and then we perform a IV-2SLS estimation using rainfall as an instrumental variable for food production. While few scholars have put the use of rainfall variation as instrument for income under scrutiny (Sarsons 2015), by pointing to alternative non-agricultural channels (e.g. urban wages or direct psychological effects) through which rainfall shocks may increase crime, a large body of literature argues that the use of this kind of instrumentation approach in rainfed agrarian settings is highly suitable (Miguel et al., 2004; Miguel 2005; Dell et al. 2015; Burke et al. 2015; Mehlum et al 2006). In either case, we conduct several robustness checks to address potential violations of the exclusion restriction (section 5.4).

5. Main empirical results

The first part of this section (5.1) presents the results on the impact of weather shocks on the various types of crime (reduced form specifications). Section 5.2 presents the results of the instrumental variable approach (first-stage and two-stage IV-2SLS). Section 5.3 presents the results for a set of robustness checks and section 5.4 refutes potential violations of the exclusion restriction.

5.1 The Impact of Weather shocks on Crime (Reduced-form)

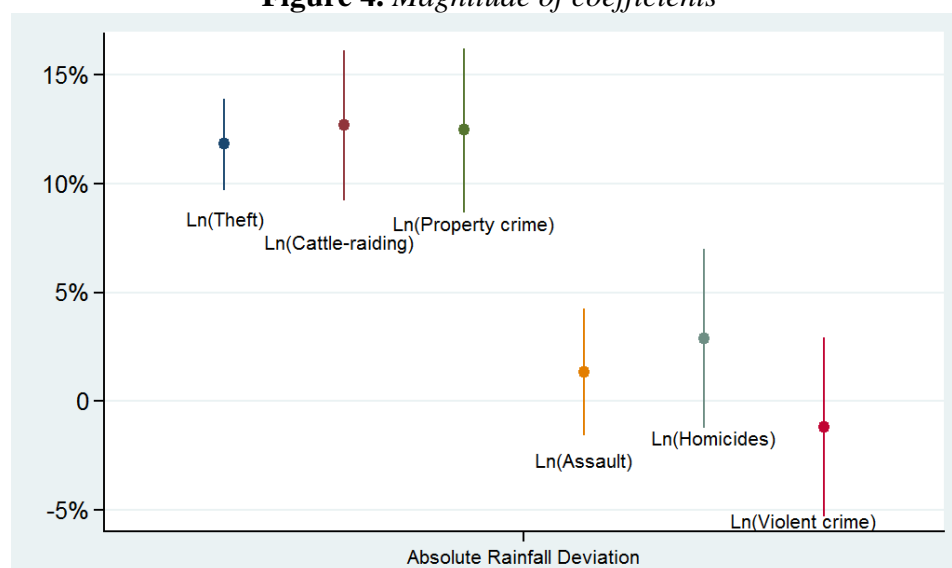
The results are presented in Table 2. In the reduced-form regression, a one standard deviation change in rainfall is associated with significantly more crime, 10.9% for thefts (column 1 in Table 4), 10.5% for cattle raiding (column 2), and 11.25% for property crimes (column 3) while it yields no significant effect for assaults (column 4), for homicides (column 5), and for violent crimes (regression 6). Their regression coefficients as well as their standard errors range are presented in Figure 4.

Table 2. The Impact of Rainfall shocks on Crime (Reduced-Form)

	Thefts	Cattle Raiding	Property Crimes	Assaults	Homicides	Violent Crimes
	(1)	(2)	(3)	(4)	(5)	(6)
<i>Absolute Rainfall Deviation t</i>	0.109*** (0.010)	0.105*** (0.018)	0.112*** (0.017)	0.014 (0.013)	0.025 (0.018)	-0.043 (0.130)
District & Year FE	Y	Y	Y	Y	Y	Y
Controls	Y	N	Y	Y	Y	Y
District-specific effects (District dummy × Year)	Y	Y	Y	Y	Y	Y
No. observations	596	417	576	605	580	600

Notes: *Significant at 10%, **5%, ***1%. Sample period: 1910–1939. OLS-FE. The dependent variables are the logarithm of each crime variable expresses as 100.000 of the population. Reported in parentheses are standard errors clustered at the district level. Controls include population density, road density and police per capita. District-specific effects indicate the interaction of each District dummy × Year.

Figure 4. Magnitude of coefficients



Notes: Regression coefficients of Table 2. Confidence Intervals set at 95%.

Table 3 presents the results when we include lagged and lead weather conditions as determinants of crime. The coefficient of rainfall shocks on property crime remains stable (about 11%) and robust to the inclusion of rainfall lag ($t - 1$) and lead ($t + 1$) (columns 2 & 3). Columns 4 to 6 show that rainfall shocks do not impact on violent crimes.

Table 3. *The Impact of Lagged and Lead Rainfall shocks on Crime*

	Ln(Property Crime)			Ln(Violent Crime)		
	(1)	(2)	(3)	(4)	(5)	(6)
<i>Absolute Rainfall Deviation t</i>	0.112*** (0.017)	0.111*** (0.016)	0.102*** (0.017)	0.007 (0.012)	0.006 (0.014)	0.017 (0.014)
<i>Absolute Rainfall Deviation t - 1</i>		0.019 (0.015)			0.023 (0.013)	
<i>Absolute Rainfall Deviation t + 1</i>			-0.004 (0.021)			-0.001 (0.008)
District & Year FE	Y	Y	Y	Y	Y	Y
Controls (time-varying)	Y	Y	Y	Y	Y	Y
District-specific effects (District dummy × Year)	Y	Y	Y	Y	Y	Y
No. observations	576	502	502	600	518	518

Notes: *Significant at 10%, **5%, ***1%. Sample period: 1910–1939. OLS-FE. The dependent variables are the logarithm of each crime variable expresses as 100.000 of the population. Reported in parentheses are standard errors clustered at the district level. Controls include population density, road density and police per capita. District-specific effects indicate the interaction of each District dummy × Year.

Next, we present the results solely for property crime, since that is our main dependent variable of interest. In Table 4, we include the square term of $RainfallDeviation_{i,t}$ and find that the effect of rainfall shocks on property crime is curvilinear (U-shaped), meaning that both drought and excessive rainfall increase crime (columns 1-4). We also test for the symmetry of the effect by including the ‘positive rainfall shock’ and ‘negative rainfall shock’ variables into the analysis. A standard deviation increase in rainfall increased property crimes by 17.7% and similarly, a standard deviation decrease in rainfall increased property crimes by 8.3%. This result is in line with previous findings by Papaioannou (2016) for Nigeria and Papaioannou & de Haas (2016) for colonial British Africa. A possible explanation 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. In the former case, the certainty of a failed harvest more rapidly reduces the opportunity cost of crime.

Table 4. Curvilinear Impact of Rainfall shocks on Property Crime

	Ln(Property crime)							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Rainfall deviation t	0.009 (0.010)	0.014 (0.015)	0.017 (0.017)	0.015 (0.018)				
Rainfall deviation squared t	0.053*** (0.007)	0.055*** (0.009)	0.051*** (0.009)	0.051*** (0.009)				
Positive rainfall shock t					0.176*** (0.028)	0.186*** (0.022)	0.172*** (0.025)	0.174*** (0.030)
Negative rainfall shock t					0.081*** (0.029)	0.083*** (0.031)	0.068** (0.035)	0.073** (0.036)
Ln(Population density)				-0.591** (0.294)				-0.533* (0.303)
Ln(Road density)				0.165 (0.175)				0.163 (0.171)
Ln(Police staff per capita)				-0.496*** (0.128)				-0.496*** (0.136)
District & Year FE	N	Y	Y	Y	N	Y	Y	Y
District-specific effects (<i>unobservable</i> × year)	N	N	Y	Y	N	N	Y	Y
No. observations	576	576	576	576	576	576	576	576

Notes: *Significant at 10%, ** 5%, ***1%. Reported in parentheses are standard errors clustered at the district level. The dependent variables is the logarithm of each property crime variable expresses as 100.000 of the population. The estimated coefficients can be interpreted as percentage changes. District-specific effects indicate the interaction of each District dummy × Year.

5.2 Poverty & Property Crime: An Instrumental Variable Approach

We now proceed by identifying the income channel as the causal explanation that drives the underlying relationship between income shocks and property crime. We use *absolute rainfall deviation*_{*i,t*} as an instrument to generate exogenous variation in food production. This way we argue that loss of income from agriculture in year *t* causally predicts higher levels of property crime in year *t* (while having no effect on violent crime). As shown in Table 5, the first-stage relationship between rainfall and food production is strongly negative: current (and not lead or lagged) rainfall deviation is significantly related to padi rice yields at 99 percent confidence (Table 5, column 1), and this relationship is robust to the inclusion: of time dummies, fixed effects and district-specific time trends (column 2), of additional controls (column 3) and of lagged rainfall deviation from the previous two years (*t-1* & *t-2*) (column 4). As an identification check, we estimate a “false experiment” specification in which lead rainfall deviation (*t+1*) is included as an additional explanatory variable. We find that the coefficient estimate is indeed near zero (column 5).

Table 5. *Rainfall shocks & Food production (First-stage)*

	Dependent variable: Food Production				
	(1)	(2)	(3)	(4)	(5)
	OLS	OLS	OLS	OLS	OLS
<i>Absolute Rainfall Deviation t</i>	-0.547***	-0.530***	-0.516***	-0.545***	-0.504***
	(0.084)	(0.086)	(0.084)	(0.096)	(0.083)
<i>Absolute Rainfall Deviation t - 1</i>				-0.067	
				(0.093)	
<i>Absolute Rainfall Deviation t - 2</i>				-0.074	
				(0.086)	
<i>Absolute Rainfall Deviation t + 1</i>					-0.022
					(0.065)
District & Year FE	Y	Y	Y	Y	Y
Controls	N	N	Y	Y	Y
District-specific effects (District dummy × Year)	N	Y	Y	Y	Y
No. observations	552	552	552	401	483

Notes: *Significant at 10%, **5%, ***1%. Reported in parentheses are standard errors clustered at the district level. Controls include population density, road density and police per capita. District-specific effects indicate the interaction of each District dummy × Year.

The second-stage equation estimates the impact of loss of income on the incidence of property crime by performing a two-stage least square estimation (IV-2SLS):

$$\begin{aligned} \ln(\text{Property crime})_{i,t} = & \beta_0 + \beta_1 \text{FoodProduction}_{i,t} \text{ [IV: AbsoluteRainfalldeviation}_{i,t}] + \\ & + \delta Z'_{i,t} + v_i + \mu_t + (\text{District dummy} \times \text{Year})_{i,t} + \varepsilon_{i,t} \end{aligned} \quad (2)$$

The estimated coefficient of food production on property crime is -0.085 (or -8.5%) in the OLS specification with time and fixed effects (Table 6, regression 1) and -0.088 (-8.8%) when district-specific effects and controls are included (regression 2). Both estimated coefficients are statistically significant at 99% confidence. The IV-2SLS estimates also indicate a negative and significant association between poverty and crime. A one standard deviation increase in rice production decreases property crime by 21.2% (regression 3). Notice that this is about double the magnitude of the analogous OLS estimate (-8.5%), suggesting that the bias in the OLS regression is large and underestimates the effect of poverty on crime. In other words, simple correlation between rice production and crime may appear misleading.

We next estimate the impact of loss of income on vagrancy arrests. Under the British colonial rule, begging was illegal and destitute people ended up in police reports. Even though vagrancy can hardly be characterized as crime, it could serve as a suitable proxy for dire poverty. We expect vagrancy to yield a similar robust correlation as property crime. Indeed, the results show that the relationship between food production and vagrancy is negative and highly significant, which suggests that depressed incomes were a major determinant of poverty. One standard deviation decrease in rice production increases the amount of arrested vagrants by 13.8% (regression 6). Table A-6 reports the IV-2SLS results on violent crime. All the estimated coefficients are nearly zero.

Table 6. Baseline IV-2SLS Results: Poverty & Crime

	Ln(Property crime)				Ln(Vagrancy)	
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	IV-2SLS	IV-2SLS	OLS	IV-2SLS
Food production t	-0.085*** (0.010)	-0.088*** (0.010)	-0.212*** (0.032)	-0.198*** (0.032)	-0.047*** (0.013)	-0.138*** (0.047)
District & Year FE	Y	Y	Y	Y	Y	Y
Controls	N	Y	N	Y	Y	Y
District-specific effects (District dummy \times Year)	N	Y	N	Y	Y	Y
No. observations	552	552	510	510	339	303

Notes: *Significant at 10%, **5%, ***1%. Reported in parentheses are robust standard errors clustered at the district level. Controls include population density, road density and police per capita. District-specific effects indicate the interaction of each District dummy \times Year. The instrumental variable is rainfall deviation at year t . Vagrancy statistics were not available for the whole sample.

5.3 Robustness checks

We now check the robustness of the preferred IV-2SLS estimates as reported in Table 6. First, in Tables A-2, we show that replacing rainfall deviation obtained from meteorological stations with an alternative measure of rainfall, based on the Matsuura and Wilmott (2009) world rainfall database (0.5 x 0.5 grid), gives nearly identical results. Second, we take into account widening differences across countries as well as heterogeneity during the 30 year horizon of this study and in Table A-3, we present the IV-2SLS results of standard errors clustered at the country level, year level as well as two-way clustered at both the country and year level.

Third, we examine the sensitivity of the main estimates to the use of alternative instrumental specifications. Column 1 of Table A-4 reports estimates using rainfall in the lagged year $t-1$ and two years earlier $t-2$ as instrumental variables. Similarly, as an identification check, we estimate a “false experiment” specification in which leads of rainfall deviation in year $t+1$ and $t+2$ are included as instrumental variables, and we find that the coefficient estimate is indeed near zero (column 2). As an additional falsification test, we re-estimate our main IV-2SLS results by using temperature shocks as an instrumental variable (column 3). These checks provide additional validation to our empirical strategy.

Table A-5 reports the IV-2SLS estimates for each individual category of crime, and Table A-6 for violent crimes. In results not reported, we obtain statistically identical results, if we use standardized beta coefficients (z-scores) for transforming the main dependent variables. Thus, the IV-2SLS results are not specific to the choice of functional form. Lastly, to ensure that our results are not driven by spatial spillovers, since rainfall patterns could be spatially correlated, we control for spatial and serial correlation using methods suggested by Hoechle (2007). The results remain largely unchanged.

5.4 Potential Violations of the Exclusion Restriction

While it is intuitively plausible that the rainfall instruments are exogenous, we have to evaluate whether they satisfy the exclusion restriction—i.e. weather shocks should affect property crime only through falling agricultural income. We acknowledge the possibility that economic channels (direct or indirect ones) other than annual rice production may affect crime in the aftermath of adverse rainfall shocks. One possible violation of the exclusion

restriction may occur in the case when rainfall shocks directly impact on crime; in an extreme rainfall scenario, flooded roads for instance, may reduce criminals' likelihood of stealing due to transportation difficulties or may hamper police's capacity to report crimes. If such channels are present, IV estimates could misattribute the direct effects of rainfall to poverty. Note though that this kind of alternative explanations do not pose a serious threat to our estimation, since excessive rainfall is associated with more (not less) crime in the reduced-form regression (coeff. +0.172 in Table 4 regression 7). Thus to the extent that a bias exists, our estimates would be lower bounds of the true impact of poverty on property crime.

Another possible concern is that the colonial states may have intervened by investing more in places with extreme poverty. If extreme poverty was declining, and property crimes were to a large extent driven by poverty, one might expect the impact of food production on crime to decrease over time. To test for such a concern, we include interaction terms between food production and a time trend, which we instrument with interactions between rainfall shocks and a time trend. However, we do not find support for the claim that the effect of poverty on property crime attenuated during the study period (results not reported).

Another possible channel is psychological, as rainfall may affect people's moods by making them more or less inclined to committing a crime. A clear candidate here is high temperature shocks which have been found to cause elevated aggression (Anderson 2001) and violent crimes (Ranson 2014). We find that temperature shocks are not positively or negatively associated with rice yields (Table A-7, column 1) nor with property crimes (column 2). However, consistent with the relevant literature (Anderson et al. 2015; Iyer & Topalova 2014; Blakeslee & Fishman 2015), we find that temperature shocks are associated with 4.3% more violent crimes (column 3).

On a cautious note, we should point out that we are unable to conclusively rule out the possibility that rainfall shocks could have a direct impact on property crime beyond its impact through food production, yet we believe that these other effects are likely to be minor.

6. Conclusion

This article suggests that income shocks, and by extension poverty, are a key underlying cause of property crime in British colonial Asia. We estimate the causal effect of reduced rice production on crime using rainfall variation as an instrumental variable for rice production, and find that the effect of abrupt income shocks on property crime is considerably large. A one standard deviation decrease in annual rice production increases property crime by 21.2%. This effect is considerably higher in magnitude to accumulated evidence from

other studies reviewed by Hsiang et al. (2013). One explanation for such a large effect may arise from the fact that we are dealing with a highly agrarian/non-industrial part of the world, where the vast majority of the total income is derived from agricultural practises such as livestock herding and (food and cash crop) farming, and where urban labour was limited.

This article also addresses a major methodological problem that lies at the core of the existing economic and economic historical literature; i.e. endogeneity and reverse causality, since the effect between poverty and crime is larger than simple OLS estimates would suggest (8.5%), highlighting the importance of using instrumental variable methods. Additionally, we show that a one standard deviation decrease in rice production increases begging and vagrancy by 14.1%. This finding suggests that rice production was a key determinant of poverty during this period.

Although we find no effect between income shocks and violent crime, our results confirm a direct extra-economic channel between high temperature and violent behaviour. A one standard deviation increase in temperature is associated with 4.3% increase in violent crime. This serves as an important validation of the empirical strategy and highlights the importance of looking beyond aggregate crime measures in this climate-crime literature, since they may shadow heterogeneous patterns across crime categories. Although this article's aim is to apply this approach in economic history, it may also be extended to more present day developing countries.

Beyond improving our understanding on local conditions of early twentieth century South and South-East Asian states, the implication of this study may be important from a public policy perspective in contemporary developing countries. Taken together, the results of this research support the idea of improved high-yield weather-resistant grains and investments in irrigation technology. The promise of a stable annual harvest would potentially eliminate much of the adverse crime-induced poverty traps, as well as the subsequent unfolding vicious cycle of crime. Unfortunately, climate change continues and it is going to bring about more erratic weather events, hitting the poorest smallholder farmers the most. A key policy priority should therefore be to aim at a long-term protection of the most vulnerable and precarious farmers of the global south.

Appendix A

Table A-1. Correlation among Crime Measures

	Property crime	Violent crime	Theft	Cattle-raiding	Assault	Homicide	Vagrancy
Ln(Property crime)	1.000						
Ln(Violent crime)	0.117	1.000					
Ln(Theft)	0.824*	0.097	1.000				
Ln(Cattle-raiding)	0.628*	-0.018	0.409*	1.000			
Ln(Assault)	0.330	0.772*	0.267	0.367	1.000		
Ln(Homicides)	0.524	0.456*	0.240	0.199	0.371*	1.000	
Ln(Vagrancy)	0.364*	0.085	0.306*	0.312*	0.509*	0.476*	1.000

Notes: Correlation coefficients are reported. * Denotes significant at 5%. All crime measures are expressed as the logarithm of per 100,000 of the population.

Table A-2. Poverty & Property Crime: Using rainfall grids

	Ln(Property crime)				Ln(Vagrancy)	
	(1)	(2)	(3)	(4)	(5)	(6)
	OLS	OLS	IV-2SLS	IV-2SLS	OLS	IV-2SLS
Food production t	-0.085*** (0.010)	-0.088*** (0.010)	-0.168*** (0.046)	-0.179*** (0.053)	-0.037** (0.013)	-0.269** (0.110)
District & Year FE	Y	Y	Y	Y	Y	Y
Controls	N	Y	N	Y	Y	Y
District-specific effects (District dummy \times Year)	N	Y	N	Y	Y	Y
No. observations	552	552	531	531	339	303

Notes: *Significant at 10%, **5%, ***1%. Sample period: 1910–1939. Reported in parentheses are robust standard errors clustered at the district level. Controls include population density, road density and police per capita. District-specific effects indicates the interaction of each District dummy \times Year. The instrumental variables are rainfall deviation at year t and in the lagged year ($t-1$).

Table A-3. Clustering Standard Errors at Different Levels

	Dependent variable: Ln(Property crime)			
	(1)	(2)	(3)	(4)
	IV-2SLS	IV-2SLS	IV-2SLS	IV-2SLS
Food Production t	-0.202	-0.212	-0.206	-0.198
	(0.0302)	(0.0327)	(0.0328)	(0.0326)
		<0.0375>	<0.0378>	<0.0393>
		[0.0358]	[0.0371]	[0.0413]
	Dependent variable: Ln(Vagrancy)			
Food Production t	-0.151	-0.145	-0.116	-0.138
	(0.0483)	(0.0501)	(0.0462)	(0.0471)
		<0.0485>	<0.0300>	<0.0369>
		[0.0628]	[0.0460]	[0.0507]
District & Year FE	N	Y	Y	Y
Controls	N	N	Y	N
District-specific effects (unobservable x year)	N	N	N	Y

Notes. The specifications and the estimated coefficients in this Table are the same as in Table 6. 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-4. Poverty & Property Crime: Using Lags and Leads Rainfall as Instruments

	Ln(Property crime)		
	(1)	(2)	(3)
	IV-2SLS	IV-2SLS	IV-2SLS
Food production t [IV: Rainfall $t - 1$ & $t - 2$]	-0.525 (0.385)		
Food production t [IV: Rainfall $t + 1$ & $t + 2$]		-0.332 (0.451)	
Food production t [IV: Temperature t]			0.261 (0.389)
District & Year FE	Y	Y	Y
Controls	Y	Y	Y
District-specific effects (District dummy \times Year)	Y	Y	Y
No. observations	366	358	552

Notes: *Significant at 10%, **5%, ***1%. Sample period: 1910–1939. Reported in parentheses are robust standard errors clustered at the district level. Controls include population density, road density and police per capita. District-specific effects indicate the interaction of each District dummy \times Year. Column 1: the instrumental variables are rainfall deviation in the lagged year ($t - 1$), and two years earlier ($t - 2$). Column 2: the instrumental variables are rainfall deviation in the lead year ($t + 1$), and two years later ($t + 2$). Column 3: the instrumental variable is temperature deviation in year t .

Table A-5. Poverty & Property Crime: Specific crime categories

	Ln(Theft)				Ln(Cattle-raiding)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	OLS	IV-2SLS	IV-2SLS	OLS	OLS	IV-2SLS	IV-2SLS
Food production t	-0.082***	-0.077***	-0.222***	-0.208***	-0.096***	-0.077***	-0.199***	-0.176***
	(0.010)	(0.010)	(0.032)	(0.032)	(0.010)	(0.009)	(0.035)	(0.039)
District & Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Controls	N	Y	N	Y	N	Y	N	Y
District-specific effects (District dummy \times Year)	N	Y	N	Y	N	Y	N	Y
No. observations	552	552	521	521	417	417	385	385

Notes: *Significant at 10%, **5%, ***1%. Sample period: 1910–1939. Reported in parentheses are robust standard errors clustered at the district level. Controls include population density, road density and police per capita. District-specific effects indicates the interaction of each District dummy \times Year. The instrumental variables are rainfall deviation at year t and in the lagged year ($t-1$).

Table A-6. Poverty & Violent Crime

	Ln(Violent crime)			
	(1)	(2)	(3)	(4)
	OLS	OLS	IV-2SLS	IV-2SLS
Food production t	-0.056	-0.001	-0.007	0.002
	(0.048)	(0.059)	(0.176)	(0.189)
District & Year FE	Y	Y	Y	Y
Controls	N	Y	N	Y
District-specific effects (District dummy \times Year)	N	Y	N	Y
No. observations	600	600	575	575

Notes: *Significant at 10%, **5%, ***1%. Reported in parentheses are robust standard errors clustered at the district level. Controls include population density, road density and police per capita. District-specific effects indicates the interaction of each District dummy \times Year. The instrumental variables are rainfall deviation at year t and in the lagged year ($t-1$).

Table A-7. Temperature Shocks & Crime

	Food	Ln(Property	Ln(Violent
	Production	Crime)	Crime)
	(1)	(2)	(2)
	OLS	OLS	OLS
Temperature deviation t	0.070	0.035	0.043**
	(0.084)	(0.025)	(0.018)
District & Year FE	Y	Y	Y
Controls	Y	Y	Y
District-specific effects (District dummy \times Year)	Y	Y	Y
No. observations	552	576	600

Notes: *Significant at 10%, **5%, ***1%. Reported in parentheses are robust standard errors clustered at the district level. Controls include population density, road density and police per capita. District-specific effects indicates the interaction of each District dummy \times Year.

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