uc3m | Universidad Carlos III de Madrid

Master's Degree in Economic Development & Growth
2018-2019

Master's Thesis

The Long-Term Impacts of the Sahel Famine for Survivors in Mali

Matthew Adam Latham

Tutor: Jordi Domenech Feliu

Abstract

This paper measures the long-term effects of the Sahel famine of the early 1970s on the health, education and material outcomes of those exposed in Mali. Deviations in birthyear cohort sizes from trend are exploited to provide a measure of the regional variation in famine intensity. Measurement error and endogeneity are treated through the use of precipitation data to instrument for famine intensity. Results imply that men show worse scarring impacts than women, with larger increases in disability rates and reductions in the time they were able to spend in schooling. No strong impacts can be found for material outcomes.

Table of Contents

Introduction

It has been long established that the health environment an individual is exposed to whilst they are either in the womb or in the early stages of childhood can have dramatic impacts on them later in life. Undernutrition whilst in gestation can “reprogram the relationship between glucose and insulin and between growth hormone and insulin-like growth factor,” having marked imapcts upon an individual’s metabolism and the general functionality of their bodies (Barker et al 1993). Levitsky & Strupp (1995) find that malnutrition can impact the cerebellum and hippocampus such that neural receptor functions can be permanently changed. With these parts of the brain attributed to both vital cognitive funcitonings such as the regulation of fear and pleasure responses, as well as motor function, it is no surprise that poor early life health conditions have been associated with increased rates of physical disability and phychological disorders such as schizophrenia (Hoek et al 1998).

The epidemiological literature has often struggled to find sufficiently accurate measurements of foetal health which can be exploited to test its impacts on later life health outcomes (Almond 2011). This challenge has been met by a number of papers in the economics literature, which exploit major shocks to early-life health in the forms of famine and epidemics. In their study of the 1984 Ethiopean famine, Dercon & Porter (2009) find that those exposed between the ages of one and three were at least 5cm shorter than control groups. The 1918 influenza pandemic in the United States is calculated by Douglas Almond (2006) to have increased disability rates amongst those exposed in-utero by as much as 20% and led to 5% reductions in wages when compared to those born just a year prior.

The Sahel famine of the early 1970s provides a previously unstudied environment within which to investigate the links between early-life health and later-life outcomes. The famine affected parts of Mauritania, Senegal, Mali, Burkina Faso, Niger and Chad and is thought to have led to the deaths of around 101,000 people (Sen 1981). The famine appeared to have its roots in a number of colonial and post-colonial policies which led to the adoption of a number of unsustainable farming and grazing practices in the hyper-arid Sahel region (Swift 1977). These practices left the region’s agricultural and pastoral populations overstretched and unprepared to react to the consequences of a drought which began in the late 1960s. The conditions associated with drought are thought to have led to the deaths of between 40 and 60% of the livestock in the region (El Khawas 1976). The loss of livestock and crops associated with the drought drove a collapse of North-South trade, wiping out the food entitlements of those living in the Sahel. The famine was deemed as requiring special treatment by the World Food Programme in early 1972 and continued to grow in its intensity until rains returned in 1974 (Sheets & Morris 1976).

The Sahel famine and Mali in particular provide a good testing ground for the study of the impacts of foetal and childhood health on adult outcomes for a few reasons. Firstly, Mali is purported to have suffered some of the worst impacts of the famine, meaning that health endowments may have been impacted severely enough for the detection of scarring impacts later in life. Second, the trigger of the famine appears to have been a swift drop in the levels of precipitation during the late 1960s as compared to the previous decade. This event varied in magnitude across regions and can thus be exploited to find exogenous variation in the intensity of famine. The 1998 housing and population census provides detailed information regarding the nativity, health status, educational attainment and occupational status of the Malian populace 25 years after the peak of the famine. This information is exploited here to give an overview of the long-term impacts of the famine for the health, educational outcomes and material wellbeing of those exposed either in-utero or between the ages of zero and five.

In the study of the impacts of famine, there exist a number of empirical challenges. At least for the Sahel famine, no direct measures exist with regards to the spatial variation in famine intensity. This issue is addressed by using the inter-regional variations in the shares of birthyear cohorts missing when be compared with past trends. Such a proxy is of course subject to measurement error, while the impacts of the famine are likely endogenous to a number of regional unobservables. These issues are addressed via the instrumenting of famine intensity with data on the deviation in precipitation rates during the drought compared with the 17 years prior. Survivor selection can also bias estimates of the impacts of such events. I test for such biases by testing for the impacts of the famine across the distributions of two of my outcome variables, Meng and Quian (2009) argue that a pattern which tends to show more severe impacts at the upper percentiles of the distribution may be implicative of such an effect.

Results suggest that men were more severely impacted by the famine, several cohorts show significant increases in disability rates and reductions in their time spent in school in response to the exposure. While women do exhibit some increases in disability rates as a result of the famine, they are not as consistent as in the male sample. Female literacy and school attendance rates in fact appear to increase slightly in more severely affected areas. Later-life material outcomes do not show any significant long-term impacts in response to exposure.

The paper will be structured as follows; I first present a discussion of the Sahel, the famine and its likely causes. A conceptual framework with regards to the potential long-term impacts of early life nutritional shocks and their implications for empirical study will then be given. I then present the econometric method and a brief discussion of some visual clues as to the famine's impacts on educational attainment. The main results of the study are then summarised and later discussed with regard to the predictions of the conceptual framework.

Famine and the Sahel

The Sahel runs from the Atlantic coasts of Mauritania and Senegal through to Lake Chad. It has a largely semi-arid climate with average annual rainfall somewhere between 150mm and 500mm. With regards to Mali in particular, the belt of the Sahel runs through northern and central parts of the country, including the regions surrounding Timbuktu, Kidal and Mopti.[1] Between 1968 and 1974, the region suffered a period of reduced rainfall which is widely regarded as sparking a famine, which reached its peak in 1973. The famine, affecting parts of Mauritania, Senegal, Mali, Burkina Faso, Niger and Chad, is estimated to have killed 101, 000 people, having its strongest impacts in Mauritania, Niger and Mali. The effects were felt most strongly amongst rural populations, specifically the Sahel's nomadic pastoralists and sedentary agriculturalists, who made up the majority of the populations of the relief camps. In order to understand how to assess the long-term impacts of the famine on survivors, it is of course vital to spend some time looking at the chronology of the famine as well as the inhabitants of the Sahel region.

At the time of the famine, the population of the Sahel region was estimated to have been between 5 and 6 million (Imperato 1976). The two worst impacted groups, the pastoral and agricultural populations, have existed interdependently in the Sahel for centuries. While the pastoralists have often relied upon relied on the agriculturalists for food grains, the agriculturalists rely on the pastoralists for meat, dairy products and fertilizer for their crops (Swift 1977). Said fertilizer comes in the form of the droppings left by the pastoral herds which the agriculturalists allow to travel across their lands.

[1] An agroecological map of West Africa is given in figure 14 in the appendix, showing the main agroecological zones (including the Sahel) of Mali and the other nations of West Africa.

Traditionally, each group would produce little more than their subsistence needs, a practice which was widely discouraged during the colonial period. Colonial governments imposed poll taxes in addition to animal taxes for the pastoralists, incentivising the expansion of herds and crops, with this policy being continued under the independent governments of the region. Especially during the post-war period, there was an effort to encourage merchants to move to previously nomadic-inhabited zones. Such merchants tended to build wells and provide veterinary services to the pastoralists. In response, the nomadic population of the Sahel changed their migration patterns. Normally, they would follow the paths of seasonal rainfall, but the establishment of new administrative zones in the Sahel led them to concentrate around base wells. With better access to veterinary services and with the construction of new wells making previously risky parts of the region more inhabitable, herd sizes grew dramatically (Clauzel 1962). At the same time, there was a reorientation of Sahelian trade, with a greater emphasis on the trading of surpluses with those in the Savanna to the south (Baier & Lovejoy 1976). Such trade incentivised a commercialisation of herding practices, which brought greater access to a wider variety of calories, but required the abandonment of some important risk coping strategies.

The expansion of herd sizes and the move to more commercialised production methods had severe knock on impacts for the ecology of the Sahel. Sinclair and Fryxell (1985) note that the concentration of expanding herds around particular wells led to a degradation of the land in the surrounding areas, speeding up the process of desertification. Further, with less plant cover in those areas which are heavily grazed, the effects of albedo[2] can work to disrupt rainfall patterns, having potentially serious impacts on the risk of drought far into the future.

In the period running up to the famine, such effects were not likely to have been of great import to much of the Sahel's population. The period between 1950 and 1967 was the wettest period the Sahel had experienced for around a century, though some reports have this damp period lasting as far back as 1930 (Matlock & Cockrum 1976). Given such high levels of rainfall, both agriculturalists and pastoralists were able to increase their production past the levels which could have previously been supported by the Sahel. Such good conditions are

[2] Albedo refers to the level of reflectivity of a surface (in this case that of the Earth). If an area becomes more heavily grazed, the surface of the planet may reflect more light, reducing the temperature of an area and thus reducing the rates at which moisture evaporates, leaving less water vapour in the upper-atmosphere to turn into rain.

argued to have distracted from the cyclical nature of rains in the region, spelling disaster at the end of the 1960s (Wiseberg 1976).

By 1968 rainfall dropped far below the average for the 1950s and earlier 1960s, leading food production to stall. This can clearly be seen in figure 1, which shows an index of per capita food production in Mali between 1961 and 1980. The drought dramatically reduced the carrying capacity of the Sahel, having huge consequences for the herds of the region – some estimates show that between 1968 and 1973 between 40 and 60% of animals died in the Sahel (El Khawas 1976). In order to maintain caloric intakes, both agriculturalists and pastoralists began to sell off their assets to attain dietary staples from the Savanna to the South. While these actions are likely individually optimal, the large collective sell off lead to a collapse of the North-South terms of trade in Mali and the other Sahelian economies (Sen 1981). At the same time, the fixed money obligations stemming from the poll taxes still had to be met, which, when coupled with the change in relative prices in North-South trade lead to the destitution of thousands. By 1972, the World Food Programme deemed the situation to require special treatment in the form of food aid. In September of that year it was described as an 'acute emergency' by the FAO (Sheets & Morris 1976). The situation continued to worsen throughout 1973, before rains returned in 1974.

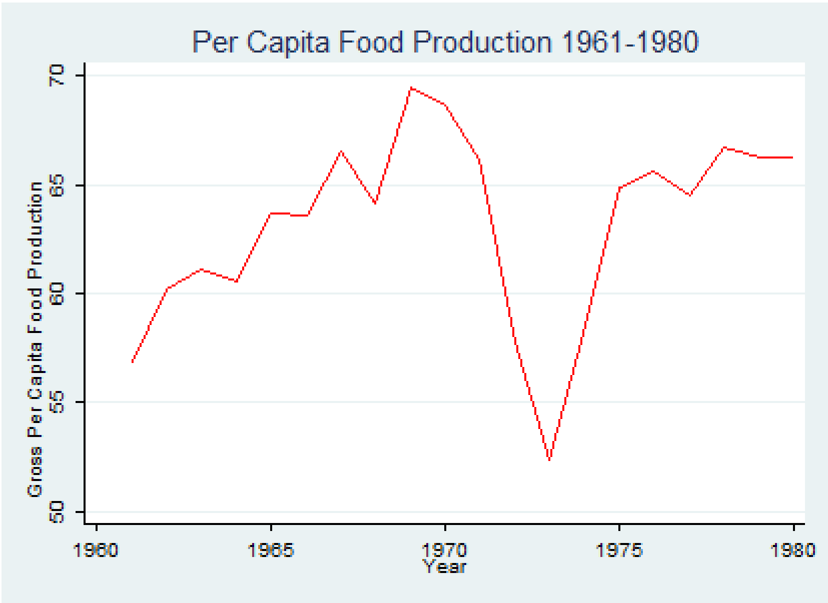

Figure 1: gross per capita food production index (2004-2006=100). Source: Food and Agriculture Organization (2018).

During the crisis, many from the Sahel migrated to relief camps in the South. While there was some praise of the response to the crisis, there were a number of reports suggesting systemic discrimination against nomads in the camps, with Sahelian governments attempting to focus more on the needs of the majority sedentary populations. The nomads were among the most vulnerable to famine in the first place, coupling this with discrimination and poor conditions in the relief camps, leading to an upsurge in cases of measles (Laya 1975) the group featured most prominently in mortality statistics (Sheets & Morris 1976).

In essence, the Sahel famine was sparked by a deviation in rainfall from its damp average in the 1950s and early 1960s, generating a reduction in the productive capacity of the Sahel's economy, a terms of trade collapse and a major subsequent nutritional shock for the Sahel's inhabitants. While rainfall variation was certainly a trigger for the famine, it appears as though it has roots in the historical interventions of governments aimed at boosting agricultural production across the Sahel region. In looking for the long-term consequences of the famine, Mali presents itself as a prime candidate for study. A population and housing census taken in 1998 provides enough information to identify those who were likely exposed to the famine, as well as the relevant outcome data for assessing their later life outcomes. Further, Mali experienced some of the most severe effects of the famine, making it more likely that some significant long-term impacts can be found and assessed. Before going on to explain exactly how these impacts will be found and assessed, I will spend some time explaining the conceptual framework behind the study of the famine's long-term impacts and how this will affect the way the investigation is approached.

Conceptual Framework

I measure the famine's impacts at the level of the birthyear cohort. These effects will be comprised of those felt purely at the individual level in addition to those generated by the interactions between exposed individuals and between exposed and non-exposed individuals. As will now be explained, it is not clear a-priori, the direction of these effects on average health, educational and material outcomes at the level of the cohort.

Most studies of the long term effects of early life shocks focus on the major individual-level effect implied by the foetal-origins hypothesis. First popularised by Barker and Osmond (1986), the hypothesis suggests that undernutrition while in the gestation period will permanently impact upon the body's metabolism and a number of other vital functions, leaving individuals less robust in their later years. These impacts manifest themselves throughout the individual's life. In childhood and adolescence, there is evidence that poor early health can disrupt the process of human capital accumulation. It may be that a child is simply left to frail to attend school regularly, as well as there being impacts upon their performance if they do attend. For example, Curry and Hyson (1999) found that children born in the UK with birthweights below 2.5kg were over 25% less likely to have passed their Maths or English O-Levels than others. With children being less likely to be able to perform in education, the question of how long children will tend to stay in education for arises. If educational performance has been reduced, then the returns to it fall. This reduces the incentive for children to remain in education or undertake it at all. Poor health can also manifest itself in lower individual productivity, having consequences for performance in the labour market. In their study of the 1984 Ethiopian famine, Dercon and Porter (2009) found that exposure in the early stages of childhood could reduce later-life earnings by around 5% per year.

If we are looking at the famine's impacts at the cohort level, we will be seeing far more than just the individual level effects. If the famine is particularly intense or the pre-existing health of the Sahel's population was poor, the outcome we observe at the cohort mean may be misleading (Almond 2006). Say we had a given distribution of health. A severe shock would impact negatively on the health of those exposed to it, putting downward pressure on the sample mean. If the shock is particularly severe or the pre-existing condition of health in the sample was poor before the fact, mortality rates amongst children and infants is likely to be high, with mortality mainly affecting those at the bottom of the health distribution. The elimination of a portion of the lower end of the health distribution will exert upward pressure on the mean. If the shock is severe enough or the initial health conditions poor enough, this second effect could dominate, leading us to find a positive impact of the famine at the mean of the health distribution, even if everyone at the individual level saw their health decline. Meng and Quian (2009) provide a means of testing for this survivor selection bias, which will be discussed shortly.

Impacts on household-level decision making may also act to counterbalance the wholly negative individual level effects. if family sizes fall during famines as a result of increased infant/child mortality, then there may be less competition for family resources. Following the quality/quantity arguments set forward by Becker and Lewis (1973), this could certainly increase investment in the surviving children's human capital, boosting attainment indicators. There is also the chance that parents choose to reallocate resources between their children if some are exposed to the shock and others are not. Yi et al (2015) present a model in which, depending upon their preferences, parents choose to either reinforce the effects of the health shock or to smooth them across the children of the household via their investments in health and education. Applying the model to a dataset on Chinese twins, they find that while health investments will tend to smooth the impacts of the shock, while educational investment appears to reinforce it. There is of course no reason to expect Malian parents to have the same preferences as Chinese ones along these axes.

If mortality rates are high enough in particular locales, such that exposed cohorts shrink dramatically in size, reduced labour market competition could in fact increase wages in more severely affected areas. Such forces may also increase returns to education, increasing the incentive to invest in it. The survivor selection bias mentioned earlier may well feed through to human capital and material outcomes; if the average individual in an exposed cohort is positively selected, they may have a number of advantages in schooling and the workplace when compared to average individuals from unexposed cohorts.

It is, at present, outside the scope of this study to investigate each of these mechanisms individually. I instead measure the net impact of their competing effects on health, educational attainment and later-life material outcomes. It is possible, however, to make some priors about the relative magnitudes of each effect. Survivor selection and the impacts of reduced cohort size on labour supply are conditional on the mortality rates associated with the famine. While it was certainly a severe shock for many, 101,000 deaths in a Sahelian population of several million is significantly lower than many famines studied previously, for example the Finnish famine of 1866-68 saw general mortality rates of 8.5% and infant mortality rates of up to 40% (Kannisto et al 1999). As such, the impacts of these mechanisms may not have particularly strong impacts on my estimates. So it appears as though impacts at the level of the individual and household will tend to dominate. Whether or not these mechanisms are complementary or not will depend upon parental preferences around reinforcing or smoothing the impacts of the famine. It is of course impossible to make anything but wild assumptions about the preferences of Malian parents here, though the results which follow may give some indication with regards to their direction.

Data

The majority of the data for this study will come from a 10% representative sample of Mali's 1998 population and housing, provided by IPUMS (2018). The census allows me to determine which cercle and year a given person was born in. Just to note, cercles are the second level administrative units in Mali, of which there are 49 alongside the country's capital, Bamako. With this information, I can see whether a person was exposed to the famine at a critical age as well as being able to see which cercle they were exposed within. Given that there was a large degree of intra-regional variation in famine intensity, the information embodied in a person's birthplace can be exploited to help identify a degree of variation within my treatment groups, improving the accuracy of my identification of the famine's long-term effects. How exactly I do this shall be explained shortly. A small caveat arises here; I am implicitly assuming that an individual was exposed to the famine in the cercle within which they were born. Given that the critical period for exposure is for a fairly short period whilst the individual is in the very earliest stages of their life, this may well be true, though they may still have moved within this period.

I take the World Food Programme and FAO's respective announcements in 1972 of the famine requiring 'special treatment' and being an 'acute emergency' (Sheets & Morris 1976) as an indicator that the famine truly started to have severe effects in that year. The famine continued to worsen throughout 1973, until being alleviated by the return of the rains in 1974.

Now, while the literature on foetal origins would suggest that the cohorts critical to this study are those who were exposed to the famine in-utero, it has been noted previously that famines in particular can have long-term impacts for those being exposed up until the age of five (Almond 2011).

With all this in mind the relevant birth cohorts for me will be those born in 1969, 1970, 1971, 1972, 1973 and 1974. These birth-year cohorts will form the treatment groups for my study, while the reference groups will be those born between 1963 and 1965. Those born between 1966 and 1968 have been omitted from the control group given their similarity in age to those in the critical cohorts and thus, they may still present some long-term effects of exposure. Those born after the famine have also been omitted from the control group; if it were the case that a great deal of institutional disruption were caused by the famine, it is likely that some of their outcome variables may also reflect some of the effects of the famine, making them inappropriate as controls. As previously mentioned, in addition to using variation between pure treatment and pure reference cohorts, I will exploit variation within my treatment groups, making use of the spatial variation in famine intensity.

The census provides information regarding whether an individual in the sample has a handicap or disability. Looking for the famine's long-term effect on such variables will provide me with my most direct test of the Barker hypothesis.

To assess the famine's impacts on human capital development, I use data on individuals' completed years of schooling. All those within the treatment group will be 24 years old or above at this stage in their lives and as such will likely be finished with schooling. As such, variations in this variable will capture the final impacts on human capital accumulation. Given that a large portion of my sample did not attend school at all, I also look to the impacts of the famine on school attendance and literacy rates, to give a broader picture of its effects on human capital formation.

The 1998 census also provides me with information on the occupations held by those surveyed. This information can be exploited to establish the variation in people's socioeconomic status. In order to do this, I convert the Malian occupational codes into an ISCO-08 format. This data is then converted into Gazenboom (2010)'s international socioeconomic index (ISEI). In essence, the socioeconomic index assumes that education mainly generates income through occupations and that socioeconomic status is the property of an occupation which converts a given level of education into a given level of income. The index is generated by taking information on education, occupations and earnings and measuring the indirect effect of education on earnings through occupation. This indirect effect is assumed to be socioeconomic status. With this measure, I am able to estimate the impacts of the famine on an exposed individual's material wellbeing later in life. It should be noted here that in all estimations, the natural logarithm of the index is used.

Summary statistics and some discussion of the major variables can be found in section C of the appendix.

Sampling

It appears as though the famine was felt predominantly in rural populations (Sen 1981). Now, while the census provides information regarding whether an individual lived in an urban or rural area in 1998, there is no information regarding whether they were born and exposed to the famine in such environments.

It may be a safe to make the assumption that the majority of migration goes from rural to urban areas, meaning that most of those living in rural areas in 1998 were also born in rural areas, while those in urban areas are some combination of those initially from urban and rural areas. Therefore in any urban sample, there will be a great deal of heterogeneity in the degrees of famine exposure amongst individuals.

As will be discussed shortly, famine intensity can be measured at the level of the cercle, or in the rural or urban subsets of these populations. However, given that a potentially large portion of the population in urban areas will inevitably have been exposed in rural regions, the measure of famine intensity for urban areas will be subject to a very large degree of error. It would pick up the average intensity of the famine felt in the urban population of a particular cercle, when that average is unlikely to be particularly applicable to either the urban born or rural born subsets of that population.

Given the inherent conceptual challenges with measuring the exposure intensity of individuals in the urban sample, they are omitted from the analysis presented in the main body of the text. This may generate a degree of selection bias; those who were born in and chose to stay in rural areas are likely to be negatively selected, potentially biasing estimates toward picking up greater scarring effects. While regrettable, such a bias is preferable over the measurement issues which would be encountered if a focus was placed on the urban sample. It can also be noted here that the urban population only constitutes 30% of the full sample.

It has also been noted previously by Stevenson et al (2000) and Fukuda et al (1998) that girls tend to be more resilient than boys when exposed to early-life nutritional shocks and as such, we would expect them to exhibit less severe long-term scarring. There is also the fact that men and women in general appear to be very different in terms of education and socioeconomic standing. For example, while 29% of men born in the sample period were literate, only 13% of women were. With such differences, it is unlikely that men and women will respond identically in terms of education and material outcomes. With this in mind, the analysis will be carried out separately for male and female populations.

Spatial Variation in Famine Intensity

As discussed earlier, there was a large variation in the severity of the famine between Mali's cercles, with its worst effects being felt in the Sahelian cercles in the Central and Northern regions of the country. In order to proxy for the spatial variation in famine intensity, I take a similar approach to Meng and Quian (2009) and measure the size of the rural birthyear cohorts in each cercle. Instead of simply using cohort size as my measure of famine intensity as Meng and Quian do, I run the following regression of the natural logarithm of cercle c's rural cohort size in year t on a cercle specific constant and time trend:

$$\ln(Cohort_{ct}) = \alpha_{0c} + \alpha_{1c}t + \varepsilon_{ct} \qquad (1)$$

The parameters are estimated over the periods from 1920 to 1965 and then from 1980 to 1988, thus avoiding the influence of the drought and famine. The equation;

$$\ln(\widehat{Cohort})_{ct} = \hat{\alpha}_{0c} + \hat{\alpha}_{1c}t \qquad (2)$$

thus provides an expected cohort size for all years following the sample period.

Now, during a period of famine, we would expect to see declining fertility rates, higher rates of infant mortality and higher levels of out-migration in those regions which were most severely affected. These impacts will all drive down the size of cohorts relative to what would be expected in the absence of a famine. Given this, we could measure these effects via:

$$-\hat{\varepsilon}_{ct} = \ln(\widehat{Cohort})_{ct} - \ln(Cohort_{ct}) \qquad (3)$$

Which, given that we have log-linearised our cohort sizes, captures the percentage deviation in cohort size, away from what would be expected in cercle c in year t.

This measure will better reflect the aforementioned effects for some birthyear cohorts than for others. The measure may be poor for the 1969, 1970 and 1971 cohorts for a number of reasons. Firstly, if we have defined the famine as beginning in 1972, it is unlikely that it will have affected the fertility decisions of the parents of these cohorts. Out-migration, specifically due to the famine, can only affect cohort sizes in a given cercle if parents move away whilst a child is in-utero, rather than at any point thereafter – it is impossible for such cohorts to reflect such a pattern. Thirdly, we know that the effects of nutritional shocks are more severe the younger a given individual is exposed (Krueger 1969). With these groups being the oldest in the treatment group, the variation in their cohort sizes will be less reflective of increased infant mortality than the variation in the sizes of later cohorts. Taking these caveats into account, I use the average of the percentage deviations in cohort sizes for the 1972 and 1973 cohorts to measure the famine intensity experienced in a given cercle:

$$intensity_c = \frac{-\hat{\varepsilon}_{c,1972} - \hat{\varepsilon}_{c,1973}}{2} \qquad (4)$$

The 1974 cohort was omitted, given that a portion of those in the cohort may have been born after the famine's conclusion. The 1972 and 1973 birthyear cohorts are the only two born whilst the famine was ongoing and thus able to reflect changes in parents' fertility and migration decisions as a result of the famine, as well as being better able to show the impacts of increased infant mortality.

Visualising the Famine's Impacts

With a means of measuring the between-cercle variation in famine intensity defined, it is worth spending some time looking for some simple evidence that the famine has had an impact on the outcomes of our cohorts of interest, especially those in the more severely affected regions. As I will now discuss, educational attainment appears to demonstrate patterns which are indicative of the famine's long-term effects. Data in this discussion are taken from the rural population. It should be noted that those figures shown here only take into account parts of the population who have attended school. Discernible patterns are difficult to demonstrate when including the full sample, given that a large portion of each birthyear cohort in our period of interest were bunched with no years of schooling, hence their omission.

Figure 2 overleaf shows a series of average number of years of schooling for each birthyear cohort between 1950 and 1975. For the earlier parts of the period, there appears to be something of an upward trend. There is then a clear negative shock for the 1968 cohort, which worsens for the 1970, 1971, 1972 and 1973 cohorts. In fact, the 1973 cohort has the worst levels of attainment out of any included in the series. With these cohorts all being exposed to the famine in their critical stages of development, such impacts may well be explainable by the famine.

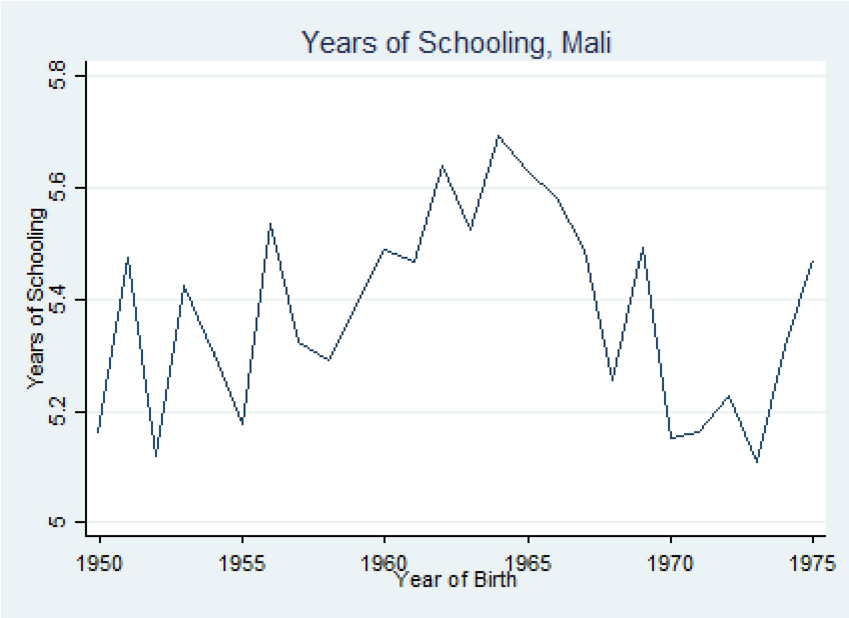

Figure 2, source: IPUMS (2018)

In addition to having an impact on average attainment, a famine may also impact upon the spread of educational attainment. If some regions are worse affected than others, then we would expect to see the between-cercle variation in educational attainment increase for our cohorts of interest. This is well demonstrated in figure 3, which shows the coefficient of variation for the average years of schooling across cercles between 1950 and 1975. The coefficient of variation increases dramatically over the cohorts from 1969 to 1975.

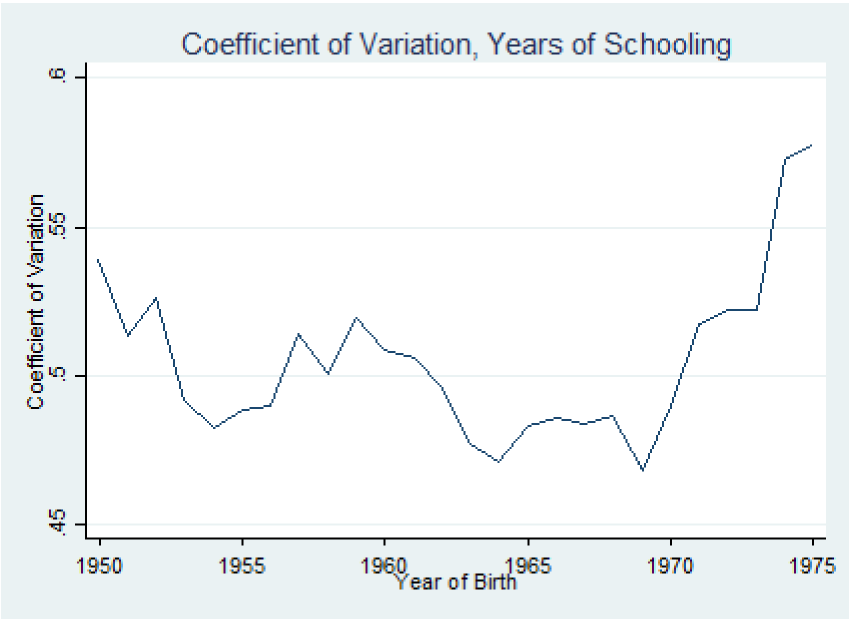

Figure 3, source: IPUMS (2018)

It will also be informative to see whether there appear to be any differences between those groups which appear less and more severely affected by the famine. Figure 4 plots the average years of schooling attained by men in rural Mali against the average for men born in cercles which saw cohorts ‘missing’ 20% or more of their expected values between 1972 and 1973. It can be seen that while before the cohorts of interest, those in worse affected cercles had higher attainment on average. In 1970 there is a dramatic reduction in the time spent in education in this group, bringing attainment well below that of the male average. While there is a slight recovery in the 1972 cohort, the attainment of those born in the more severely impacted regions is still about 6 months below that of the earlier cohorts and now roughly on par with the average.

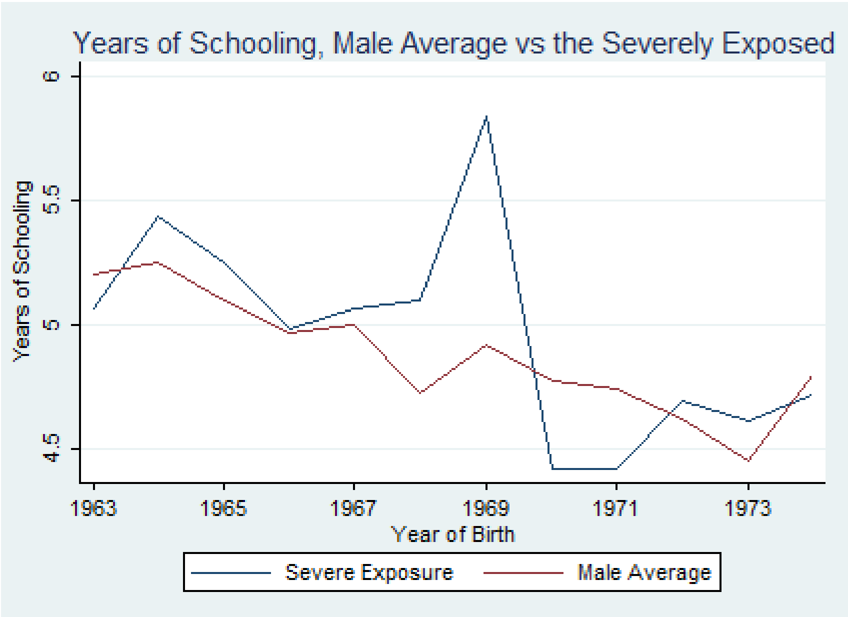

Figure 4, source: IPUMS(2018)

So, it appears that amongst those who had some schooling, overall attainment fell amongst the famine cohorts, whilst becoming more variable between cercles. There is also some indication that in those areas where the famine was felt more severely, the reductions in educational attainment were larger. Figures 2 and 3 are recreated using the data for the natural logarithm of the ISEI index in figures 9 and 10 in the appendix. There, we see similar drop offs in the value of the index and increases in its coefficient of variation for the exposed cohorts.

Econometric Strategy

General Model

With the famine intensity variable defined, I am able to estimate the following equation:

$$y_{ict} = \gamma_c + \rho_t + \sum_{\tau=1969}^{1974} \beta_\tau(\rho_\tau * intensity_c) + u_{ict} \qquad (5)$$

Where y_{ict} is the outcome variable for individual i, born in cercle c in year t; γ_c is a cercle fixed effect and ρ_t is a birthyear fixed effect. Given that we expect the impact of the famine to vary depending on a person's age at exposure, I allow its impacts to vary across the treatment cohorts. The equation is estimated for the birth cohorts from 1963 to 1974, with the 1963, 1964 and 1965 birthyears being omitted from the set of birthyear fixed effects. Were we looking at an individual born in cercle c in year τ, the model would estimate:

$$y_{ic\tau} = \gamma_c + \rho_\tau + \beta_\tau intensity_c + u_{ic\tau} \qquad (6)$$

Where γ_c captures the average of the outcome variable y, for the 1963, 1964 and 1965 cohorts in cercle c and ρ_τ captures the average change in the outcome variable between the control cohorts and the year τ cohort for those born in a cercle with famine intensity of zero. β_τ thus reflects the average marginal impact of famine intensity on y, holding constant time-invariant cercle effects as well as those effects which occurred in year τ which were unrelated to the famine.

For the continuous outcome variables, least squares estimation techniques are applied, while probit estimation is implemented for all binary outcomes. In all cases, standard errors are clustered at the cercle level.

Now, it is worth explaining how exactly each β_τ can be interpreted. It is common practice in previous studies to simply split groups into those exposed in-utero and those exposed in their early childhood. But given that the data from the census only provides information on the year, not the month, that someone was born, this is not possible here. As such, some cohorts will have been exposed as both children and whilst in-utero. The 1969, 1970 and 1971 cohorts were only exposed as children. All those exposed in the 1974 cohort were exposed in-utero, though those born at the very end of the year may not have seen any direct exposure to the famine. All of those in the 1973 birthyear cohort were exposed both in-utero and in early childhood, with the same being able to be said for a large share of those in the 1972 cohort. As such, $\{\beta_{1969}, \beta_{1970}, \beta_{1971}\}$ can be seen as treatment effects for childhood exposure, β_{1974} is mainly reflective of in-utero exposure, while $\{\beta_{1972}, \beta_{1973}\}$ are reflective of the treatment effect for someone exposed both in-utero and as a child.

We can make some predictions with regards to the relative magnitudes of these coefficients. There will be two factors influencing this, one being length of exposure and the other being age at exposure. The severity of the famine's impacts will tend to be greater the longer an individual is exposed for, as well as the younger they were when exposed. Those born between 1969 and 1972 will have been exposed for the full duration of the famine, with a portion of the 1972 cohort's exposure being in-utero. The 1973 cohort will, on average, have been exposed for the majority of the famine, with a large portion of this being in-utero. The 1974 cohort will have been exposed for the smallest share of the famine, but with most of this being in-utero. Given this, we would expect that the health effects would be most severe for the 1972 and 1973 cohorts. It follows that effects become more severe as we move through the 1969-1971 cohorts, however it is not clear how these groups should compare with the 1974 cohort. Such predictions are most applicable to health outcomes. When it comes to education and material outcomes, the ordering of coefficients will depend on a more complex range of mechanisms.

IV Strategy

A few problems arise with the famine intensity variable in this setting. Firstly, given that it is a proxy variable and not a direct measure of the famine, it may be measuring the impact of the famine with error. Second, there are likely to be omitted variables both correlated with famine intensity and the outcomes. As a result, regular OLS and probit estimates will not produce consistent estimates of β_τ. I therefore propose an IV strategy, using precipitation data to establish exogenous variation in famine intensity.

As discussed previously, the famine was triggered by a change in rainfall patterns from the rather pluvial 1950s and mid to late 1960s compared with a severely dry spell starting at the end of the latter decade. These patterns are shown in figure 5, which gives the across-cercle average annual precipitation. There exists a clear drop off in Mali's precipitation from 1968 to 1973 compared to the previous period, which does not appear to recover until 1974.

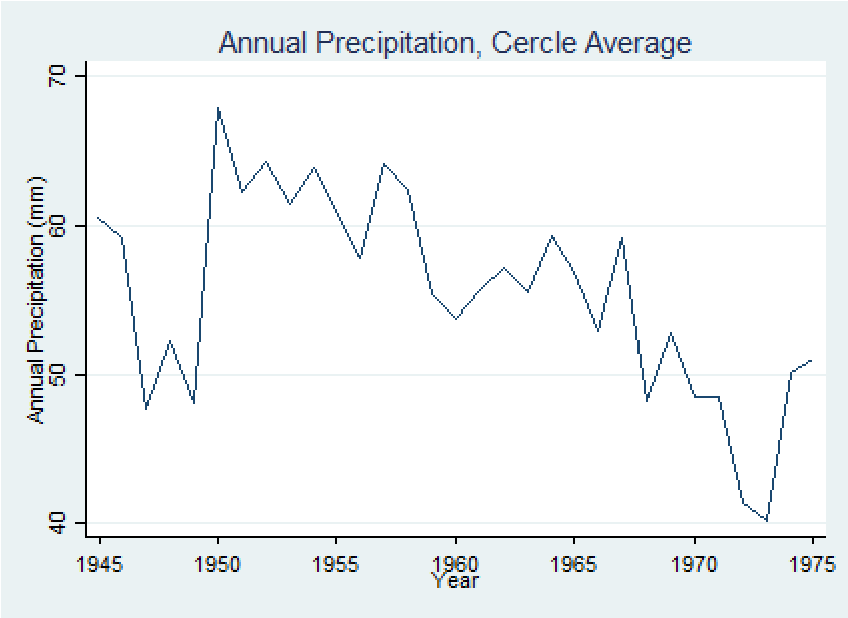

Figure 5: Average Cercle Precipitation (1945-1975), Source: Willmott & Matsuura (2001).

We can see variation between cercles in terms of the drop in precipitation from 1968 to 1974. Figure 6 shows demeaned series for the annual precipitation for the average cercle and Kolokani, which, according to my measure of famine intensity was one of the worst affected regions.

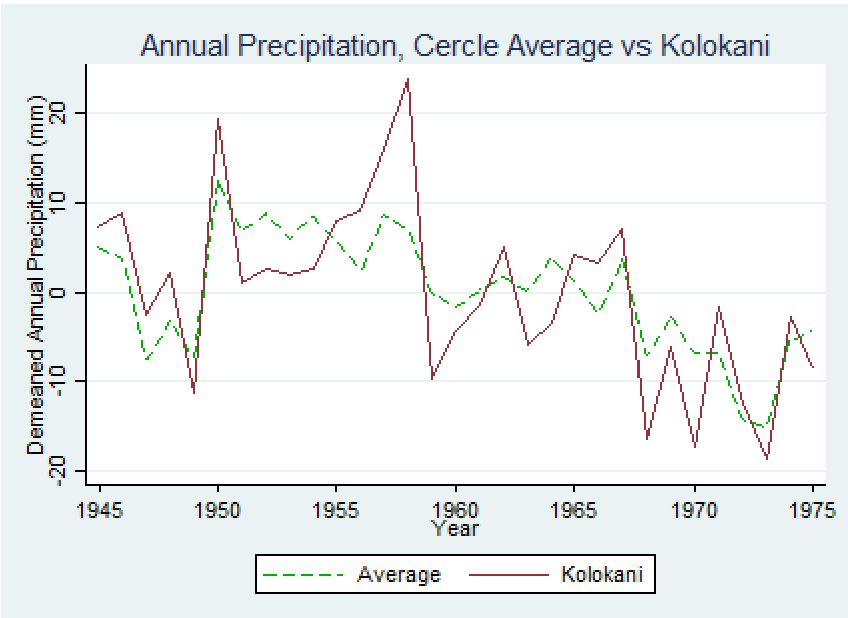

Figure 6: Demeaned Annual Precipitation, Cercle Average & Kolokani, Source: Willmott & Matsuura (2001).

As can be seen, Kolokani's precipitation levels experience larger fluctuations in the drought period compared with earlier. This is in line with Sen (1981)'s observation that those cercles which saw a greater variation in rainfall saw worse effects of the famine. Taking a more general approach, there can be found a 32.23% correlation[3] between my measure of famine intensity and the percentage deviations in precipitation levels between the drought period (1969-1973) and the 17 years prior across cercles. So it appears as though there exists some evidence of a connection between precipitation patterns and the intensity of famine.

With this in mind, I propose to use the percentage deviation in rainfall in the years 1969, 1970, 1971, 1972 and 1973 compared with the average for 1950-1967 as instruments for famine intensity. My first stage equation in a given birthyear τ will then be:

$$intensity_c = \sum_{t=1969}^{1973} \delta_t \rho_\tau precipdev_{ct} + \rho_\tau + \gamma_c + v_c \qquad (7)$$

Where ρ_τ and γ_c are as they were in equation 5, $precipdev_{ct}$ is the percentage deviation in precipitation in cercle c in year t compared with that cercle's average between 1950 and 1967 and δ_t is a parameter.

It is likely that the deviations in precipitation within cercles are highly correlated with one another. In order to defend against issues of multicollinearity, I also have the option of using the average of the deviations from 1969 to 1973 as a single instrument for cercle-wide famine intensity. The downside here is of course that, when compared to equation 7, less variation in famine intensity will survive to the second-stage equation.

The data on precipitation provided by Willmott & Matsuura (2001) who collect data from the Global Historical Climatology Network's (GHCN) station records of monthly and annual average precipitation to provide data on annual average precipitation for a large number of weather stations at an international level. Their series is available for between 1950 and 1999. In Mali's case, the data has been made available at the cercle level by Goodman et al (2019), making it easily incorporated into this study.

Survivor Selection

While the IV strategy will correct for biases stemming from the measurement error and endogeneity surrounding the famine intensity variable, as explained earlier, survivor selection may also bias my estimates. Such an effect is likely to bias my estimates toward zero. In its

[3] This, along with a few other pairwise correlations between famine intensity and precipitation variables can be found in table 10 in the appendix.

presence, any estimates from equation 5 should be taken as lower bounds for the severity of the famine's long-term impacts. To confirm whether or not survivor selection is having an effect, I can estimate the following adaptation of equation 5 via 2SLS:

$$y_{ct} = \gamma_c + \rho_t + \sum_{\tau=1969}^{1974} \beta_\tau(\rho_\tau * intensity_c) + \epsilon_{ct} \qquad (8)$$

Where y_{ct} is the value of a given decile in the distribution of y_{ict} in a given cercle*birthyear cell from equation 5. All other variables and parameters are as they were previously. The regression here will be weighted by the size of each cercle*birthyear cell, thus if I were to test for impacts at the mean, it would give the same estimates as equation 5.

The pattern of the β_τs across deciles will give some indication of whether survivor selection bias is present. If it is the case, then we should see the coefficients growing more strongly negative as we move from the lower deciles upwards. This is because we would expect to see greater mortality rates amongst those at the lower end of the outcome distribution, leaving only the more able left in these parts of the outcome distribution, thus 'improving' the observed effect of the famine at these parts of the distribution. Such an effect is far less likely to be found amongst the upper percentiles.

It is worth noting here that this equation can only be estimated for the years of education and the international socioeconomic index.

Results

Here I present the results of my estimations, first presenting some benchmark OLS and probit estimates, before going on to present results from IV estimates and looking at the famine's impacts at different parts of the distributions of schooling years and the ISEI. The implications of these results will be discussed in more detail in the subsequent section.

OLS & Probit

Output tables for the OLS and probit estimates can be found in table 1 on page 23. In general, there do appear to be signs of scarring effects of the famine, with these being more severe in the male samples. The impacts do not appear to be entirely negative however, as will be discussed, female literacy and school attendance rates seem to increase in response to increases famine intensity.

Disability Rates

All point estimates show up, expectedly, as positive in the disability regressions. Women in the 1969 birthyear cohort appear to have been significantly affected. Let's say that we had a woman from a rural area in the cercle of Kolondieba, an area experiencing famine intensity very close to the mean. If we were to move Kolondieba's famine intensity from its true value to one standard deviation above, we would see an 8.8% increase in that woman's probability of having some form of handicap. Henceforth, this exercise will be called a Kolondieba standard deviation experiment. While no single male cohort experiences such a strong effect, male disability rates do appear to be more responsive to famine exposure overall. The most strongly impacted male group seem to be those from the 1972 cohort, with an effect significant at the 1% level and expected 8.3% increase in disability rates from the standard deviation experiment. The 1974 cohort could expect to see an increase of 6.2%, which is significant at the 10% level. We also see a marginally significant impact for the 1969 cohort, which would predict an increase in disability rates by 4.6%.

Years of Schooling

Men again appear to have seen worse scarring effects in terms of schooling years than women. All the point estimates in the male sample are negative and are significant for the 1970, 1971 and 1973 cohorts. These coefficients would predict reductions in their time spent in school by around 1 month each after a standard deviation increase in famine intensity. In the female sample, while some coefficients do appear as negative, none are significant. The goodness of fit for the female sample is also only half that of the male sample, with respective R-squareds of 6.2% and 12.4%.

Literacy Rates

In contrast to what we would classically expect, almost all point estimates on the famine intensity birthyear interactions are positive. Within the male sample, none show up as statistically significant. There do appear to be positive significant impacts of the famine for the 1972 and 1973 female cohorts. If true, these estimates would imply that a repetition of the Kolondieba experiment would lead to increases in female literacy rates of 3.2% and 2.1% in each cohort respectively.

School Attendance Rates

As with literacy rates, the results for school attendance go against the simple assumption that exposure to the famine would have entirely negative impacts. In all cases, point estimates come out as positive, while of negligible magnitude in the male sample, they appear stronger in the female one. The coefficients for the 1970, 1971 and 1972 female cohorts are all significant at least at the 5% level and the aforementioned standard deviation experiment predicts 5%, 8.6% and 7.7% increases in school attendance rates.

International Socioeconomic Index

All coefficients on the famine intensity interactions appear with the expected negative signs and impacts for men in the sample appear slightly stronger on average than those for women. Results appear to be stable across the cohorts with a test of the equality of coefficients unable to reject the null. None, however, are statistically significant. If we were to take the point estimates as they are, after a standard deviation increase in the severity of the famine, we could expect a 1-point reduction in the index for men and slightly less than this for women. In a practical context, this is not of a great deal of interest.

Table 1: OLS and single-stage probit results

	Disabilities		Years of Education		Literacy		School Attendance		ln(ISEI)	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
P_{1969}*Intensity	3.109	4.039*	-0.118	-0.151	0.573	1.088	1.163	2.869	-1.284	-1.225
	(2.116)	(2.143)	(0.657)	(0.295)	(0.458)	(0.932)	(1.312)	(1.87)	(1.116)	(1.159)
P_{1970}*Intensity	2.8	3.017	-0.664*	-0.0951	0.689	0.552	1.823	3.459**	-1.211	-1.074
	(2.211)	(1.862)	(0.393)	(0.146)	(0.462)	(0.788)	(1.448)	(1.741)	(1.070)	(1.010)
P_{1971}*Intensity	2.481	2.509	-0.694*	0.197	-0.0031	1.041	1.376	4.874***	-1.146	-1.154
	(1.881)	(2.038)	(0.372)	(0.161)	(0.314)	(0.783)	(1.143)	(1.762)	(0.958)	(1.055)
P_{1972}*Intensity	4.605**	2.797	-0.442	0.0498	0.443	1.531*	1.537	4.529**	-1.324	-1.184
	(1.855)	(1.815)	(0.527)	(0.179)	(0.427)	(0.908)	(1.373)	(1.833)	(1.120)	(1.012)
P_{1973}*Intensity	2.792	1.613	-0.761**	-0.118	0.383	1.070*	1.259	2.43	-0.959	-0.886
	(1.917)	(1.556)	(0.299)	(0.098)	(0.347)	(0.63)	(1.073)	(1.728)	(0.846)	(0.846)
P_{1974}*Intensity	3.797*	2.493	-0.659	0.00642	0.526	1.212	1.859	3.152	-1.343	-1.109
	(1.946)	(2.022)	(0.567)	(0.229)	(0.383)	(0.843)	(1.294)	(1.945)	(1.140)	(1.104)
Cercle Effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	45,502	57,100	41,290	55,692	45,239	56,485	45,761	57,152	43,392	25,104
R-squared			0.124	0.062					0.965	0.967

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Birthyear effects are presented separately in table 4 in the appendix.

2SLS & IV Probit Estimates

The results discussed above are likely subject to a number of biases stemming from endogeneity and measurement error. Measurement error, assuming that it is randomly distributed, will bias coefficients towards zero, while it is likely that endogeneity is exaggerating the impacts of the famine. The following IV estimates should address these issues, giving a more accurate picture of the famine's long-term impacts. The results table for the IV estimations is given on page 27.

Before discussing the final results, it is worth having a quick look at the first-stage equation. Results are presented in column 1 of table 2 overleaf. Precipitation variables appear statistically significant at the 1% level for the years 1969, 1970 and 1971 and the marginally significant for 1972 (p=10.04). An F-test for joint significance rejects the null with an F-statistic of 26.09. The general picture is implicative of the narrative that those regions which suffered the largest changes in their precipitation levels between 1969 and 1974 as compared with the period from 1950-1967. The negative significant coefficient on the deviation for 1969 does appear odd, however. Across the cercles, the variable is positively correlated with the deviations from other years, suggesting that those who saw greater deviations in 1969 also saw them in the following years. A pairwise regression of intensity and the precipitation deviation from 1969 implies no statistically significant correlation between the two, so while the variation in the 1969 deviations which is in line with the general pattern is likely positively correlated with famine intensity, it appears as though there was some idiosyncratic variation, specific to 1969 which moves in the opposite direction.

Multicollinearity is a major concern here. In column 2 of the table are the variance inflator factors of each coefficient in the regression. As can be seen, none present particularly worrying results, with the highest VIF being below 3. Even with a fairly conservative VIF limit rule, this is not of great concern and as such, the use of all precipitation deviations is preferred over the average of the five.

Disability Rates

In comparison to the OLS estimates, all the IV results move closer to zero, though they all remain positive. A clearer pattern of more severe scarring for men emerges here, while coefficients are of similar magnitudes for both sexes for the earlier birthyear cohorts, female coefficients reduce in size against male ones for those cohorts exposed in-utero. In the male sample, the 1972 cohort sees an effect which is significant at the 1% confidence level and those for the 1969, 1971 and 1974 cohorts are all marginally significant. Carrying out the Kolondieba standard deviation exercise would lead to increases in disability rates by 7%, 3.6%, 3% and 3.4% respectively. Impacts are less pronounced for the female sample, with the impact only being marginally significant for the 1969 cohort – here, carrying out the same experiment would generate a 2.3% increase in disability rates.

With this being the only pure health outcome variable being looked at, we would expect to see the largest impacts being felt by those cohorts exposed in-utero. Here, this would be the 1972, 1973 and 1974 cohorts. While impacts appear most significant for the 1972 cohort, the general pattern does not indicate that in-utero exposure would lead to a necessarily worse outcome than childhood exposure, with the 1969 cohort appearing to be worse affected than either the 1973 or 1974 cohorts.

Table 2: Famine intensity and precipitation deviations

VARIABLES	Intensity	VIF
$Precipdev_{1969}$	-0.397***	3.33
	(0.0746)	
$Precipdev_{1970}$	0.708***	2.51
	(0.0701)	
$Precipdev_{1971}$	0.305***	2.32
	(0.102)	
$Precipdev_{1972}$	0.125	2.22
	(0.0768)	
$Precipdev_{1973}$	-0.176	1.6
	(0.115)	
Observations	597	
R-squared	0.181	

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Years of Schooling

If we compare the 2SLS results with those from the OLS estimates, no clear patterns emerge in terms of how correcting for measurement error and endogeneity affect the results; in some cases, coefficients move further from zero and in others they may move closer. We do, however, see a greater number of statistically significant effects.

In the male sample, the coefficient for the 1971 cohort becomes decidedly more negative, though its standard error also grows significantly, moving it into insignificance. The coefficients for the 1970, 1973 and 1974 cohorts appear more strongly negative and the 1974 coefficient becomes significant at the 10% level. In these cases, a standard deviation increase in famine intensity would lead to an expected reduction in schooling years by 1.2, 1.7 and 2.1 months respectively.

While most of the female cohorts see negative point estimates for their famine intensity birthyear interactions, most are not significantly different from zero. Interestingly enough, the only significant effect appears to be for the 1972 cohort, who actually see their schooling years increase in response to the famine. Here, a standard deviation increase in famine intensity would lead to an increase in average schooling years by around half a month. So while it is interesting that the impact here is positive, the effect does not appear to be of great practical significance.

Literacy Rates

Literacy results do not present any changes in comparison to the single stage probit estimates.

School Attendance Rates

The pattern of results for school attendance rates does not appear to be particularly different when instruments for famine intensity are used. The main impact appears to be that all coefficients have moved closer to zero. No results appear statistically significant in the male sample. For women, as before, coefficients for the famine birthyear interactions are positive and significant for the 1970, 1971 and 1972 cohorts. If subjected to the Kolondieba experiment, these cohorts could expect to see 3.4%, 7.6% and 5.5% increases in school attendance rates.

International Socioeconomic Index

In the case of the ISEI, it appears as though endogeneity biases were pushing the coefficient estimates in the negative direction. If we compare with the OLS estimates, the coefficients all move positively, with only the coefficient for the 1974 female cohort being statistically significant. If we consider that a standard deviation increase in the intensity of famine with this variable would generate a 4.19% change in the index, the equivalent of a fairly minor promotion, this isn't a particularly noticeable impact.

Table 3: IV results

	Disabilities		Years of Education		Literacy		School Attendance		ln(ISEI)	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
P_{1969}*Intensity	2.473	2.393	0.472	-0.174	0.573	1.088	0.752	1.918	-0.00632	0.0212
	(1.612)	(1.560)	(0.687)	(0.420)	(0.458)	(0.932)	(1.267)	(1.419)	(0.0712)	(0.160)
P_{1970}*Intensity	1.558	1.810	-0.818*	-0.0421	0.689	0.552	1.046	2.540*	-0.0467	-0.0966
	(1.360)	(1.232)	(0.467)	(0.242)	(0.462)	(0.788)	(1.330)	(1.321)	(0.0727)	(0.105)
P_{1971}*Intensity	2.025	1.770	-1.913	0.195	-0.0031	1.041	0.929	4.337***	-0.0545	-0.0396
	(1.247)	(1.436)	(1.189)	(0.310)	(0.314)	(0.783)	(1.089)	(1.442)	(0.0529)	(0.110)
P_{1972}*Intensity	3.972***	1.907	0.0963	0.288*	0.443	1.531*	1.204	3.524**	-0.0416	-0.0116
	(1.547)	(1.369)	(0.574)	(0.155)	(0.427)	(0.908)	(1.348)	(1.532)	(0.0524)	(0.0765)
P_{1973}*Intensity	1.561	0.8161	-1.119***	-0.203	0.383	1.070*	0.588	1.409	0.0446	0.0285
	(1.189)	(1.047)	(0.360)	(0.147)	(0.347)	(0.63)	(1.012)	(1.232)	(0.101)	(0.0761)
P_{1974}*Intensity	2.356	0.816	-1.377*	-0.293	0.526	1.212	1.214	2.371	-0.0918	0.322**
	(1.477)	(1.316)	(0.772)	(0.383)	(0.383)	(0.843)	(1.231)	(1.467)	(0.101)	(0.128)
Cercle Effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	45,502	57,100	41,290	55,692	45,239	56,485	45,761	57,152	43,392	25,104

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Birthyear effects are presented separately in table 5 in the appendix.

Decile Analysis

While there do appear to be some long-term impacts of the famine on the outcome variables, many cohorts do not appear to be affected in any significant way. As noted by Almond (2006), if a nutritional shock indices high enough mortality may leave only the more robust within the population surviving. Such an effect may be biasing my estimates toward zero. In order to check for such an impact, I test for the famine's impacts at the different deciles of the distributions of schooling years and the ISEI. Even in the absence of survivor selection, such an analysis can shed some light on the distributional impacts of the famine.

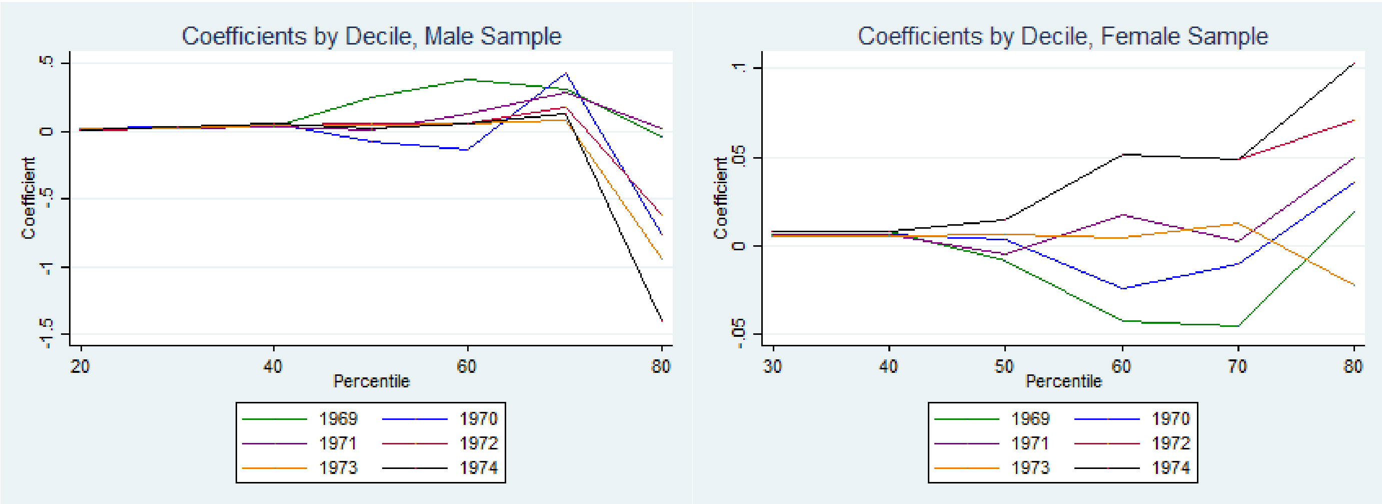

Figure 7: Coefficients by Decile, Years of Education

Figure 7 graphically represents the results of the quantile analysis from equation 8 for the male and female samples, using years of education as the outcome variable. Each line maps the coefficients for each birthyear cohort. In the male sample, the 2nd decile to the 8th are displayed and the 3rd to the 8th in the female sample. The 1st and 9th are omitted given that both are likely to capture the impacts of bunching at the very top and very bottom of the distributions. The 2nd decile is missing from the female sample given that the outcome here is constant and zero across cohorts.

The male sample exhibits very consistent patterns across the cohorts and deciles. There appears to be no long-run impacts of the famine upon the lower parts of the distribution, with some significantly negative impacts at the upper end of the distribution. While the general pattern is somewhat suggestive of survivor selection bias, there are a number of inconsistencies. The existence of positive coefficients around the 60th and 70th percentiles, most notably for the 1969 and 1970 cohorts are not particularly indicative of survivor selection.

The female does not present any common patterns. The 1971, 1972 and 1974 cohorts follow similar trends to one another, as do the 1969 and 1970 cohorts. The former trio appear to show a pattern in direct opposition to what we'd expect with survivor selection, with no impact amongst the lower deciles and strongly positive ones in the upper parts of the distribution. The 1969 and 1970 cohorts see increasingly negative coefficients from the 50th to 70th percentiles, before they recover at the 80th. The 1973 cohort has a coefficient pattern similar to those amongst the male sample and is the only one here even slightly indicative of survivor selection.

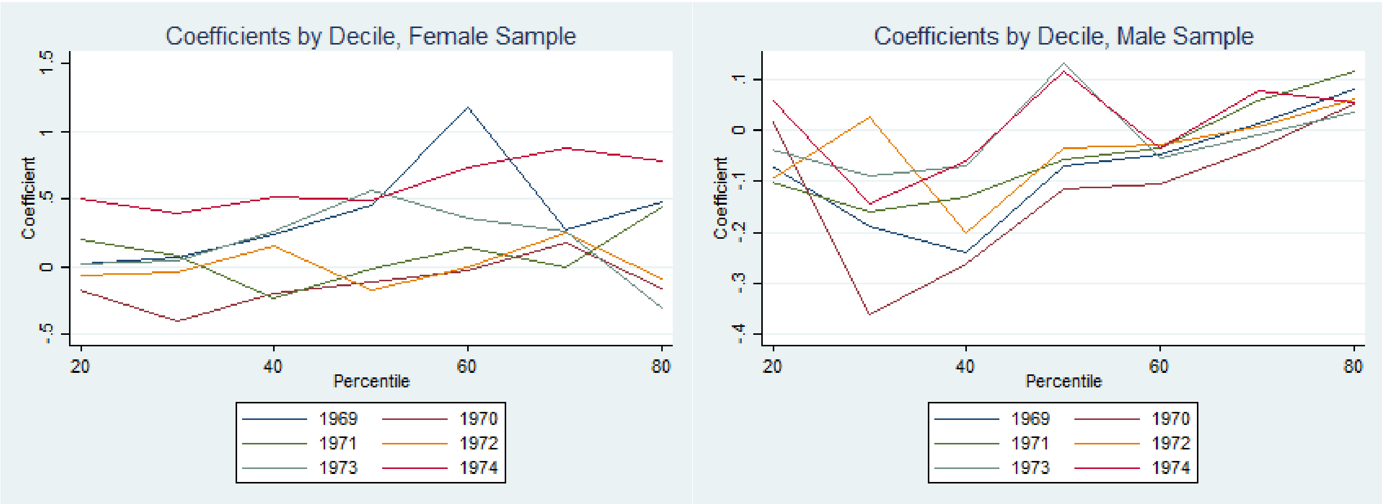

Figure 8: Coefficients by Decile, ln(ISEI)

The above figure shows a similar analysis for the natural logarithm of the ISEI. In neither the male nor the female sample do we see any indication of survivor selection biases. In the female sample, coefficients appear to be fairly consistent within cohorts, with the exception of a spike for the 60th percentile in the 1969 sample. For the male sample, there is something more of a trend in the coefficients – we tend to see coefficients very close to zero for the 20th percentile, which turn largely negative up until the 50th percentile - the greatest negative effects appear around the 30th or 40th, implying that the bottom half of the occupational distribution tends to bunch together and move downwards. At the median, we see positive impacts for the 1973 and 1974 cohorts and all cohorts appear to show an upward trend in their coefficients once we move into the upper half of the distribution.

Discussion

Absent of major selection biases, theory would lead us to expect health outcomes to exhibit long term declines in response to the shock, with such impacts being more pronounced for men and those born in 1972 or 1973. With regard to human capital formation, predictions are less obvious. A negative impact on individuals' health may leave an individual unable to attend school or less able to perform in it, pushing down performance indicators. There do exist, however, correcting mechanisms at the household level or above which can counteract such effects. Predictions surrounding material outcomes are subject to the same degree of uncertainty. So how do the results of this study line up with these predictions and are the effects of any true practical significance to those exposed to the famine?

First, we can look to results for disability and handicap rates as a rough indicator of health within each cohort. As the theory predicts, all impacts appear to be negative and slightly more severe for men. For men, the impact of the Kolondiaba exercise varied between generating an increase in disability rates within an affected birthyear*cercle cohort by between 3 and 7%. While such numbers may not seem to be of a great deal of practical significance, they appear far more serious if we look to the more severely affected cercles. If we repeat the exercise, increasing intensity to its maximum, we would expect to see 20% increases in disability rates for the 1974 and 1969 cohorts and a 15% increase for the 1971 cohort. So while in areas of moderate famine intensity, impacts may be bad but fairly negligible, while in regions which saw the worst of the famine, health impacts may have been quite severe.

In the male sample, as predicted, the 1972 cohort appears to be the most severely affected, though the general pattern is not indicative of my prior predictions with regards to the ordering of the coefficients. For example, the second and third strongest impacts appeared for the 1969 and 1974 cohorts, while the 1973 cohort appears to get off lightly. The pattern fits more poorly in the female sample, with the only marginally significant impact being felt by the 1969 cohort and little elsewhere.

In addition to health-scarring, male educational attainment appears to have suffered in response to famine exposure, with the 1970, 1973 and 1974 cohorts predicted to lose around a month of schooling after a standard deviation increase in the famine's severity. The decile analysis also implies a reduction in the upper end of male educational attainment. This, alongside null findings for male school attendance imply that while boys who were exposed to the famine, though no less likely to go to school than their unexposed counterparts, remained within school for less time. The loss of a month of schooling will not affect the educational attainment of these cohorts in any noticeable way, so for the majority of these cohorts, the famine's impacts on attainment are unlikely to have been particularly strong. If we again consider those exposed in the most severely affected regions, the impacts are more notable. This can be seen in figure 9, which shows the model's predictions for male schooling years for Kati (with famine intensity of zero), Dioila (a cercle with moderate exposure) and Kidal, the most severely impacted region. While Dioila suffers a small drop in comparison to Kati, there is a noticeable reduction in years of education for the exposed cohorts in Kidal. In fact, the model estimates that these cohorts lost between 4 and 8 months of schooling as a result of famine exposure.

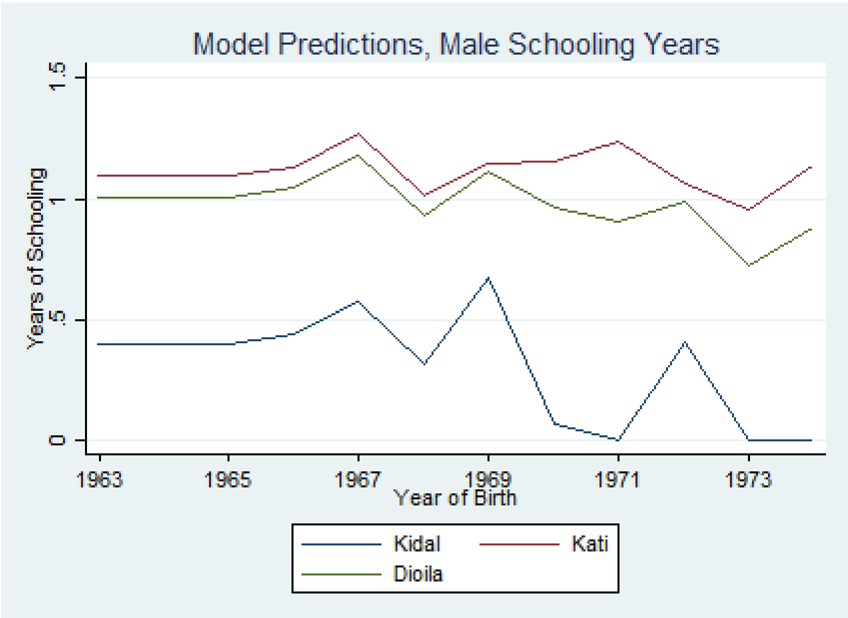

Figure 9: model predictions of male years of education

Interestingly, female educational attainment appears to have responded positively to the famine, with increases in literacy rates and school enrolment rates of up to 3.2% and 7.6% respectively in response to the Kolondieba exercise. On average, girls do not seem to have responded in any strong way with regard to how long they stay in school. The strongest effect here that we notice is for the 1972 cohort, though the estimate here implies that a standard deviation increase in famine intensity would lead to girls from this cohort spending around half a month longer in school – this is far from dramatic.

The disparate impacts of famine exposure on male and female educational attainment may seem odd at first glance, though they are of slightly less concern if put into context. The fundamental point is that girls began with incredibly low levels of attainment in the sample. In the reference cohort (those born between 1963 and 1965) 19.9% of rural men were literate compared with a 6.1% share of women. With regards to schooling years, the average rural female only spent 0.24 years in school, with only 4.85% of women spending longer than a year in education. Changes of around 3% in terms of literacy rates or 7% with regards to school attendance are not of a large enough magnitude to change the landscape with regard to female education. It should also be noted here that rural populations in a number of Malian regions are incredibly sparse. In Kidal for example, there were only 158 people on average in birthyear cohorts during the sample period. Here, a change in literacy or schooling rates of less than 10 percent would require very little in terms of real numbers of people becoming literate or beginning to attend school.

It does not appear to be the case that people's material outcomes had been significantly affected by famine exposure. All results from regressions for the ISEI turn up as statistically insignificant, except for the 1974 female cohort – though in this case, the impact has almost no practical significance. If we look to distributional impacts, there does not appear to be much to say for the female sample, though something of a pattern does emerge for men. As discussed in the previous section, the lower half of the ISEI's distribution appears to see some consistently negative impacts. It should be noted, however, that the largest coefficient in absolute magnitude of this set is only -0.361 (the 1970 cohort at the 30th percentile). Such a coefficient would imply a standard deviation increase in famine intensity would only be associated with a 3.76-point change in the ISEI index, which is far from any real significance.

The lack of any significant findings here may be symptomatic of the index's inability to capture any variation within occupational groups, as well as the huge representation of farmers, especially in the male sample. In essence, we could have two individuals in the sample, both cereals farmers, with one being exposed to the famine and the other not. It could well be that given their health, the unexposed farmer is twice as productive as the other and thus enjoys a better material standard of living than the other. However, as they are both just identified as 'cereals farmers' by the index, it is impossible to confirm this. With this inability to capture any within occupational variation and with much of the sample concentrated at one point within the socioeconomic index, the majority of the variation that is being explained is that between non-farming occupations and the variation in the placement of the non-farmers and the farmers. This variation unlikely to be wholly representative of the variation material outcomes across those in the sample.

So, within the sample we can see some long-lasting impacts of the famine on health and human capital accumulation. For men, we see increases in rates of disability and handicap in response to exposure, as well as decreases in the amount of time they spend in school. While in areas where the famine was less intense, these impacts are not so severe, they can be very much disruptive in the most seriously affected areas. For women we see some negative long-term health impacts, but less in comparison to men. Female human capital appears to respond somewhat positively in response to exposure, though put in context of their absolute levels of attainment, such moves are unlikely of huge import. With the data available it is difficult to see whether the aforementioned impacts have fed through to people's material outcomes. Women seem largely unaffected. Though the direction of point estimates for men imply some scarring, as does an analysis of the non-farmer sample, there is no strong evidence pertaining to anything of practical significance in the full sample.

Conclusion

This study aims to provide an overview of the long-term impacts of exposure to the Sahel famine of the early 1970s on health, education and material outcomes. I find that amongst the rural populace, the health of those cohorts exposed at critical stages of their lives presents some evidence of long-term scarring, with the most severe impacts being felt by men. With regards to education, impacts differ for men and women; educational attainment appears to be adversely affected in male cohorts, while it responds somewhat positively for women. There are no apparent impacts on material outcomes, though this may be symptomatic of their measurement here. In contrast to past evidence, the study uncovers no strong evidence that in-utero exposure to nutritional shocks is any worse than childhood exposure.

The paper overcomes a number of empirical challenges in estimating the long-term impacts of famine. In the absence of any direct measure of the spatial variation in famine intensity, the approach of using the share of birthyear cohorts 'missing' in years of famine provides a useful somewhat intuitive proxy here, which could be extended to other similar events. The use of precipitation data exploits likely exogenous variation in the triggers of the famine to overcome biases stemming from endogeneity and measurement error. Finally, the measurement of the famine's impacts across the deciles of schooling years and socioeconomic index both provides a rough test for the presence of survivor selection bias, as well as giving some idea of the distributional impacts of the famine.

While achieving some success in uncovering the effect of the famine at the cohort level, this general approach is doomed to fail when it comes to untangling the effects of the different mechanisms through which a famine can transmit itself. So while indicative of some impacts, to get a full view of the famine's effects on both outcomes and the decision-making mechanisms which generate them, a finer grain approach will be required.

Bibliography

ALMOND, D. (2006): "Is the 1918 Influenza Pandemic Over? Long-Term Effects of In Utero Influenza Exposure in the Post-1940 U.S. Population." Journal of Political Economy 114(4), pp. 672-712.

ALMOND, D. EDLUND, L. LI, H. & ZHANG, J. (2007): "Long-term effects of the 1959-61 China famine: mainland China & Hong Kong." NBER Working Paper No. 13384.

BARKER, D. & OSMOND, C. (1986): "Infant Mortality, Childhood Nutrition, & Ischaemic Heart Disease in England & Wales." The Lancet, 327(8489), pp. 1077-1081.

BARKER, DJ. GLUCKMAN, PD. GODFREY, KM. HARDING, JE. OWENS, JA. ROBINSON, JS. (1993): "Foetal nutrition and cardiovascular disease in adult life." The Lancet 341(8850), pp. 938–941.

BECKER, G. & LEWIS, H. (1973): "On the interaction between the quantity and quality of children." Journal of Political Economy, 81(2, Part 2), pp. S279-S288.

CASE, A., FERTIG, A. & PAXSON, C. (2005): "The Lasting Impact of Childhood Health & Circumstance." Journal of Health Economics, 24(2), pp. 365-389.

CLAUZEL, J. (1962): "Evolution de la vie economique et des structures sociales du pays nomade du Mali de la conqure francaise a l'autonomie interne (1893- 1958)." *Revue Tiers Monde* 3 (9), pp. 283-311.

CURRIE, J. HYSON, R. (1999): "Is the impact of shocks cushioned by socioeconomic status? The case of low birth weight." American Economic Review 89(2), pp. 245–250.

DERCON, S. & PORTER, C. (2009): "Live Aid Revisited: Long-Term Impacts of the 1984 Ethiopian Famine on Children." Journal of the European Economic Association 12(4), pp. 927-948.

El KHAWAS, M. (1976): "A Reassessment of International Relief Programs." pp. 77-100 in: M. H. Glantz, ed.: *The politics of natural disaster; the case of the Sahel drought*. Praeger Publishers, New York, Washington, London.

Food & Agriculture Organisation. (2018). *FAOSTAT*. [online] Available at: http://www.fao.org/faostat/en/#data.

FUKUDA, M. FUKUDA, K., SHIMIZU, T. & MOELLER, H. (1998): "Decline in sex ratio at birth after Kobe earthquake." Human Reproduction 13(8), pp. 2321–2322.

GERBER, P. MOONEY, H. DIJKMAN, J. TARAWALI, S. & DE HAAN, C. (2010): "Livestock in a Changing Landscape: Experiences and Regional Perspectives." Vol. 2. Washington, Covelo and London: Island Press

GOODMAN, S. BENYISHAY, A. LY, Z. & RUNFOLA, D. (2019): "GeoQuery: Integrating HPC systems and public web-based geospatial data tools." Computers & Geosciences 122, pp. 103-112.

HOEK, HW. BROWN, AS. & SUSSER, E (1998): "The Dutch Famine and Schizophrenia Spectrum Disorders." Social Psychiatry & Psychiatric Epidemiology 33 (8), pp. 373–379.

IMPERATO, PJ. (1976): "Health care systems in the Sahel: before and after the drought." pp. 283–302 in: M. H. Glantz, ed.: *The politics of natural disaster; the case of the Sahel drought*. Praeger Publishers, New York, Washington, London.

KANNISTI, V. CHRISTENSEN, K. VAUPEL, JW. (1997): "No Increased Mortality in Later Life for Cohorts Born During Famine." American Journal of Epidemiology 145(11), pp. 987–994.

KRUEGER, RH. (1969): "Sole long-term effects of severe malnutrition in early life." The Lancet 294(7619), pp. 514–517.

LAYA, D. (1975): "Interviews with farmers & livestock owners in the Sahel." African Environment: Environmental Studies and Regional Planning 1(2), pp. 49-93.

LEVITSKY, D. & STRUPP, B. (1995): "Malnutrition and the Brain: Changing Concepts, Changing Concerns." Journal of Nutrition 125 (8), pp. 2212S–2220S.

LOVEJOY, PE. BAIER, S. (1976): "The desert-side economy of the central Sudan." pp. 145-175 in: M. H. Glantz, ed.: *The politics of natural disaster; the case of the Sahel drought*. Praeger Publishers, New York, Washington, London.

MATLOCK, W. & COCKRUM, E. (1976): "Agricultural production systems in the Sahel." pp. 232–255 in: M. H. Glantz, ed.: *The politics of natural disaster; the case of the Sahel drought*. Praeger Publishers, New York, Washington, London.

MENG, X. & QUIAN, N. (2009): "The Long-Term Consequences of Famine for Survivors: Evidence from a Unique Natural Experiment using China's Great Famine." NBER Working Paper no. 14917.

Minnesota Population Center. ***Integrated Public Use Microdata Series, International: Version 7.1*** [dataset]. Minneapolis, MN: IPUMS, 2018. https://doi.org/10.18128/D020.V7.1

SEN, A. (1981): "Poverty and Famines: an essay on entitlement and deprivation." Oxford: Clarendon.

SHEETS, H.: MORRIS, R. (1974): "Disaster in the Desert: Failures of International Relief in the West African Drought." Humanitarian Policy Studies, The Carnegie Endowment for International Peace, Washington, DC.

SINCLAIR, A. & FRYXELL, J. (1985): "The Sahel of Africa: Ecology of a Disaster." Canadian Journal of Zoology 63(5), pp.987-994.

STEVENSON, D. VERTER, J. FANAROFF, A. et al. (2000): "Sex differences in outcomes of very low birthweight infants: The newborn male disadvantage." Archives of Disease in Childhood. Foetal & Neonatal Edition 83(3): F182-F185.

SWIFT, J. (1977): "Sahelian Pastoralists: Underdevelopment, Desertification, & Famine." Annual Review of Anthropology 6(1), pp.457-478.

UMANA-APONTE, M. (2011): "Long-term effects of a nutritional shock: the 1980 famine of Karamoja, Uganda." The Centre for Market and Public Organisation, Working Paper No. 11/258.

WILLMOTT, CJ. & MATSUURA, K. (2001): “Terrestrial Air Temperature and Precipitation: Monthly and Annual Time Series (1950 - 1999).”

WISEBERG, L. (1976): “An international perspective on the African famines.” Canadian Journal of African Studies 9(2), pp. 293-313.

YI, J. HECKMAN, J. ZHANG, J. & CONTI, G. (2015): “Early Health Shocks, Intra-household Resource Allocation & Child Outcomes.” The Economic Journal 125(528), pp. F347-F371.

Appendix

A: ISEI Graphs

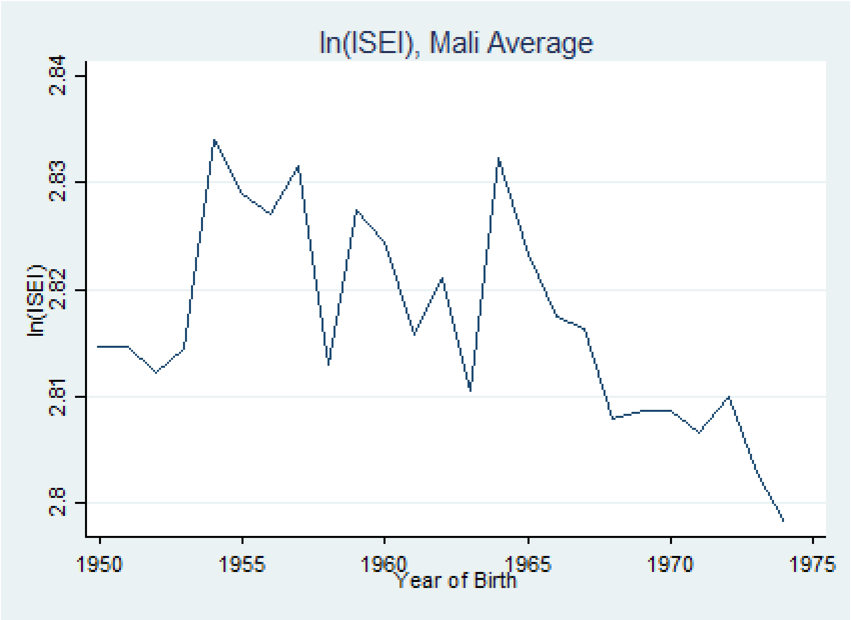

Figure 9, source: IPUMS (2018)

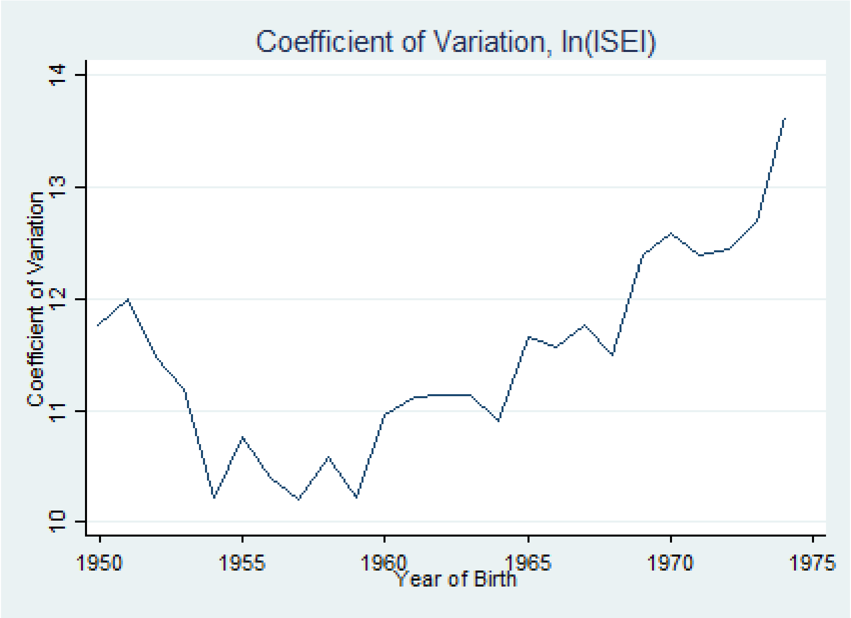

Figure 10, source: IPUMS (2018)

B: Birthyear Effects

Table 4: birthyear effects for OLS and probit estimations (extension of table 1)

	Disabilities		Years of Education		Literacy		School Attendance		ln(ISEI)	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
P_{1966}	-0.688*	-0.713*	0.159	0.0287	-0.0679	-0.341*	-0.407*	-0.900**	0.332	0.371
	(0.369)	(0.385)	(0.101)	(0.0401)	(0.0876)	(0.204)	(0.242)	(0.399)	(0.295)	(0.323)
P_{1967}	-0.613	-1.209**	0.301**	0.118**	-0.0192	-0.286	-0.336	-0.665	0.355	0.448
	(0.391)	(0.488)	(0.128)	(0.0571)	(0.0955)	(0.239)	(0.264)	(0.426)	(0.315)	(0.393)
P_{1968}	-0.663**	-0.708**	0.0327	-0.0036	-0.215**	-0.378*	-0.446*	-0.739**	0.324	0.353
	(0.336)	(0.344)	(0.109)	(0.0422)	(0.0908)	(0.195)	(0.264)	(0.336)	(0.297)	(0.311)
P_{1969}	-0.851**	-1.299***	0.204	0.0706	-0.0737	-0.37	-0.367	-0.832**	0.408	0.434
	(0.412)	(0.424)	(0.158)	(0.0466)	(0.107)	(0.25)	(0.292)	(0.362)	(0.361)	(0.387)
P_{1970}	-0.943**	-1.018**	0.189	0.0559	-0.11	-0.33	-0.408	-0.810**	0.409	0.423
	(0.422)	(0.416)	(0.124)	(0.0455)	(0.126)	(0.24)	(0.322)	(0.354)	(0.364)	(0.371)
P_{1971}	-0.834**	-1.038**	0.191	0.0341	-0.0991	-0.328	-0.386	-0.963***	0.373	0.429
	(0.375)	(0.408)	(0.133)	(0.0437)	(0.0989)	(0.226)	(0.267)	(0.346)	(0.334)	(0.377)
P_{1972}	-1.154***	-1.112***	0.118	0.0717	-0.135	-0.386	-0.328	-0.828**	0.406	0.436
	(0.371)	(0.4)	(0.144)	(0.0548)	(0.118)	(0.26)	(0.318)	(0.377)	(0.361)	(0.372)
P_{1973}	-0.912**	-0.855**	-0.0388	-0.0151	-0.285***	-0.440**	-0.359	-0.858**	0.352	0.392
	(0.386)	(0.357)	(0.11)	(0.0372)	(0.102)	(0.209)	(0.273)	(0.347)	(0.323)	(0.348)
P_{1974}	-1.034***	-1.016**	0.131	0.0672	-0.238**	-0.338	-0.271	-0.672*	0.407	0.421
	(0.386)	(0.416)	(0.149)	(0.0493)	(0.101)	(0.243)	(0.297)	(0.383)	(0.365)	(0.383)
Observations	45,502	57,100	41,290	55,692	45,239	56,485	45,761	57,152	43,392	25,104

Table 5: birthyear effects for 2SLS and IV probit estimations (extension of table 3)

	Disabilities		Years of Education		Literacy		School Attendance		ln(ISEI)	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
P_{1966}	-0.818***	-0.828**	0.0399	-0.0207	-0.0679	-0.341*	-0.818**	-0.828**	-0.00302	-0.00227
	(0.324)	(0.334)	(0.0369)	(0.0206)	(0.0876)	(0.204)	(0.324)	(0.334)	(0.00418)	(0.00590)
P_{1967}	0.700**	-1.263***	0.176**	0.0614**	-0.0192	-0.286	-0.700**	-1.263***	-0.000642	-0.0103
	(0.352)	(0.442)	(0.0699)	(0.0311)	(0.0955)	(0.239)	(0.352)	(0.442)	(0.00624)	(0.00713)
P_{1968}	0.819***	-0.848***	-0.0807**	-0.0497**	-0.215**	-0.378**	-0.819***	-0.848***	-0.0162***	-0.00574
	(0.280)	(0.293)	(0.0383)	(0.0202)	(0.0908)	(0.195)	(0.290)	(0.293)	(0.00425)	(0.00588)
P_{1969}	0.904**	-1.334***	0.0511	0.0218	-0.0737	-0.370	-0.904**	-1.334***	-0.00972	-0.0139
	(0.363)	(0.382)	(0.0598)	(0.0413)	(0.107)	(0.250)	(0.363)	(0.382)	(0.00709)	(0.00855)
P_{1970}	1.023***	-1.088***	0.0607	0.00330	-0.110	-0.330	-1.023***	-1.088***	-0.0133**	-0.00272
	(0.375)	(0.360)	(0.0449)	(0.0225)	(0.126)	(0.240)	(0.375)	(0.360)	(0.00536)	(0.00735)
P_{1971}	0.903***	-1.100***	0.131	-0.0145	-0.0991	-0.328	-0.903***	-1.100***	-0.0137***	-0.00915
	(0.314)	(0.361)	(0.131)	(0.0246)	(0.0989)	(0.226)	(0.314)	(0.361)	(0.00526)	(0.00830)
P_{1972}	1.185***	-1.178***	-0.0337	0.00727	-0.135	-0.386	-1.185***	-1.178***	-0.0145***	-1.78e-05
	(0.342)	(0.365)	(0.0442)	(0.0251)	(0.118)	(0.260)	(0.342)	(0.365)	(0.00485)	(0.00664)
P_{1973}	0.982***	-0.962***	-0.143***	-0.0592***	-0.285**	-0.440**	-0.982***	-0.962***	-0.0231***	-0.0114**
	(0.330)	(0.308)	(0.0296)	(0.0167)	(0.102)	(0.209)	(0.330)	(0.308)	(0.00731)	(0.00576)
P_{1974}	1.065***	-1.09***	0.0395	0.0316	-0.238***	-0.338	-1.065***	-1.090***	-0.0161*	-0.0391***
	(0.352)	(0.368)	(0.0663)	(0.0335)	(0.101)	(0.243)	(0.352)	(0.368)	(0.00855)	(0.00992)
Observations	45,502	57,100	41,290	55,692	45,239	56,485	45,761	57,152	43,392	25,104

C: Summary Statistics and More

Table 6: disability types and numbers in the data

Disability	Count
Blindness	1,220
Difficult seeing	2,299
Leprosy	422
Trypanosomiasis	157
Tuberculosis	249
Mental disorder	527
Onchocerciasis	371
Deaf, mute, deaf and mute	966
Difficult hearing	565
Disability in the limbs	1,715

Table 7: summary statistics, male sample

Variable	Obs	Mean	Std. Dev.	Min	Max
Disability	45,934	0.007946	0.088788	0	1
Years of Schooling	45,934	10.44344	29.36078	0	98
Literacy	45,252	0.192964	0.394629	0	1
School Attendance	45,934	0.032286	0.176759	0	1
ISEI	43,407	16.7772	5.564023	10	89
ln(ISEI)	43,407	2.787513	0.23124	2.302585	4.488636

Table 8: summary statistics, female sample

Variable	Obs	Mean	Std. Dev.	Min	Max
Disability	57,618	0.006456	0.080092	0	1
Years of Education	57,618	3.452602	17.51508	0	98
Literacy	56,505	0.057552	0.232897	0	1
School Attendance	57,618	0.00873	0.093026	0	1
ISEI	25,113	17.822	5.393087	10	89
ln(ISEI)	25,113	2.848101	0.235783	2.302585	4.488636

Table 9: summary statistics, famine intensity and precipitation

Variable	Obs	Mean	Std. Dev.	Min	Max
Intensity	50	0.038087	0.166079	-0.28735	0.479391
$Precipdev_{1969}$	50	-0.16539	0.124493	-0.45684	0.074249
$Precipdev_{1970}$	50	-0.20906	0.111611	-0.60247	-0.01133
$Precipdev_{1971}$	50	-0.20983	0.092896	-0.42834	-0.06489
$Precipdev_{1972}$	50	-0.35189	0.128115	-0.72919	-0.12473
$Precipdev_{1973}$	50	-0.36138	0.097842	-0.68904	-0.2252

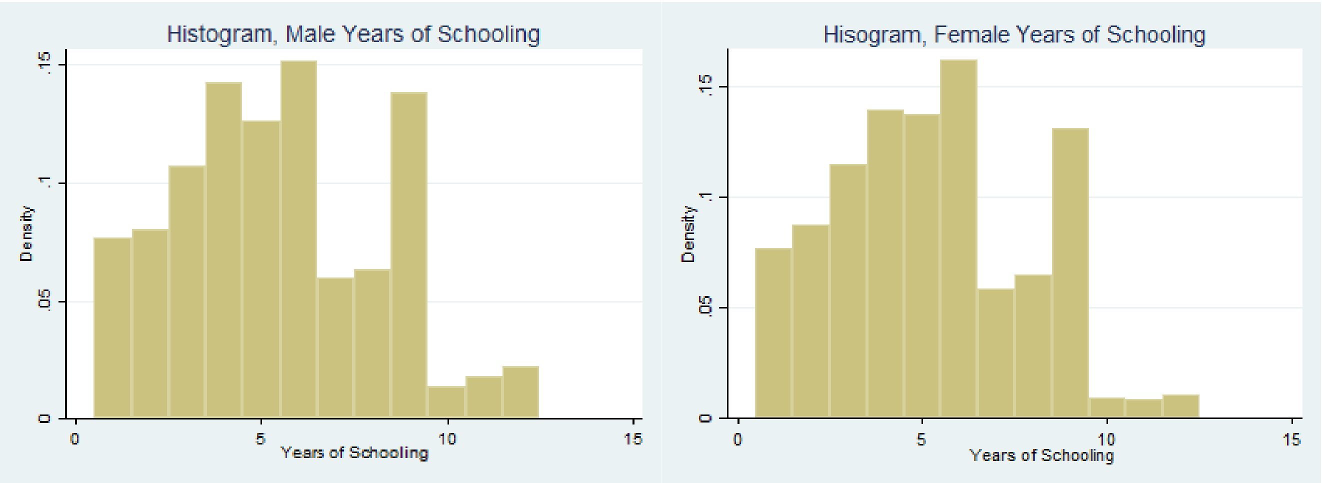

Figure 11: schooling years histograms (excluding 0 years)

Of those men born between 1963 and 1974 who had schooling years available, 78% report zero schooling years, with this share being at its maximum (81.59%) for the 1973 cohort and minimum (73.58%) for the 1967 cohort. In the female cohort, 91.7% report 0 years of schooling, with a maximum (92.72%) in the 1973 cohort and a minimum (89.47%) in the 1967 cohort.

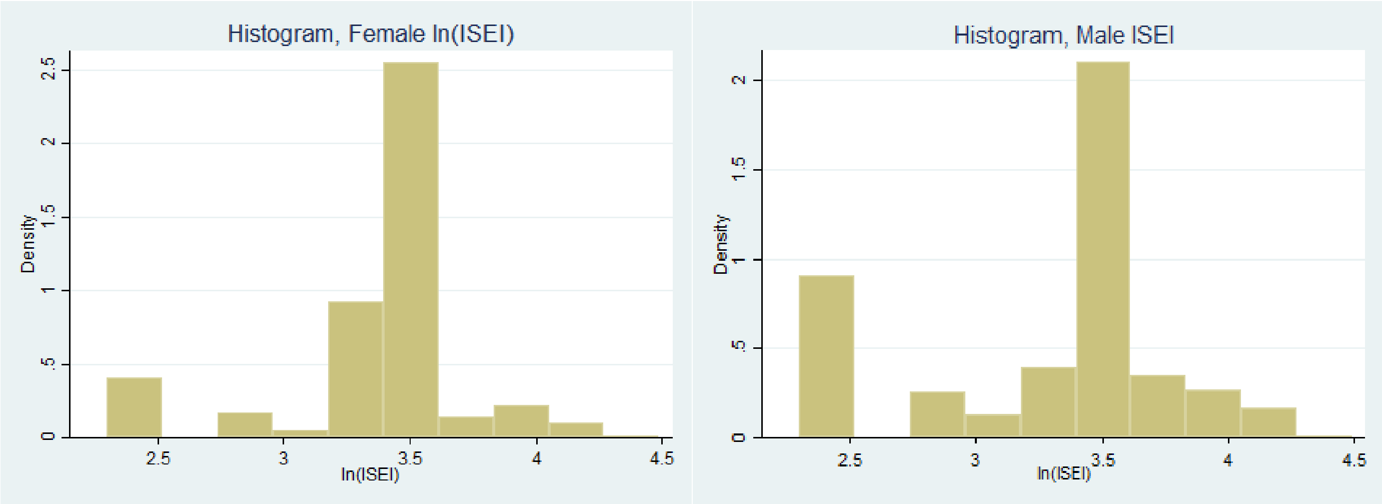

Figure 12: ln(ISEI) histograms (excluding cereals, rice and peanut farmers)

In the male sample, of those born between 1963 and 1974 who had a classifiable occupation, 84.51% were classified as farmers of cereals, rice and peanuts. The share is highest in the 1974 cohort (86.72%) and lowest in the 1971 cohort (81.41%). In the female sample, the average share is 82.2%, with a maximum for the 1970 cohort (84.63%) and a minimum in the 1966 cohort (80.6%). With these shares being fairly constant across cohorts, much of the variation in the ISEI which is explained is the change in the position of those who are not farmers of this kind relative to the farmers, as well as the within group variation of the non-farmers.

Table 10: pairwise correlations between famine intensity and precipitation variables

	Intensity	Average Deviation	$Precipdev_{69}$	$Precipdev_{70}$	$Precipdev_{71}$	$Precipdev_{72}$	$Precipdev_{73}$
Intensity	1						
Average Deviation	0.3223	1					
$Precipdev_{69}$	0.2151	0.7616	1				
$Precipdev_{70}$	0.3006	0.7108	0.559	1			
$Precipdev_{71}$	0.107	0.5334	0.3843	-0.0668	1		
$Precipdev_{72}$	0.4197	0.7756	0.3441	0.5341	0.2509	1	
$Precipdev_{73}$	0.063	0.8099	0.479	0.3903	0.5179	0.5831	1

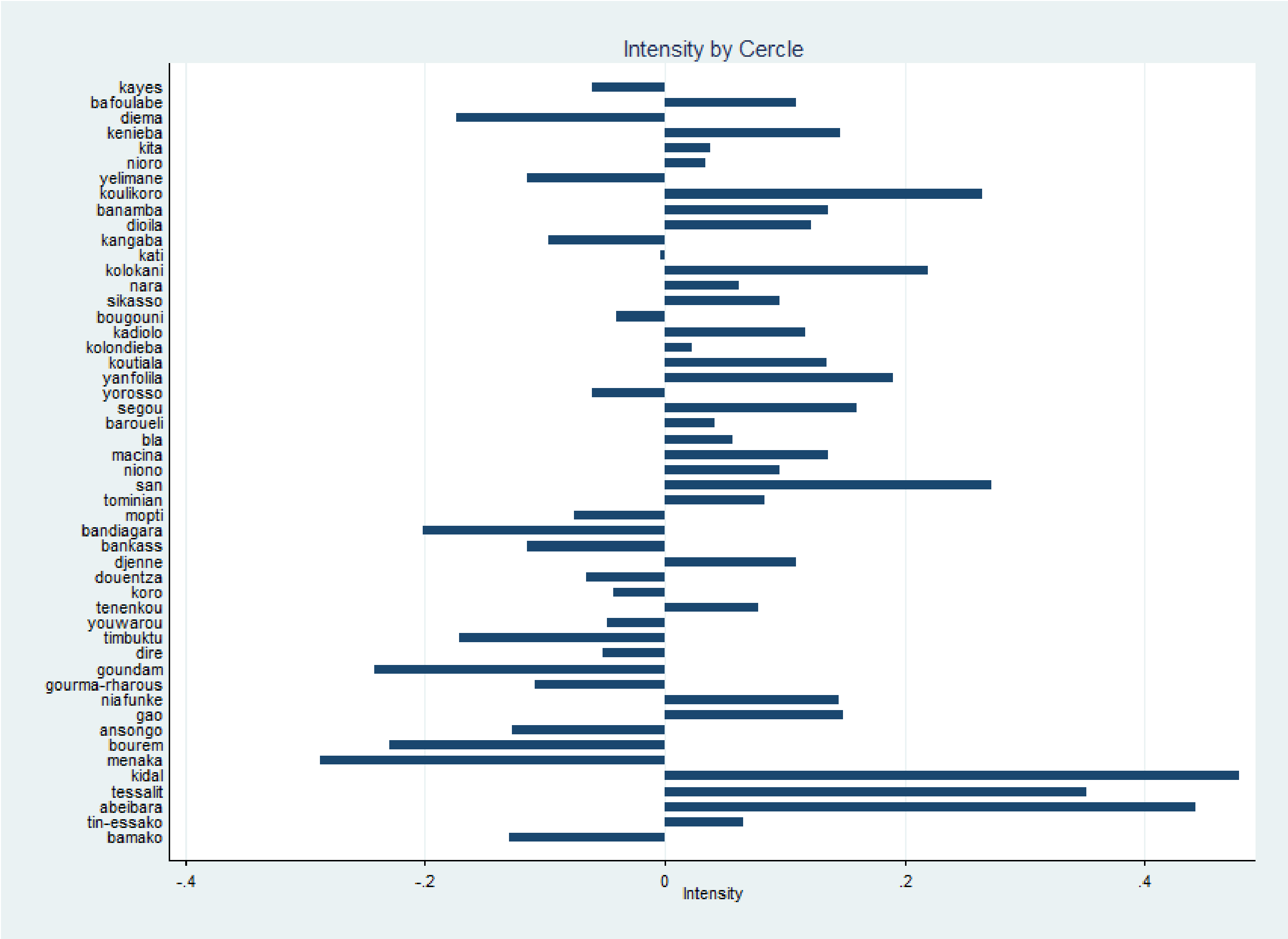

Figure 13: famine intensity by cercle

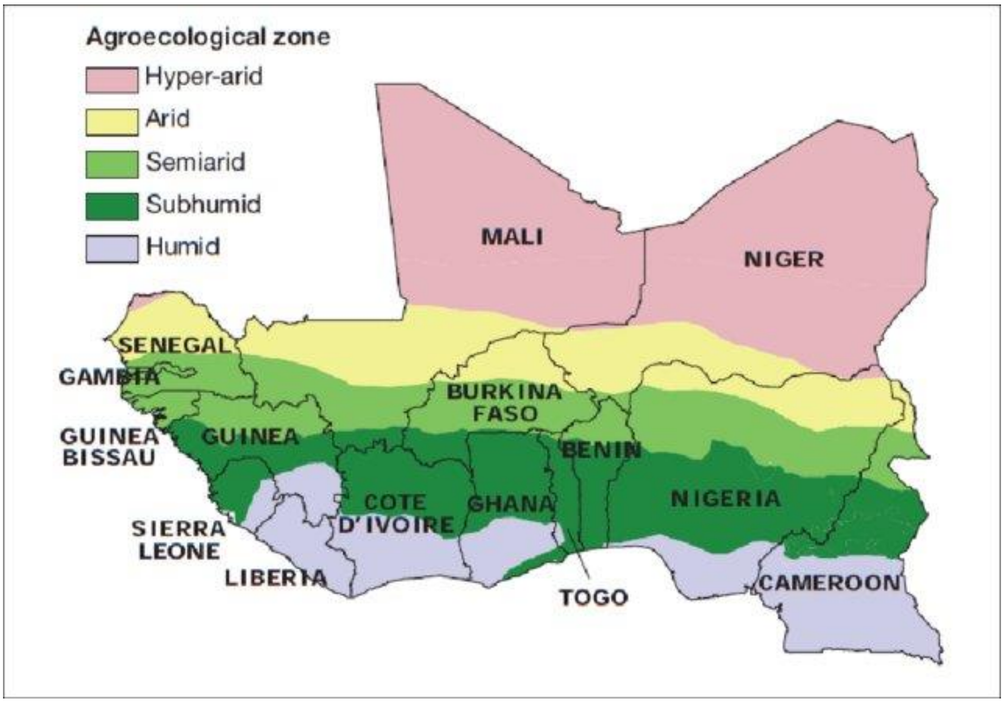

Figure 14: agroecological map of West Africa, source: Ly et al (2010)

The map on the page above shows an agroecological map of West Africa. Mali can be seen in the upper left part of the map. The green zones show the semiarid and sub-humid Saharan zone of the country. The Sahel is the arid band. The majority of the famine's effects were seen in these arid areas and the hyper-arid regions further North. Such regions mark the border between the Sahel and the Sahara.