The Indirect Impact of Antiretroviral Therapy

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Abstract

In response to AIDS mortality in Sub-Saharan Africa, international donors have collaborated with many national governments to provide free antiretroviral therapy (ART) to people with HIV. We explore the impact of this decline in objective mortality risk on subjective perceptions of mortality risk, as well as mental health, and agricultural labor supply and output. Through a difference-in-difference identification strategy, we find that ART availability substantially reduces subjective mortality risk and improves mental health in rural Malawi, including among HIV-negative respondents. People allocate significantly more time to subsistence maize cultivation and increase maize output. These results show a novel link between mortality conditions and economic development through the channel of mental health. Findings for the HIV-negative subpopulation also demonstrate that the impact of the AIDS epidemic and ART are broader than previously understood.

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1 Introduction

The consequences of the HIV/AIDS epidemic have been devastating for Sub-Saharan Africa (SSA). In the past decade and a half, period life expectancy in Southern Africa has fallen from 62 to 48 years (UN Population Division 2010). 33 million people are currently infected with HIV and 2.4 million people become infected each year in the region (UNAIDS 2010). Antiretroviral therapy is a treatment regimen that prolongs life and reduces infectiousness for people with HIV (NIAID 2011, Smith et al. 2011). To address the prohibitive cost of ART for low-income people, international donors began supplying free medicine in endemic countries in 2002. By 2005, 810,000 people had received treatment under this initiative. Free provision of ART has reversed this trend in countries with the highest HIV prevalence (Jahn et al. 2008, Bongaarts et al. 2011, Herbst et al. 2009).

An increase in ART availability reduces objective mortality risk. Existing studies find that mortality risk influences human capital investment, risky sex, and other behaviors, by changing the incentives of decision makers (DeWalque et al. 2007, Thirumurthy et al. 2012, Fortson 2011, Baranov and Kohler 2012). However mortality risk may also affect behavior through the channel of mental health. The fear of a terminal illness induces stress and may trigger anxiety and depression (Taylor and Ashelford 2008, Burridge et al. 2009, Varni et al. 2012). Mortality rates in communities with high HIV prevalence resemble those of civilians in armed conflict, who commonly suffer from poor mental health (Murthy and Lakshminarayana 2006).

A person's mental health affects his or her ability to focus, exert effort, and complete tasks, which in turn influence labor supply and productivity (Lim et al. 2000, Renna 2008, Cornwell et al. 2009). Banerjee and Duflo (2007) and Case and Deaton (2005) conjecture that a poverty trap may exist in the developing world because poverty begets poor mental health and therefore low productivity. We show below that the decline in mortality risk through free ART provision is associated with better mental health and substantially greater labor supply and agricultural output. Because of its effect on labor supply and productivity, mental health may be an important channel through which disease conditions influence economic development (Acemoglu and Johnson 2007, Bleakley 2007).

A mapping from objective to subjective mortality risk mediates this behavior response. Existing studies of mortality risk posit but do not directly show the link between objective and subjective mortality risk. Manski (2004) and Hurd and McGarry (1995) note that objective and subjective probabilities often diverge. An examination of subjective mortality risk and its components allows us to explore why HIV-negative people may respond strongly to ART availability. In particular, ART availability may have a large effect on subjective infection risk, which is an especially difficult parameter to infer.

This study examines the effect of ART availability on subjective mortality risk, mental health, and subsistence maize production. Free ART became available near some sample communities in 2008, greatly increasing access for people nearby. We use a difference-in-difference identification strategy that compares people who live near and far from ART, before and after the medicine becomes available. For respondents 3 kilometers from an ART facility, the arrival of ART reduces subjective mortality risk by 9 percentage points and improves a mental health index by 4.3 percent. People spend 22 percent more time cultivating their own plots and produce 31 percent more maize. Results are strong even among people without HIV, which is striking because HIV-negative people do not directly benefit from ART.

Additional results substantiate the link between subjective mortality risk, mental health, and maize output. For people who are HIV-negative, subjective mortality risk incorporates both perceived HIV infection risk and perceived mortality risk conditional on infection. We find that ART availability causes people to revise both of these elements downward. People specifically report less anxiety and depression, as well as fewer mental-health limitations on their activities and accomplishments. Although they increase their own labor supply, respondents do not utilize other farm inputs such as land, fertilizer, or hired labor more intensively.[1] These findings suggest that improved mental health drives the increase in maize output.

The identifying assumption of our analysis is that people living near and far from ART do not experience differential trends in subjective mortality risk, mental health, or maize output for reasons other than ART availability. A comparison of respondents near and far from ART does not show level or trend differences that would spuriously generate this pattern. Results are robust to controlling for a battery of other variables, including other distances, demographic characteristics, economic shocks, and social support programs.

This study makes three main contributions. We estimate the relationship between objective and subjective mortality risk for the first time in a developing country. Existing studies of mortality risk posit but do not document an effect of objective risk on subjective expectations (Jayachandran and Lleras-Muney 2009, Fortson 2011). Secondly, we provide the first well-identified estimate of the effect of mortality risk on mental health and subsistence cultivation. Despite its potential importance, the role of mental health for poverty and underdevelopment is not well understood. Lost output due to poor mental health may be an additional way in which endemic disease interferes with economic growth. Finally, results for HIV-negative people show that ART has tangible economic and welfare benefits aside from the health of ART recipients. Program assessments of ART provision should account for these diffuse benefits.

2 A Model of Mortality Risk

To contextualize the analysis and discussion of the paper, this section develops a simple model of subjective mortality risk. This exercise illustrates how the components of sub-

[1] ART availability may also directly affect the mental health of people caring for sick dependents. Using African DHS data and the Gallup World Poll, Deaton et al. (2010) correlate the loss of a family member to AIDS and other illnesses with self-reported sadness and depression. A reduced burden on caretakers is unlikely to drive the effect on mental health because the effect is not specific to people with close HIV-positive acquaintances. ART availability may also affect agricultural labor supply and output by changing the demand for calories and other consumption.

jective mortality risk are related if agents formulate perceptions rationally. We derive a prediction for the effect of ART availability under the assumption that risky behavior and HIV prevalence are exogenous. We then discuss the implications if ART availability causes people to reoptimize risky behavior or otherwise changes steady-state HIV prevalence. Although every parameter may vary individually because of idiosyncrasy in perceptions, we omit individual subscripts for visual clarity.

The primary outcome in our analysis is the individual's subjective all-cause mortality risk over a given interval, $m \in (0, 1]$. HIV-negative and HIV-positive mortality risks, m^- and $m^+ \in (0, 1]$, are defined over the same interval. Non-zero values of m^- incorporate competing mortality risks such as malaria, accidents, and old age. We consider intervals of 1, 5, and 10 years in the empirical analysis below. To avoid complications that arise if people formulate expectations dynamically, we assume that people do not consider periods beyond this interval. Each individual has a predetermined subjective probability that he or she is HIV-positive, $p \in [0, 1]$.

We assume for tractability that people match with sexual partners randomly by encounter. The infection risk for an HIV-negative person is a function of HIV prevalence, $\omega \in [0, 1]$, the transmission probability from a single sexual encounter, $\phi \in [0, 1]$, and the number of sexual encounters, $r \geq 0$. These definitions avoid the complexity that different forms of risky behavior may have distinct transmission probabilities. The risk of HIV infection after a single encounter is $\omega\phi$. For convenience define π to be the probability that an HIV-negative person remains uninfected after a single encounter: $\pi \equiv 1 - \omega\phi$. The probability of infection after r encounters is $1 - \pi^r$. Subjective mortality risk is the following weighted average:

$$m = pm^+ + (1 - p)\Big[(1 - \pi^r)m^+ + \pi^r m^-\Big] \tag{1}$$

In this expression, $m = m^+$ for people who know they are HIV-positive. For people who know they are HIV-negative, m is the average of m^+ and m^-, weighted by the probability of infection.[2]

ART directly influences mortality risk through two channels. Define $a \in [0, 1]$ to be the continuous probability that an HIV-positive person receives ART ("ART availability"). By diminishing the viral concentration in the body, ART reduces the HIV-positive mortality risk ($\frac{dm^+}{da} < 0$) and the transmission probability ($\frac{d\phi}{da} < 0$). ART availability does not change the subjective probability of current infection, p. For simplicity, we assume that $\frac{\partial r}{\partial a} = 0$ and $\frac{\partial \omega}{\partial r} = 0$ and subsequently discuss the impact of relaxing these assumptions. The derivative of equation (1) with respect to a shows the effect of ART on subjective mortality risk.

$$\frac{dm}{da} = p\frac{\partial m^+}{\partial a} + (1-p)\left[(1-\pi^r)\frac{\partial m^+}{\partial a} + r\omega\pi^{r-1}(m^+ - m^-)\frac{\partial \phi}{\partial a}\right] \; < \; 0 \qquad (2)$$

In this expression, ART availability has an unambiguously negative effect on subjective mortality risk. By setting $p = 1$ or $p = 0$, we obtain the effect of ART for people who know they are HIV-positive and HIV-negative. For people with HIV, m equates to m^+, so that $\frac{dm}{da} = \frac{\partial m^+}{\partial a}$. The effect of ART availability for HIV-negative people consists of two parts. The first bracketed term is the effect on HIV-positive mortality risk, which is mediated by the probability of future infection. The second bracketed term is the effect on infection risk, which is mediated by the perceived difference between HIV-positive and HIV-negative mortality risk. Because of the infection risk channel, ART availability may have a larger effect for people who are HIV-negative than for people who are HIV-positive.

ART availability may also influence risky behavior and steady-state HIV prevalence (DeWalque et al. 2007, Lakdawalla et al. 2006). Kremer (1996) models the relationship between risky behavior and HIV prevalence among heterogeneous agents. In general, ART

[2] To formulate this expression, we implicitly assume that all risky sexual behavior occurs prior to the interval. If m^+, m^-, and r vary over time, mortality risk over the interval $[0, I]$ equals:

$$m = pm^+(0) + (1-p)\left[\int_o^I (1-\pi^{r(t)})m^+(t)dt + \int_o^I \pi^{r(t)} m^-(t)dt\right]$$

availability may cause r and ω to either increase or decrease. For low-risk people, ART availability increases risky behavior by reducing the cost of HIV. For high-risk people, ART availability may curtail fatalism and decrease risky behavior. The effect of ART availability on steady-state HIV prevalence consists of multiple countervailing arguments. ART availability may increase prevalence by prolonging the lives of people with HIV but may reduce prevalence by cutting the number of new infections. ART availability also affects prevalence through the channel of risky behavior.

After incorporating these channels, ART availability has a theoretically ambiguous effect on subjective mortality risk. In principle, risky behavior and HIV prevalence may increase by enough to offset the direct effects of ART availability in equation (2). In Section 4.2 we examine the effect of ART availability on these individual components and find no evidence of an effect on risky behavior or subjective HIV prevalence.

3 Context

Malawi is a small, landlocked country in Southern Africa with a population of 15.4 million and GDP per capital of $343. The population is over 90 percent rural; many people reside in remote villages and support themselves through subsistence agriculture. Transportation infrastructure is rudimentary: primary roads are paved but secondary roads are typically unimproved. In rural areas people may congregate at small trading centers along main thoroughfares. Fewer than 5 percent of households in our sample (described below) own cars or motorcycles. The population is 55 percent Protestant, 20 percent Catholic, and 20 percent Muslim. Although Malawi has been historically stable, a period of political and economic instability began in 2010 when former President Mutharika postponed local elections and enacted several unconstitutional laws. These policies, coupled with poor economic management, led international donors to withdraw $800 million in aid in 2010 (Economist 2011).

The HIV/AIDS epidemic is the central public health issue in Malawi. National HIV prevalence has declined from a peak of 14.7 percent in 1998 to 11 percent in 2010 (UNAIDS 2010). As of 2008, life expectancy at birth is 52.9 years (WHO 2010). AIDS is the leading cause of adult death (AVERT 2012). Heterosexual sex is the primary mode of HIV transmission in Malawi and elsewhere in SSA. The social, economic, and psychological consequences of the HIV/AIDS epidemic in Malawi have been substantial. Respondents in our sample reportedly attend a median of three funerals per month. 53 percent of respondents are "worried a little" or "worried a lot" about contracting HIV and 39 percent think they may already be infected.

With US$294 million from the Global Fund to Fight AIDS, Tuberculosis, and Malaria, Malawi's Ministry of Health gradually began providing free ART to eligible recipients in 2004. In Round 1 of this rollout (2004-2005), the Ministry of Health attempted to maximize geographic coverage by dispensing ART through 60 hospitals and clinics. Authorities chose facilities that were adequately staffed to implement the program. In Round 2 (2006-present), officials relaxed the eligibility criteria for facilities and considered all clinics with at least one clinician and data clerk.[3] Most facilities are not equipped to measure the CD-4 counts of patients and use a clinical diagnosis of Stage 4 AIDS to determine ART eligibility.[4] According to Watkins and Swindler's (2009) unstructured interviews, prior to the ART rollout people saw ART as only available to the rich.

Limited transportation networks in rural Malawi are an important impediment to ART access. To receive medicine, a patient must appear in person at an ART facility once every two weeks during the first two months of treatment, and then once per month subsequently. With few cars or motorbikes, patients must walk several kilometers to an ART facility, which is particularly taxing for someone with AIDS. Potential ART recipients cannot easily relocate closer to clinics: land is communally managed and property and rental markets

[3]Despite the continued rollout of ART after 2008, ART primarily becomes available in the study regions between 2006 and 2008. The nearest ART facility changed for only 30 study respondents between 2008 and 2010.

[4]Appendix Table 1 summarizes the characteristics of clinics by ART status in 2008. Clinics that provide ART are much larger and offer more comprehensive services than non-providing clinics.

do not exist. For this reason, people near an ART facility have greater access than people far away. We document the relationship between proximity to an ART facility and access to ART among HIV-positive respondents in our sample. 23 HIV-positive respondents have identifiable locations in the 2012 survey round, which focuses on people 45 and older. People receiving treatment live an average of 3.5 kilometers closer to an ART facility than those not receiving treatment, a difference that is statistically significant.

Maize is the primary staple crop and the main calorie source for subsistence farmers in Malawi. Over 95 percent of the households in our sample cultivate maize. Farmers plant during November and harvest in June and July, relying on rudimentary tools such as handheld hoes and simple drip irrigation. Households cultivate a median of 1.2 hectares, which may be divided among multiple irregular plots. People generally acquire land through inheritance or cultivate communal property. Rainfall, fertilizer, and labor heavily influence maize yields. Many farmers lack the cash to purchase fertilizer during the growing season and therefore use less than the optimal amount (Heisey and Mwangi 1996, Sauer et al. 2006). Malawi implemented a temporary but generous fertilizer subsidy in 2005/06 that raised national maize production by 26-60 percent (Dorward et al. 2011). Subsidy coupons entitled households to purchase fertilizer at aggressive discounts. Due to a shortage of fertilizer under the subsidy, people with village political connections benefitted most from the program.

We use data from the Malawi Longitudinal Study of Families and Health (MLSFH), summarized by Anglewicz et al. (2009). The MLSFH is an ongoing biennial panel survey of up to 4,000 respondents in three distinct regions of Malawi.[5] The sample is entirely rural, and respondents typically reside in small villages that are connected through unpaved secondary roads. We use survey rounds from 2004, 2006, 2008, and 2010. Data on subjective expectations and mental health are available from the final three rounds, while data on agricultural production are available in all rounds. Since ART reached the MLSFH survey areas

[5] Rumphi District, Mchinji District, and Balaka District are located in the north, center, and south of the country, respectively. Inhabitants of the north are predominantly Protestant and practice matrilineal kinship while people in the south may also be Muslim and practice patrilineal kinship. The north is generally wealthier, more educated, and, more sexually conservative than the south, while the center falls in between.

between 2007 and 2008, the 2004 and 2006 rounds allow us to consider whether covariates exhibit pre-treatment trends.[6] Although 25 percent of respondents attrit from the MLSFH sample from 2006 to 2010 (Bignami-Van Assche et al. 2003), attrition is uncorrelated with ART proximity. Respondents are tested for HIV in the 2004, 2006, and 2008 rounds (Obare et al. 2009).

For each household, we use GPS coordinates to calculate the distance by road to the nearest ART facility. Figure 3 shows the approximate location of sample households in the Mchinji District, as well as the locations of clinics, trading centers, and roads. Figure 4 shows the frequency distribution of distance to an ART facility in 2008: 18 percent of respondents live within 5 kilometers of a facility and 68 percent live within 10 kilometers. Because the MLSFH sample is rural, few respondents actually live directly adjacent to ART facilities, which are usually near trading centers and primary roads.[7]

The MLSFH uses an innovative, interactive methodology to measure subjective mortality risk (Delavande and Kohler 2009). After explaining and demonstrating the concept of probability, surveyors elicit the subjective probability that the respondent will die within the next 1, 5, or 10 years.[8] The survey also measures subjective perceptions of HIV infection risk, HIV status, and infant mortality risk. Analyzing these variables, Delavande and

[6] In 2006, the median distance to an ART facility was 27 kilometers. Several clinics in the study area began providing ART after the 2008 survey. These clinics were generally further away from MLSFH respondents than existing ART facilities, so that the distance to the nearest ART facility changed for only 30 respondents from 2008 to 2010. Results below are unchanged if we regress on actual, time-varying ART proximity.

[7] Therefore respondents are unlikely to learn directly about the effectiveness of ART from clinic patients or staff.

[8] The questionnaire includes the following script: "I will ask you several questions about the chance or likelihood that certain events are going to happen. There are 10 beans in the cup. I would like you to choose some beans out of these 10 beans and put them in the plate to express what you think the likelihood or chance is of a specific event happening. One bean represents one chance out of 10. If you do not put any beans in the plate, it means you are sure that the event will NOT happen. As you add beans, it means that you think the likelihood that the event happens increases. For example, if you put one or two beans, it means you think the event is not likely to happen but it is still possible. If you pick 5 beans, it means that it is just as likely it happens as it does not happen (fifty-fifty). If you pick 6 bins, it means the event is slightly more likely to happen than not to happen. If you put 10 beans in the plate, it means you are sure the event will happen. There is not right or wrong answer, I just want to know what you think. Let me give you an example. Imagine that we are playing Bawo. Say, when asked about the chance that you will win, you put 7 beans in the plate. This means that you believe you would win 7 out of 10 games on average if we play for a long time."

Kohler (2009) conclude that responses "take into account basic properties of probability and vary meaningfully with observable characteristics and past experience." Average subjective risks of HIV infection and infant mortality are not far from objective probabilities. When asked about the likelihood of visiting the market within two days and within two weeks, over 90 percent of respondents correctly provide a weakly greater probability over the longer interval. Despite the concern that subjective probabilities lack a cardinal interpretation (Bertrand and Mullainathan 2001), Delavande, Giné, and McKenzie (2011a, 2011b) show responses are robust to variations in the elicitation methodology.

The MLSFH data allow us to decompose subjective mortality risk into the components that we highlight in Section 2. Within this framework, ART availability may affect subjective HIV-positive mortality risk and subjective infection risk. The survey includes the respondent's own infection risk in the future on a four-point Likert scale as well as the infection probability within one year for a hypothetical person with "normal sexual behavior."

The HIV infection risk for an HIV-negative person over a given interval is a function of the transmission probability, HIV prevalence, and the frequency of risky behavior.[9] The MLSFH elicits subjective HIV prevalence and several measures of risky sexual behavior, including details about the respondent's three most recent sexual relationships. We construct three variables: the total number of partners, the number of partners that were concurrent with other partners, and the number of partners suspected to be HIV-positive. Because sexual behavior is difficult to elicit accurately (Helleringer et al. 2011, Clark et al. 2011), we also examine fertility (the respondent's total number of children) as a marker for risky behavior.

MLSFH respondents appear to exaggerate mortality risk. Figure 1 plots the frequency distribution of mortality risk assessments over the five-year horizon. The median respondent

[9]The MFLSFH includes a measure of the subjective transmission probability during a single sexual encounter. Respondents almost always indicate that transmission occurs with certainty, although the actual probability is around 0.003 (Ray et al. 2001). Respondents may not have understood that the question was conditioned on a single sexual encounter. Therefore we do not make use of this variable.

reports a 40 percent chance of dying within five years.[10] Most subjective responses far exceed the objective mortality risk in Malawi. Figure 2 compares the subjective and life-table estimates of mortality risk for five-year age groups. At the MLSFH median age of 36, respondents report a five-year mortality risk of 50 percent while the period life table suggests an actual risk of 9.5 percent.[11]

The survey includes several mental health variables. The SF-12 questionnaire is a standard instrument for measuring subjective mental and physical health (Ware et al. 2001, Ware et al. 1996, Macran et al. 2003, Fleishman et al. 2006). The MCS-12 and PCS-12 are summary indicators of mental and physical health that are derived from this set of twelve subjective health questions. Each index ranges from 0 to 100 and is calibrated to have a mean of 50 among US respondents. The mental health component elicits whether the respondent feels "calm and peaceful", energetic, and "downhearted or depressed" on a six-point Likert scale. They survey also asks whether "emotional problems (such as feeling stressed or anxious)" have interfered with the respondent's activities and accomplishments. These final variables directly measure whether poor mental health has hampered productivity.

Maize cultivation is the modal form of labor in this setting. The MLSFH elicits the number of kilograms of maize harvested during the last growing season. The survey also measures key farm inputs, including land, fertilizer use, investment in new equipment, the use of hired labor, and the respondent's own time allocation toward farming. We examine the extensive margin of fertilizer use, investment in new equipment, and use of outside labor because only a minority of households utilize these inputs. In 2004, 2006, and 2010, the survey elicits the number of hours per week that the respondent spends on his or her own farm, in home production, and in other economic activities. Husband-wife pairs make up 63 percent of the MLSFH sample. To avoid double counting maize output on the same plot,

[10] A response of "50 percent" may indicate epistemic uncertainty rather than a subjective probability of 50 percent (Fischhoff and Bruine de Bruin 1999).

[11] The MLSFH and life-table probabilities are not directly comparable because the MLSFH is not nationally representative and because life-table calculations are retrospective while subjective probabilities are prospective.

we down-weight these observations. ART becomes available at many clinics in the MLSFH study areas early in 2008, after households have planted the 2008 harvest. Therefore the treatment effect of ART availability on maize output may be stronger in 2010 than 2008.

To estimate the effect of ART availability, our identification strategy compares the change in outcomes over time for respondents near and far from ART. Figures 5, 6, and 7 illustrate the identifying variation for our regressions by plotting the subjective mortality risk, the MCS-12, and log maize production by year and proximity to ART. The means underlying these figures control for region-specific time trends for consistency with subsequent regressions. We divide the sample into distance bins that are near, middle, and far. Figures 5 and 6 show that subjective mortality risk and mental health have remained steady among respondents near ART. For respondents far from ART, subjective mortality risk has risen and mental health has declined. Either aging within the sample or a lag in perceptions of HIV prevalence and AIDS mortality may explain these trends.[12] Respondents near ART exhibit greater subjective mortality risk and worse mental health prior to 2008. An examination of this pattern by region (available from the authors) shows that it is isolated to the Balaka District. Figure 7 shows similar maize output prior to the arrival of ART but faster growth in output near ART facilities.

Summary statistics for the estimation sample appear in Table 1. The table distinguishes between respondents who are near and far from ART, before and after the ART became available in 2008. The distance to ART is correlated with the distance to trading centers and primary roads but is uncorrelated with age or household size. It is difficult to isolate an observable cause of the baseline difference in outcomes that appears in Figures 5 and 6. Respondents living near ART have somewhat less education, land, and livestock. Although actual HIV prevalence is similar near and far from ART, people near ART facilities perceive greater prevalence. The frequency of self-reported risky behavior is also similar among

[12] According to UNAIDS (2010), AIDS deaths peaked in 2004. If people learn about HIV prevalence by observing AIDS deaths, they may believe that prevalence peaked in 2004, implying high AIDS mortality in subsequent years.

people near and far from ART, although people near ART have more partners they suspect are HIV-positive.

Our empirical strategy relies on an assumption that the outcomes for people near and far from ART exhibit similar unobserved trends. Table 2 investigates this possibility by reporting the change from 2004 to 2006 (before ART became available) in observable characteristics that are recorded in both years. The negative trend in perceived HIV prevalence is larger among respondents far from ART. Since outcomes improve with ART availability, this differential trend biases against finding the observed effect.

Regressions below control for a battery of observable characteristics that may influence subjective mortality risk, mental health, and agricultural productivity. Demographic characteristics include education, household size, roof construction, livestock ownership, and monetary wealth. Economic shocks include the death of the breadwinner, poor crop yields, income losses, grain price fluctuations, divorce, and damage to physical assets. Social support programs include food and education subsidies, agricultural supports, and unconditional cash transfers.

4 Estimation

4.1 Empirical Strategy

In this section, we estimate the effect of ART availability on subjective mortality risk, mental health, and maize output. We then estimate the effect of ART on components of each outcome. A difference-in-difference identification strategy compares the change in outcomes for people near and far from ART. We use the following regression specification.

$$y_{ijrt} = \beta Post_t \times Prox_{ijr} + \alpha_{ijr} + \delta_{rt} + \epsilon_{ijrt} \quad (3)$$

In this expression, i indexes the individual, j indexes the village, r indexes the region, and t indexes the time period. y_{ijrt} is the outcome variable. Proximity ($Prox_{ijr}$) is the inverse distance to the nearest ART facility in 2008.[13] $Post_t$ is a dummy for the 2008 and 2010 survey rounds, which occurred after ART became available near some respondents. α_{ijr} is an individual fixed effect and δ_{rt} is a region-specific time fixed effect. Standard errors are clustered by village and are robust to heteroskedasticity.

With an individual fixed effect, regressions are identified through the differential change in outcomes among people near ART. As we discuss above, the levels and trends of observed characteristics do not suggest that respondents near ART have become more optimistic or productive for unrelated reasons. To address further the potential for differential trends among people near ART, regressions include a battery of observable characteristics. We control for the proximity of a primary road, a clinic (regardless of whether it offers ART), and a trading center. We also control the household's demographic characteristics, use of public programs, and exposure to economic shocks, as described above. We interact all controls with $Post_t$ to allow these variables to have different effects before and after ART arrives.

4.2 Results for Subjective Mortality Risk

Estimates of the effect of ART availability on subjective mortality risk appear in Table 3. Columns 1-3 show estimates of specification (3) for 1-year, 5-year, and 10-year horizons. ART availability has the greatest effect on mortality risk over a 5-year horizon. According the coefficient estimate in Column 2, the arrival of ART causes a person living 3 kilometers away (for whom $Prox_{ijr} = \frac{1}{3}$) to revise downward his mortality risk perception by 9 percentage points. Figure 8 illustrates the treatment effect non-parametrically with a local polynomial regression. The effect declines monotonically from 0 to 6 kilometers and remains statistically indistinguishable from zero beyond 6 kilometers. Column 4 differentiates between the 2008

[13]Results below are robust to using straight-line distance to calculate proximity.

and 2010 rounds, both of which occur after the arrival of ART. The effect of ART availability is similar in both years, suggesting that the arrival of ART causes a level shift in expectations.

We evaluate the robustness of the estimate in Columns 5-6 of Table 3. Column 5 controls for the proximity to a primary road, clinic (regardless of whether it offers ART), and trading center. By interacting each variable with $Post_t$, we control for any component of the treatment effect that may be due to the colocation of ART facilities and these amenities. Coefficients on these controls are small and do not change the estimate for ART proximity. In Column 6, we control for household demographics, economic shocks, and social support programs. These controls (also interacted with $Post_t$) have a jointly significant effect on mortality risk. Including these variables slightly increases the coefficient estimate for ART proximity.

Table 4 shows that the result remains robust after excluding four key groups. In Column 1, we omit people who ever test positive for HIV. Because a response of 50 percent may reflect epistemic uncertainty rather a risk perception of 50 percent (Fischhoff and Bruine de Bruin 1999), Column 2 excludes people who ever respond 50 percent.[14] Column 3 excludes people who ever attrit. Column 4 excludes respondents from the Balaka District, where pre-ART mortality risk is not balanced among people near and far from ART. In each case, estimates are slightly smaller than in Column 2 of Table 3 but are strongly significant.

Next we examine the effect of ART availability on the components of subjective mortality risk. As we describe in Section 2, ART may affect both subjective HIV-positive mortality risk and subjective HIV infection risk. Infection risk is a function of risky behavior and subjective assessments of HIV prevalence and the transmission probability. Regressions for these components appear in Table 5. Column 1 provides the effect of ART availability on HIV-positive mortality risk.[15] According to the estimate, the arrival of ART causes a person

[14]The result is robust to excluding respondents who say 0 or 10 percent. Because average objective mortality risk ranges from 7-9 percent, the elicitation methodology may prevent these respondents from answering accurately. The result is also robust to excluding respondents who say 0, 50 or 100 percent. These response may be focal points that do not always reflect subjective probabilities.

[15]The survey elicits the hypothetical HIV-positive mortality risk from all respondents. The HIV-positive subsample is too small to estimate this effect in a non-hypothetical way.

living 3 kilometers away to revise downward his perception of HIV-positive mortality risk by 5 percentage points.

Columns 2 and 3 show that ART availability significantly reduces subjective infection risk for the respondent "in the future" and for a hypothetical person with normal behavior over one year. To decompose this response further, we estimate the effect of ART availability on subjective HIV prevalence and risky sexual behavior. In Column 4, ART availability has no effect on perceived HIV prevalence. Columns 5-7 estimate the effect of ART on three self-reported measures of risky behavior: "number of partners," "number of concurrent partners," and "number of HIV-positive partners." DeWalque et al. (2007), Lakdawalla et al. (2006), and (Thirumurthy et al. 2012) argue that ART may increase the frequency of risky sex by reducing the cost of HIV. The effect of ART availability on these outcomes is zero in our sample, but is imprecisely estimated. Sexual behavior is difficult to measure because people have strong incentives to misreport (Helleringer et al. 2011, Clark et al. 2011). Finally, Column 8 shows the effect of ART on fertility, a marker for unprotected sex. ART availability significantly reduces fertility, which is not consistent with greater risk taking after ART.[16]

4.3 Results for Mental Health

Estimates of the effect of ART availability on mental health appear in Table 6. Panel A includes the full sample while Panel B isolates the HIV-negative subsample. Column 1 shows a large and significant effect of ART availability on the MCS-12. For a person 3 kilometers from an ART facility, the arrival of ART improves the mental health score by 2.4 points. The magnitude of this effect is 53 percent of the difference between people who are HIV-positive and HIV-negative. Similar variation in the MCS-12 is associated tangible differences in income and household circumstances in other settings (Larson 2002, Balsa et al. 2009). Figure 9 shows non-parametrically that the effect on mental health declines monotonically with distance and eventually becomes negative. In contrast, Appendix Table

[16]Irrespective of risk-taking, this result suggests that ART availability may cause households to revise optimal family size downward, in contrast to the findings of Shapira (2010) and Forston (2009).

2 shows an insignificant effect of ART availability on the PCS-12 physical health index. This finding serves as a falsification test because ART availability does not directly improve physical health for most respondents, who are HIV negative. The table also shows no effect of ART availability on the presence of physical limitations on activities or accomplishments.

Next we examine the effect of ART availability on relevant components of the MCS-12. Columns 3-5 show regressions for "always feels energetic," "is not depressed," and "feels calm and peaceful." We find a positive and significant effect for each outcome. For someone 3 kilometers from an ART facility, the arrival of ART increases the probability of a positive response by 13 to 18 percentage points. Finally, Columns 6 and 7 show that ART availability has ameliorated mental-health limitations on respondents' activities and accomplishments. These results substantiate a link between the mental health effect and the agricultural output effect below. Panel B replicates the estimates for the HIV-negative sample. Results are similar, indicating that the mental health benefits of ART availability accrue among the wider population. Appendix Table 3 reproduces Table 6 while controlling for other proximity measures, demographic variables, economic shocks, and public programs, as in Column 6 of Table 3.

4.4 Results for Maize Production

Table 7 shows the impact of ART availability on maize production. The table distinguishes between the 2008 and 2010 periods because people made 2008 planting decisions in 2007, in some cases prior to the arrival of ART. Regressions include month-of-interview dummies to control for seasonality in maize production.[17] For 63 percent of the sample, both spouses are interviewed concurrently. We use probability weights to weight all households equally. As before, Panel A includes the full sample while Panel B isolates the HIV-negative subsample.

In Column 1, ART availability has a positive and significant effect on maize production.

[17] The survey elicits the amount of maize produced during the last harvest, which occurs during June and July. Respondents interviewed closer to the harvest may answer this question more accurately. Including these controls in other regressions doe not qualitatively change any findings.

According to the 2010 coefficient, the arrival of ART causes maize production to increase by 257 kilograms (31 percent) for someone 3 kilometers from an ART facility. Figure 10 plots this effect non-parametrically, showing a steadily decreasing effect that reaches zero near 12 kilometers. The magnitude of this response is consistent with the large increase in the time allocated to own cultivation, discussed below. This effect is in the same ballpark as the 20-60 percent increase in output that followed the 2005/06 fertilizer subsidy program (Dorward et al. 2011). Columns 2-5 examine the effect of the ART rollout on farm inputs. We find small and insignificant effects of ART availability on land ownership, the use of new farm equipment, and the use of hired labor. Estimates for fertilizer use are negative, which may reflect the 2005/06 fertilizer subsidy. The lack of an effect for these inputs suggests that output does not rise because of greater agricultural investments.

Columns 6-8 show the effect of ART availability on time allocation, which is unavailable in the 2008 survey round. Column 6 shows that ART availability increases the time allocation to own cultivation. The arrival of ART causes a respondent 3 kilometers from a facility to allocate 33 additional minutes per day to own cultivation. Columns 7 and 8 show positive effects of ART availability on the time allocated to home production and to other economic activities. These results carry over to the HIV-negative subsample. Appendix Table 4 reproduces Table 7 while controlling for other proximity measures, demographic variables, economic shocks, and public programs, as in Column 6 of Table 3.

5 Discussion and Conclusion

The analysis above links the rollout of free ART in Malawi to a statistically significant and substantively relevant decline in subjective mortality risk, mental health, and maize output. Mechanisms other than subjective mortality risk and mental health are unlikely to explain the effect of ART on labor supply and maize cultivation. Although ART could improve mental health by easing the burden on caretakers, the mental health response is not stronger among people who have a close HIV-positive acquaintance. While ART could improve effort in cultivation through an investment motive, other investment channels such as land and fertilizer do not increase with ART availability. Instead respondents increase the time devoted to productive activities, including cultivating their own plots, while reporting fewer mental-health limitations on their activities and accomplishments.

With HIV prevalence of 10.6 percent, a minority of the population directly benefits from ART availability. Our results suggest that ART provision has much broader benefits than previously understood. Likewise, an accounting of the cost of the HIV/AIDS epidemic in SSA should recognize the economic and welfare costs to people who never become infected. We should not understate the direct utility loss associated with the perceived risk of an impending terminal disease.

Finally, our findings suggest that respondents have exaggerated mortality risk from HIV. If one interprets subjective probabilities cardinally, then the 9 point decline in risk due to ART availability equals the baseline *level* of mortality risk from all causes. Such a large response is inconsistent with people correctly perceiving the risk of AIDS mortality. People may systematically exaggerate mortality risk because they have difficulty learning about this parameter. Without precise data on mortality and HIV, people may rely on signals from public health authorities and from peers. HIV awareness campaigns in Africa have typically provided a distilled message about the lethality of HIV in order to discourage risky behavior.

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Table 1: Summary Statistics by Proximity to ART and Time Period

Time period:	Before ART			After ART		
ART Proximity:	Far	Near	P-value (differenc	Far	Near	P-value (differenc
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Expectations						
Mortality risk: own (5 year)	0.38	0.41	0.00	0.42	0.42	0.45
Mortality risk: HIV+ person (5 year)	0.68	0.70	0.07	0.71	0.71	0.31
Likelihood of HIV infection: own (future)	0.68	0.80	0.00	1.08	1.05	0.48
HIV infection risk: typical person (1 year)	0.22	0.23	0.30	0.29	0.30	0.73
Panel B: Characteristics						
Distance to nearest clinic (km)	7.13	4.63	0.00	7.13	4.63	0.00
Distance to nearest primary road (km)	5.10	4.26	0.00	5.10	4.26	0.00
Distance to nearest market (km)	6.34	4.39	0.00	6.34	4.39	0.00
Education	5.38	5.05	0.02	5.20	4.93	0.01
Age	35.3	35.5	0.64	38.3	38.4	0.79
Household size	5.39	5.29	0.36	5.30	4.97	0.00
HIV positive	0.07	0.08	0.28	0.10	0.12	0.18
HIV positive (perceived)	0.25	0.30	0.01	0.46	0.46	0.83
Land (hectares)	3.45	2.25	0.36	2.05	1.69	0.01
Metal roof	0.15	0.19	0.04	0.20	0.25	0.00
Number of cattle	0.85	0.72	0.38	0.70	0.53	0.06
Number of pigs	0.71	0.61	0.30	0.96	0.95	0.95
Number of goats	2.08	1.69	0.01	1.9	1.45	0.00
Panel C: Outcomes						
Mental health (MCS-12)	55.9	55.0	0.01	53.6	53.7	0.68
Corn yield (KG)	991	830	0.04	1080	1173	0.28
Sample size	2,478	--	--	4,956	--	--

Note: the sample is divided according to the median distance to an ART facility, which is 8.6 kilometers.

Table 2: Trends in Summary Statistics Prior to the Arrival of ART

ART Proximity:	Far	Near	P-value (differenc
	(1)	(2)	(3)
Pre-treatment change in:			
Education	0.06	0.06	0.93
Metal roof	0.02	0.02	0.85
Land (hectares)	2.27	0.71	0.43
Number of cattle	0.12	-0.24	0.06
Number of pigs	0.04	-0.23	0.09
Number of goats	0.12	0.00	0.45
HIV positive	0.01	0.01	0.23
HIV positive (perceived)	-0.12	-0.05	0.04
Corn (KG)	243	324	0.47
Sample size	1,237	1,114	--

Note: the table reports the mean difference between 2004 and 2006. The sample is divided by the median distance to ART of 8.6 kilometers.

Table 3: Baseline Regressions

Dependent variable:	Subjective mortality risk					
Horizon	1 year	5 years	10 years	5 years		
	(1)	(2)	(3)	(4)	(5)	(6)
Post × ART proximity	-0.15	-0.28	-0.23	--	-0.28	-0.24
	(0.06)	(0.08)	(0.08)		(0.08)	(0.08)
2008 × ART proximity	--	--	--	-0.26	--	--
				(0.08)		
2010 × ART proximity	--	--	--	-0.30	--	--
				(0.08)		
Post × clinic proximity	--	--	--	--	0.001	0.003
					(0.001)	(0.001)
Post × market proximity	--	--	--	--	-0.001	0.001
					(0.000)	(0.001)
Post × road proximity	--	--	--	--	-0.003	-0.001
					(0.001)	(0.002)
Individual fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Region × year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
F test: controls	--	--	--	--	--	3.98
(p value)						(0.00)
Sample size	5357	5350	5349	5350	5350	3772
R squared	0.04	0.04	0.03	0.04	0.04	0.07

Note: standard errors appear in parentheses. Standard errors are clustered by village and are robust to heteroskedasticity. Demographic controls, economic shocks, and public programs are described in the text.

Table 4: Robustness Tests

Dependent variable:	Mortality risk (5 year)			
Regression excludes:	HIV-positive	Respondents saying 5	Attriters	Balaka District
	(1)	(3)	(5)	(6)
Post × ART proximity	-0.27	-0.24	-0.24	-0.26
	(0.07)	(0.09)	(0.08)	(0.07)
Sample size	5061	3109	3609	3510
R squared	0.04	0.04	0.04	0.06

Note: the table reports coeffcients and standard errors, which are clustered by village and are robust to heteroskedasticity. All regressions include individual fixed effects and region-specific time fixed effects.

Table 5: ART Availability and the Components of Subjective Mortality Risk

Dependent variable:	HIV-positive mortality risk	HIV infection risk: self (future)	HIV infection risk: normal person (1 year)	Perceived HIV prevalence	Number of partners	Number of concurrent partners	Number of HIV-positive partners	Fertility
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post × ART proximity	-0.14	-0.67	-0.18	0.01	-0.06	0.04	-0.24	-0.84
	(0.05)	(0.21)	(0.05)	(0.03)	(0.25)	(0.13)	(0.25)	(0.17)
Individual fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region × time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sample size	5407	6726	5406	6963	3804	3804	3804	7409
R squared	0.05	0.07	0.09	0.10	0.19	0.02	0.02	0.33

Note: standard errors appear in parentheses. Standard errors are clustered by village and are robust to heteroskedasticity. All regressions include individual fixed effects and region-specific time fixed effects.

Table 6: ART Availability and Mental Health

Dependent variable:	MCS-12	High energy	Not depressed	Calm and peaceful	No mental limitations on activites	No mental limitations on accomp.
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Full Sample						
Post × ART proximity	7.30	0.39	0.50	0.53	0.19	0.14
	(1.95)	(0.17)	(0.18)	(0.11)	(0.09)	(0.07)
Panel B: HIV-Negative Subsample						
Post × ART proximity	7.76	0.43	0.53	0.57	0.16	0.13
	(1.90)	(0.16)	(0.18)	(0.11)	(0.07)	(0.06)

Note: The table reports coefficients and standard errors, which are clustered by village and are robust to heteroskedasticity. Outcome variable definitions are described in the text.

Table 7: ART Availability, Maize Cultivation, and Time Allocation

Dependent variable:	ln(maize)	ln(land)	Any fertilizer	Any new equipment	Any hired labor	Time: own farm	Time: home production	Time: other economic activities
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Full Sample								
2008 × ART proximity	0.34	-0.03	0.02	-0.09	-0.05	--	--	--
	(0.26)	(0.29)	(0.14)	(0.09)	(0.11)			
2010 × ART proximity	0.81	-0.07	-0.34	-0.04	-0.19	1.29	1.29	3.10
	(0.28)	(0.17)	(0.16)	(0.12)	(0.13)	(0.83)	(1.23)	(1.72)
Panel B: HIV-Negative Subsample								
2008 × ART proximity	0.40	0.03	-0.03	-0.05	-0.03	--	--	--
	(0.28)	(0.35)	(0.14)	(0.09)	(0.10)			
2010 × ART proximity	1.00	-0.04	-0.43	-0.01	-0.21	1.20	0.76	3.21
	(0.27)	(0.19)	(0.16)	(0.12)	(0.14)	(0.84)	(1.01)	(1.70)

Note: The table reports coefficients and standard errors, which are clustered by village and are robust to heteroskedasticity. Outcome variables are defined in the text.

Appendix Table 1: Comparison of Clinics With and Without ART Services

	All clinics			Sample clinics		
	No ART	ART	P-value (difference)	No ART	ART	P-value (difference)
	(1)	(2)	(3)	(4)	(5)	(6)
Population of catchment area	19,575	43,386	0.00	12,493	34,422	0.01
Number of beds	11.9	109.4	0.00	6.29	75.8	0.16
Electricity	0.33	0.61	0.00	0.43	0.75	0.35
Flush toilet	0.25	0.59	0.00	0.29	0.75	0.17
HIV testing and couseling	0.67	0.76	0.03	1.00	1.00	--
Outpatient	0.78	0.8	0.74	1.00	1.00	--
Inpatient maternity	0.61	0.78	0.00	0.43	1.00	0.07
Inpatient general	0.12	0.48	0.00	0.14	0.50	0.24
Antenatal services	0.67	0.8	0.00	0.86	1.00	0.48
STI treatment	0.28	0.52	0.00	0.29	0.50	0.53
Tuberculosis	0.57	0.71	0.00	0.86	1.00	0.19
Laboratory	0.14	0.56	0.00	0.00	0.50	0.21
Sample size	596	147	--	7	4	--

Appendix Table 2: ART Availability and Physical Health

Dependent variable:	PCS-12	No physical limitations on activites	No physical limitations on accomp.
	(1)	(2)	(3)
Panel A: Full Sample			
Post × ART proximity	2.95	0.02	0.06
	(2.05)	(0.12)	(0.13)
Panel B: HIV-Negative Subsample			
Post × ART proximity	2.49	0.02	0.03
	(1.94)	(0.12)	(0.13)

Note: The table reports coefficients and standard errors, which are clustered by village and are robust to heteroskedasticity.

Appendix Table 3: ART Availability and Mental Health with Additional Controls

Dependent variable:	MCS-12	High energy	Not depressed	Calm and peaceful	No mental limitations on activites	No mental limitations on accomp.
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Full Sample						
Post × ART proximity	7.32	0.39	0.50	0.53	0.19	0.14
	(1.95)	(0.16)	(0.18)	(0.11)	(0.09)	(0.07)
Panel B: HIV-Negative Subsample						
Post × ART proximity	7.77	0.43	0.54	0.57	0.16	0.13
	(1.90)	(0.16)	(0.18)	(0.11)	(0.07)	(0.06)

Note: The table reports coefficients and standard errors, which are clustered by village and are robust to heteroskedasticity. Outcome variable definitions are described in the text. All regressions include distance controls, demographic controls, economic shocks, and public programs, as described in the text.

Appendix Table 4: ART Availabillity, Maize Cultivation, and Time Allocation with Additional Controls

Dependent variable:	ln(maize)	ln(land)	Any fertilizer	Any new equipment	Any hired labor	Time: own farm	Time: home production	Time: other economic activities
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Full Sample								
2008 × ART proximity	0.35	-0.01	0.02	-0.01	-0.01	--	--	--
	(0.25)	(0.23)	(0.13)	(0.09)	(0.12)			
2010 × ART proximity	0.73	-0.11	-0.28	0.01	-0.14	1.58	0.94	2.97
	(0.30)	(0.15)	(0.15)	(0.11)	(0.14)	(0.90)	(1.07)	(1.75)
Panel B: HIV-Negative Subsample								
2008 × ART proximity	0.40	0.06	-0.02	0.01	0.01	--	--	--
	(0.26)	(0.29)	(0.13)	(0.09)	(0.12)			
2010 × ART proximity	0.89	-0.07	-0.35	0.04	-0.15	1.46	0.58	2.95
	(0.30)	(0.16)	(0.15)	(0.11)	(0.15)	(0.90)	(0.94)	(1.76)

Note: The table reports coefficients and standard errors, which are clustered by village and are robust to heteroskedasticity. Outcome variables are defined in the text. All regressions include distance controls, demographic controls, economic shocks, and public programs, as described in the text.

Figure 1: Distribution of 5-Year Subjective Mortality Risk

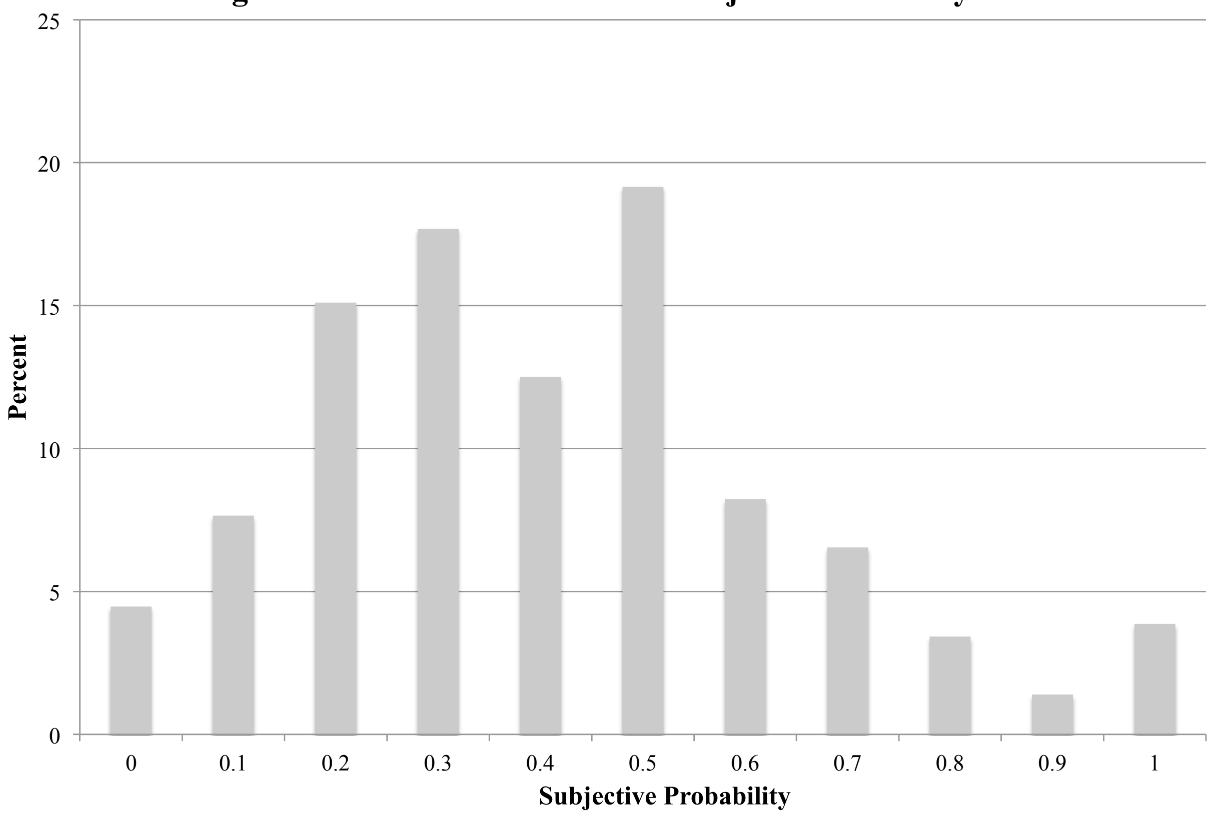
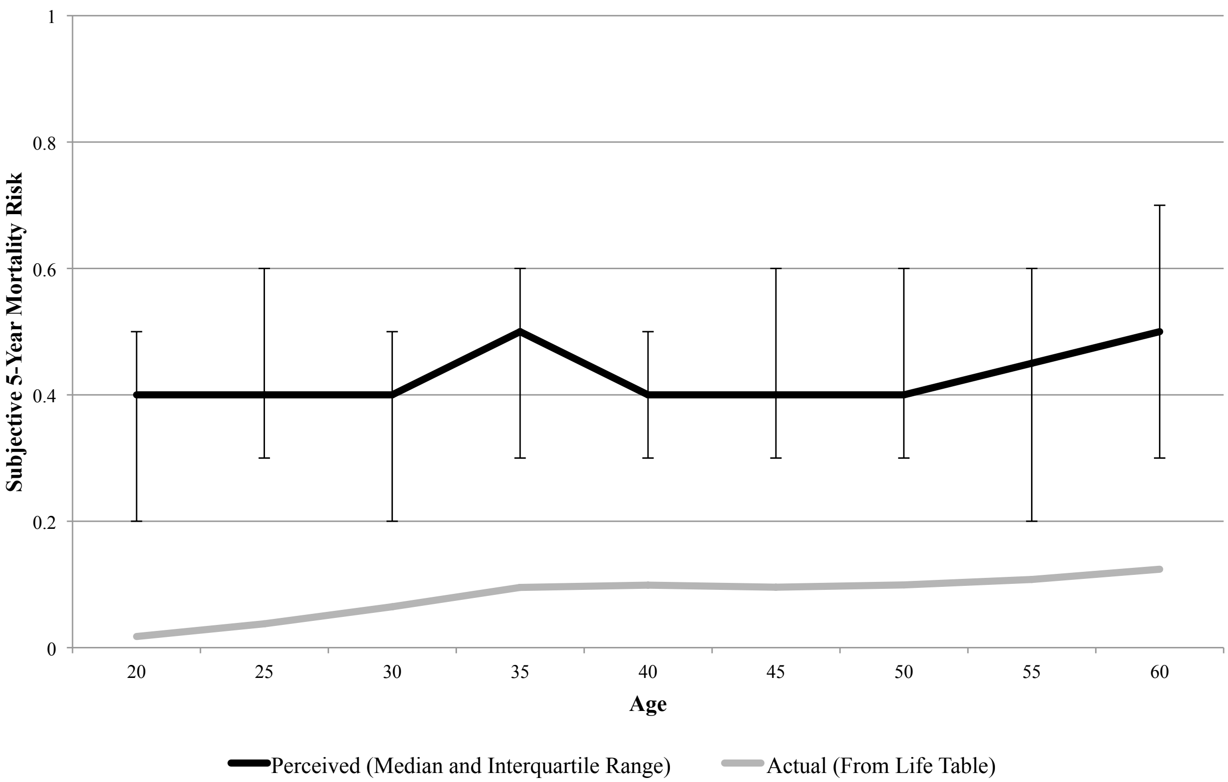


Figure 2: Subjective and Actual Mortality Risk by Age



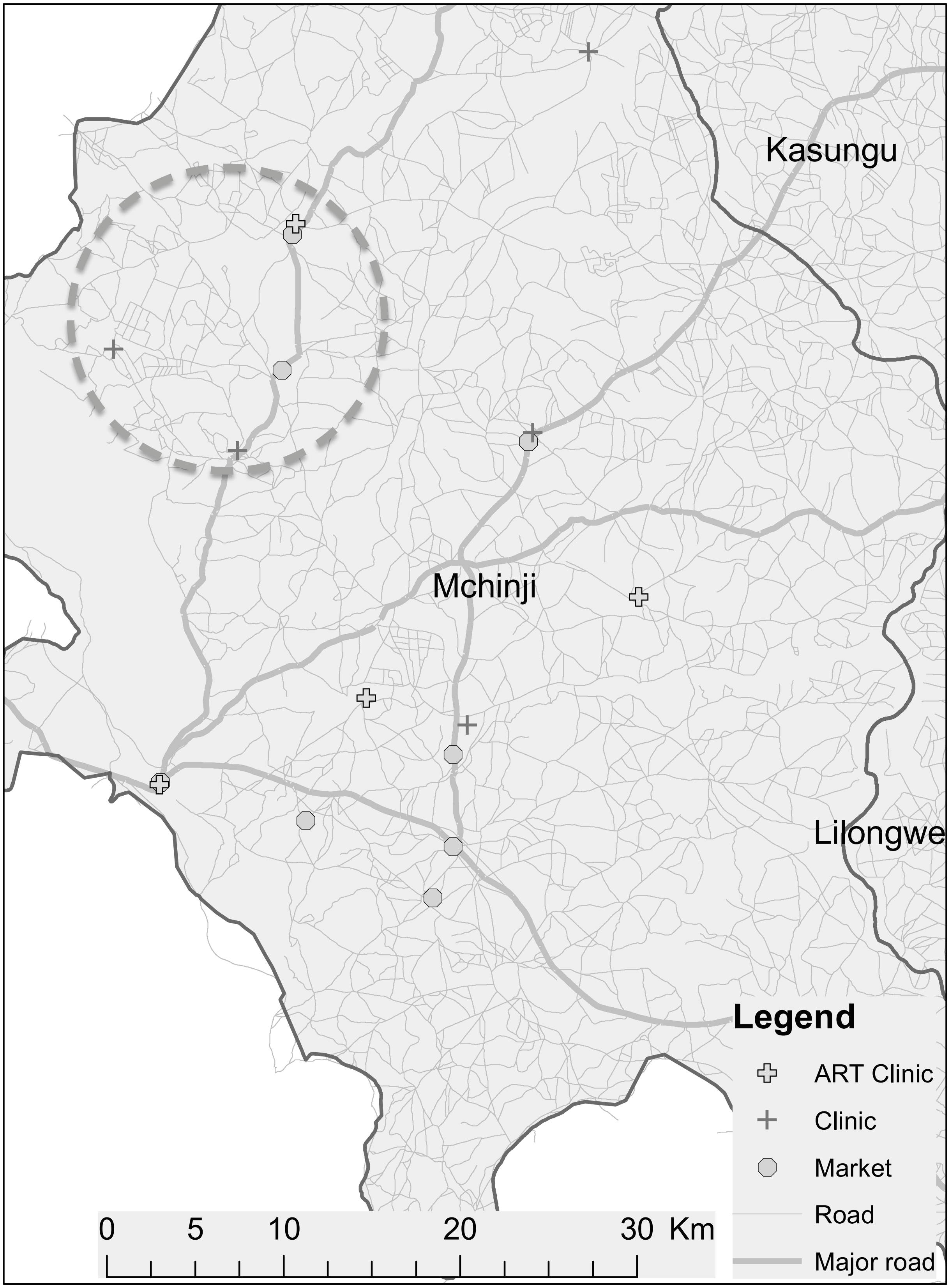
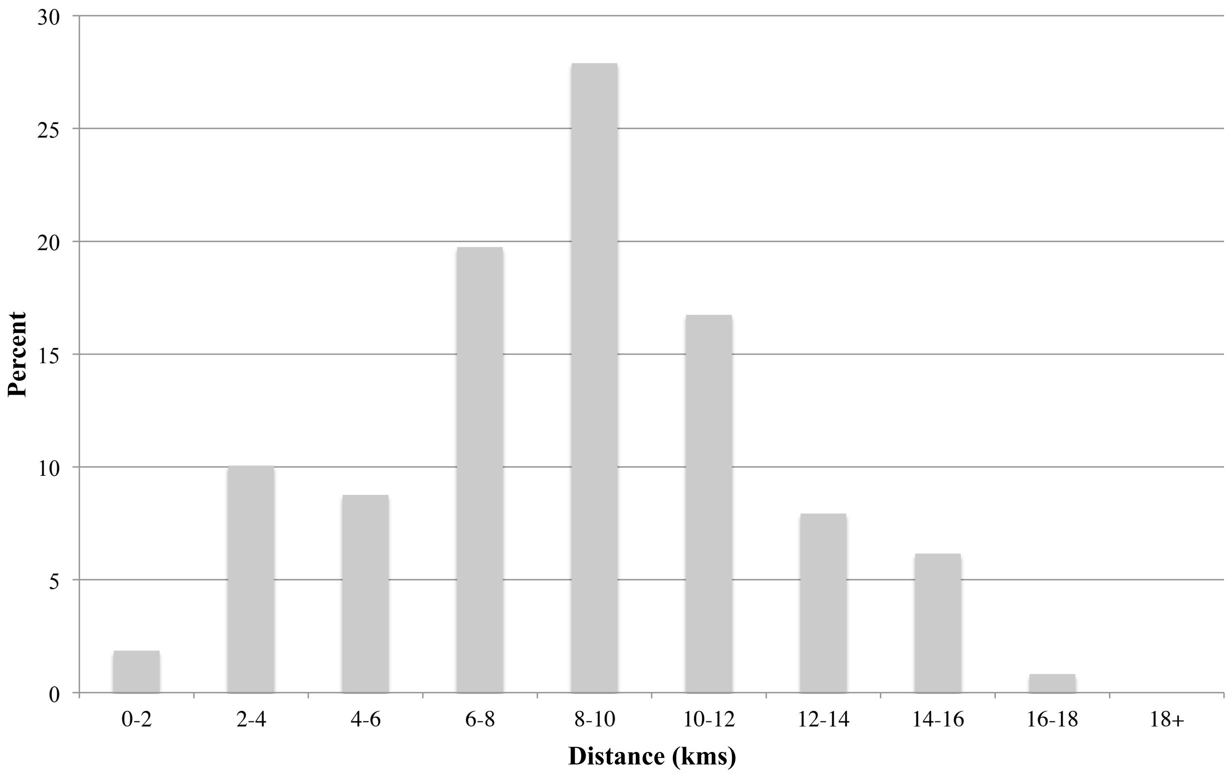


Figure 3: The Approximate Survey Area Within Mchinji Region

Figure 4: Distribution of Distance to an ART Clinic



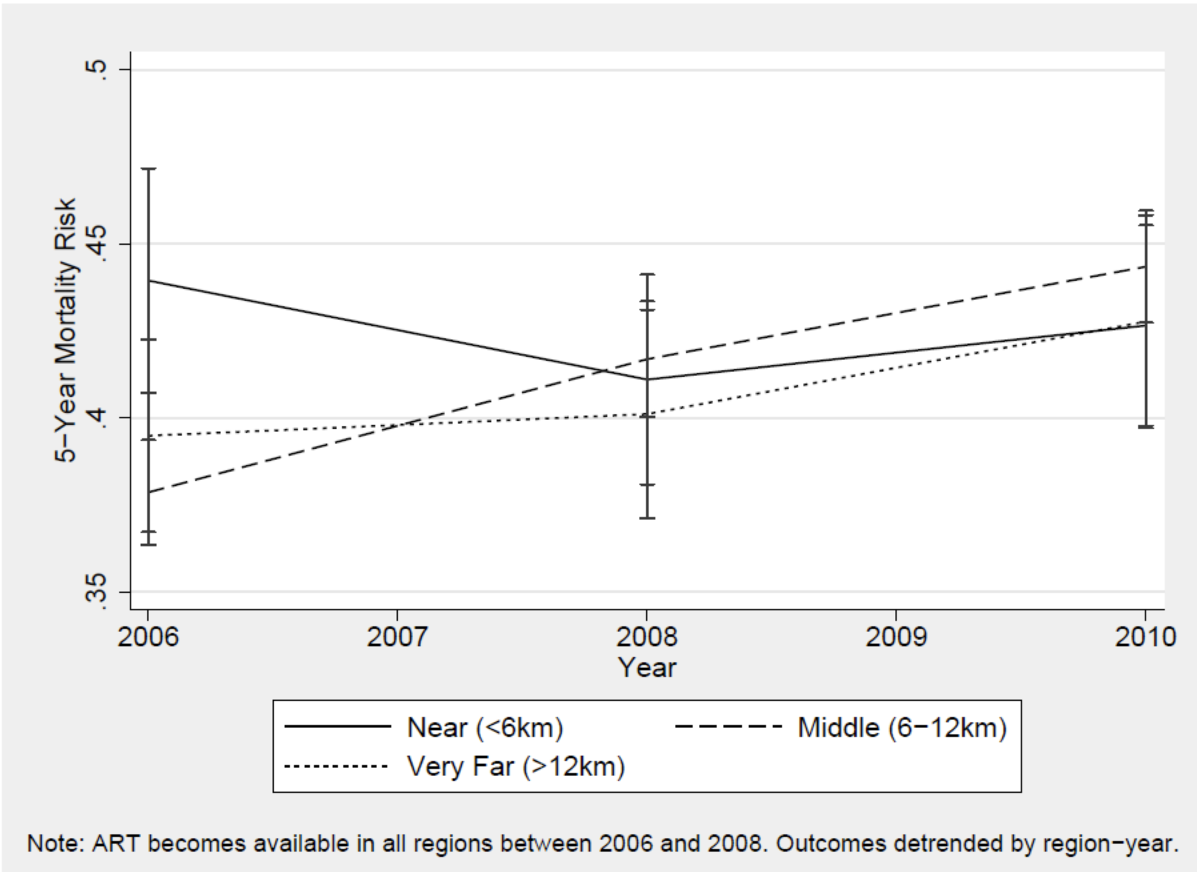


Figure 5: Subjective Mortality Risk by ART Proximity and Year

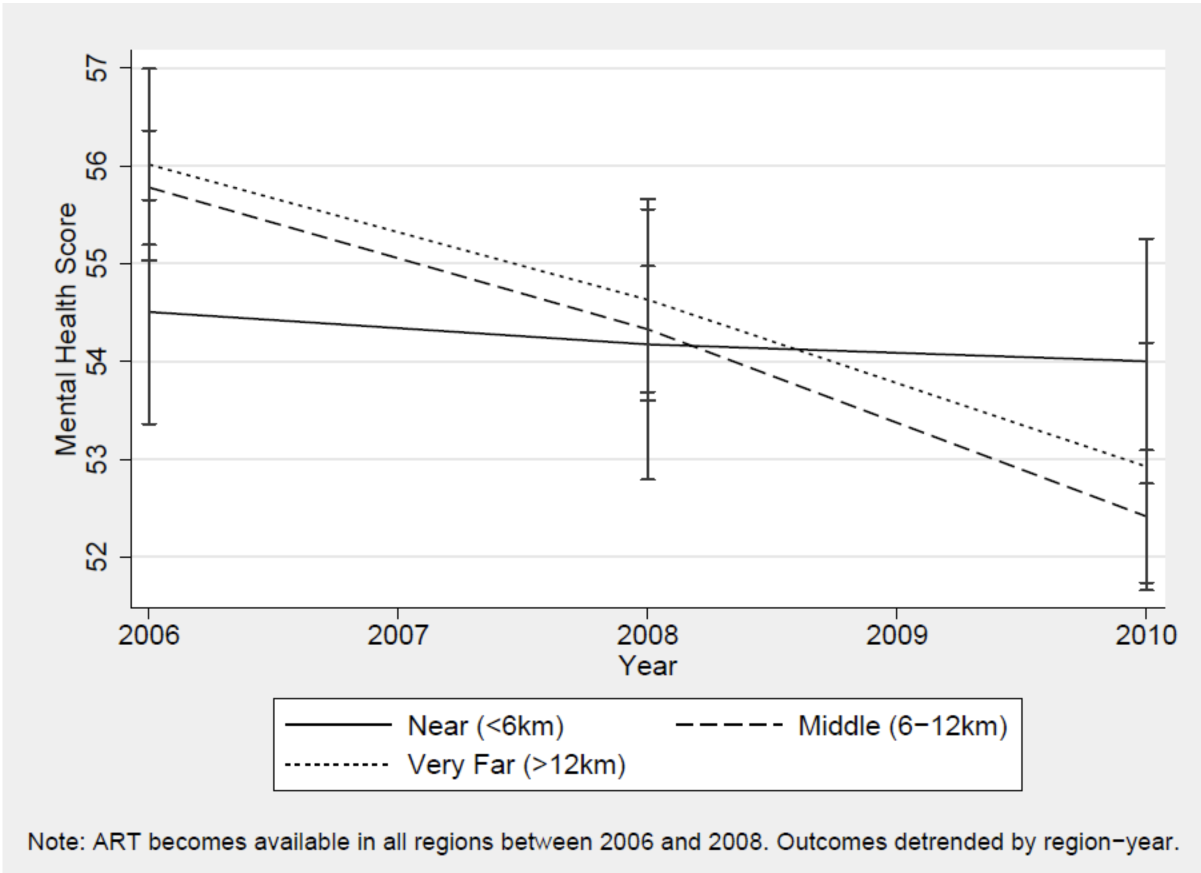


Figure 6: Mental Health (MCS-12) by ART Proximity and Year

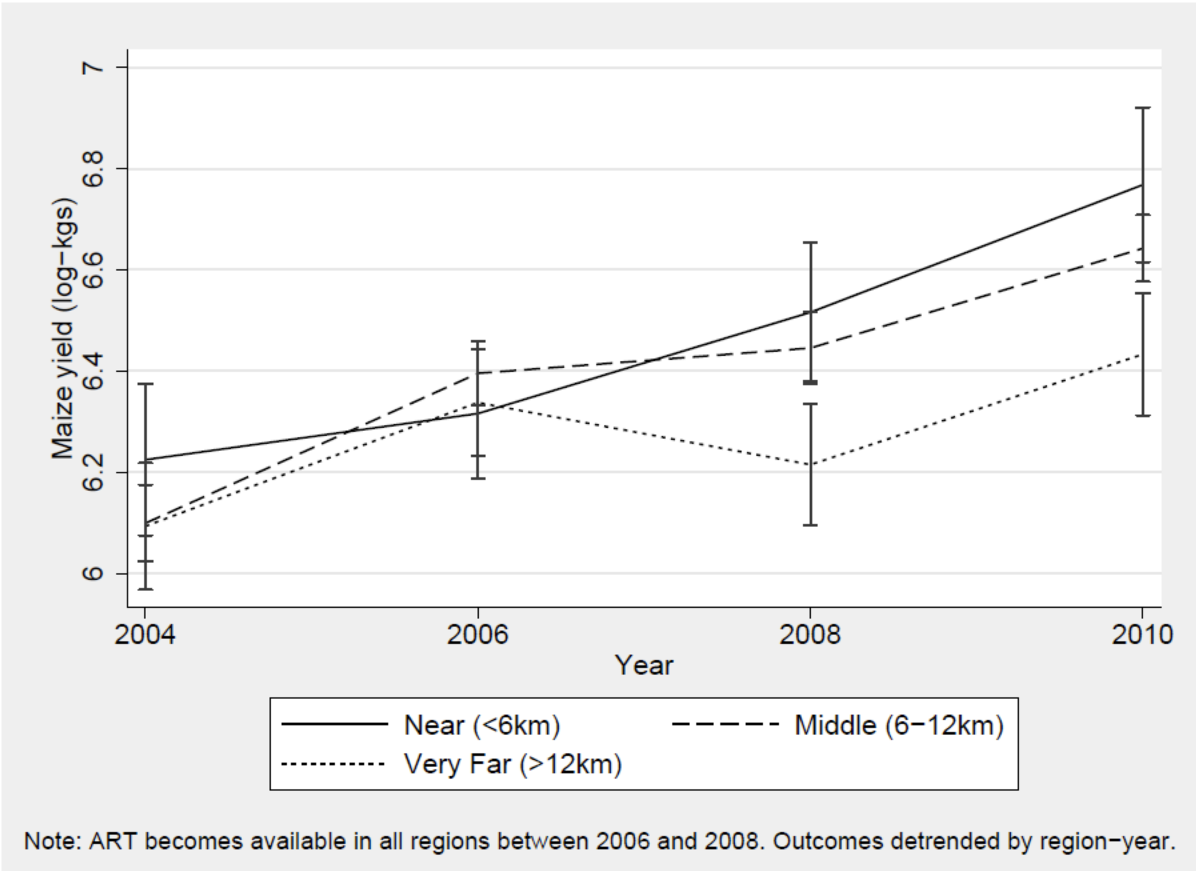


Figure 7: Log Maize Production by ART Proximity and Year

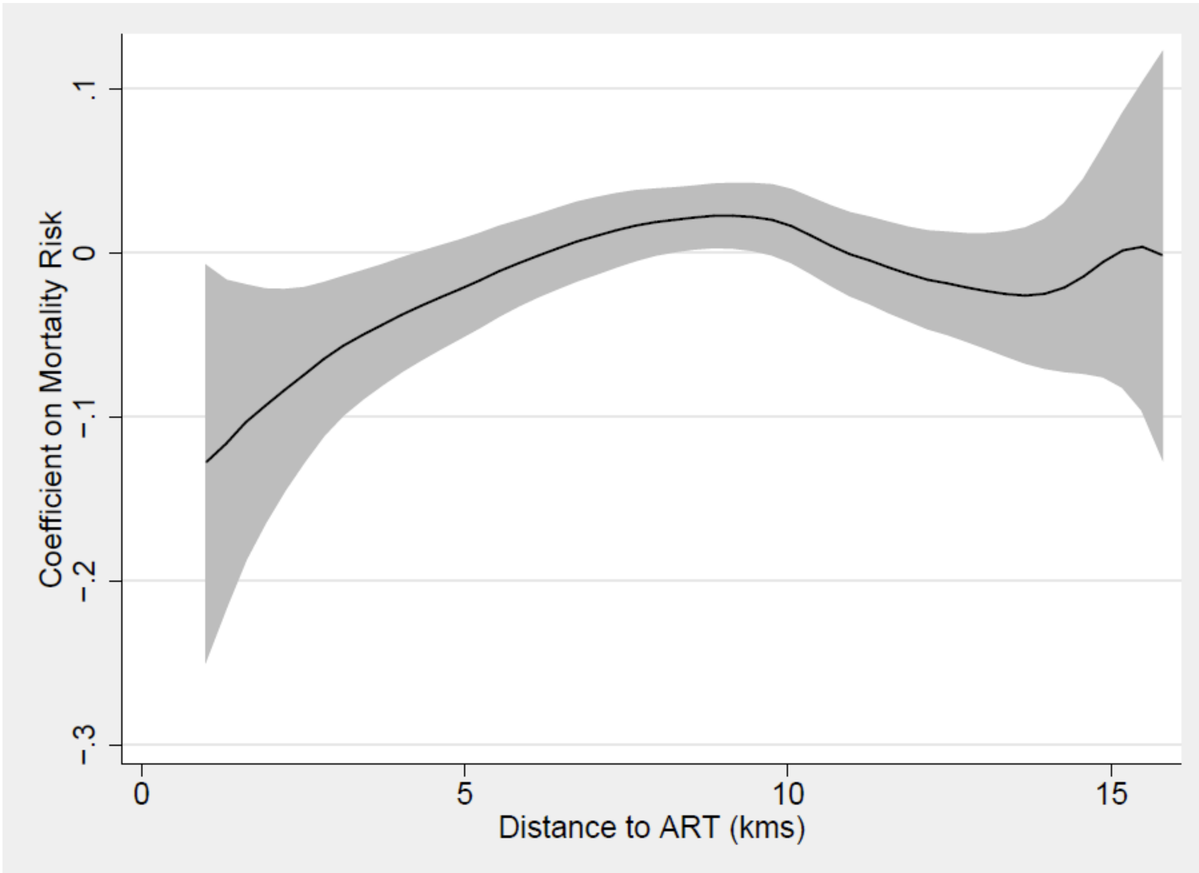


Figure 8: Local Linear Regression of Subjective Mortality Risk on ART Proximity

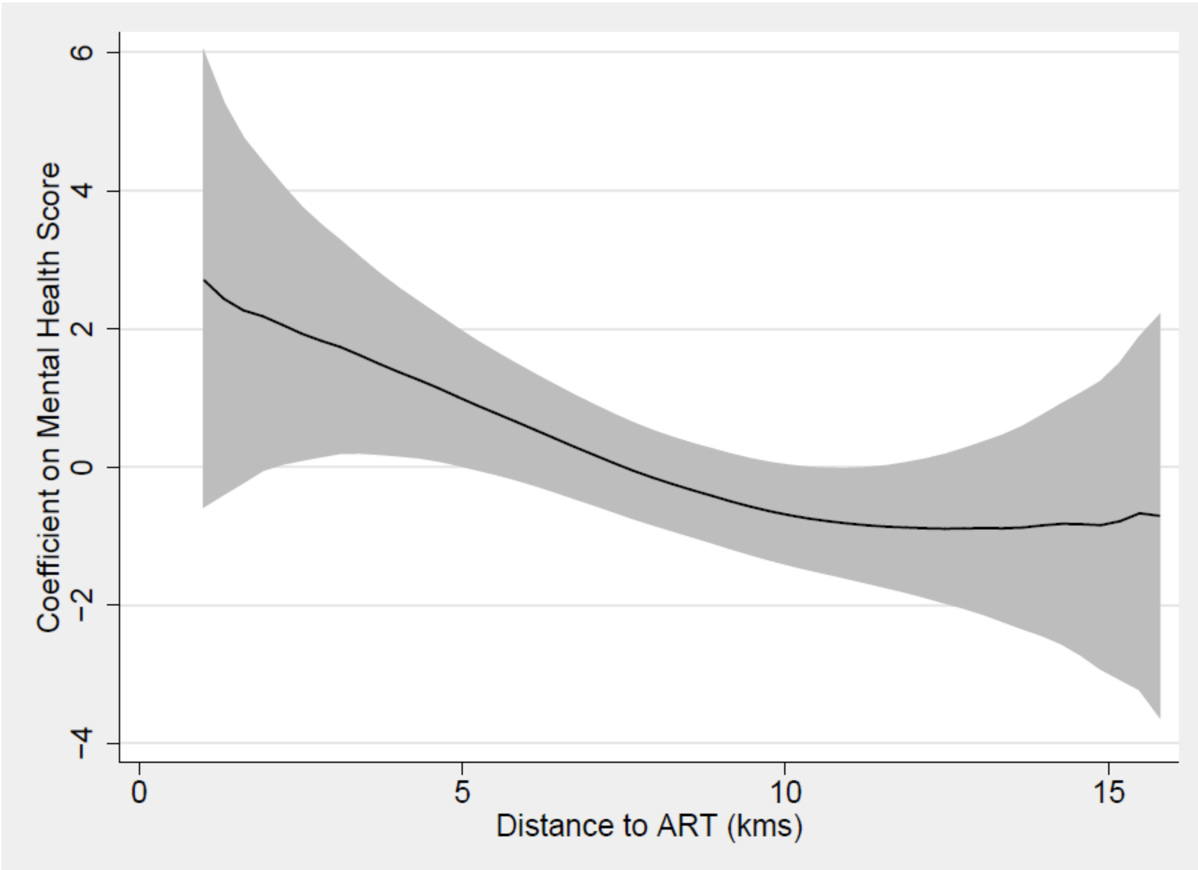


Figure 9: Local Linear Regression of Mental Health Score on ART Proximity

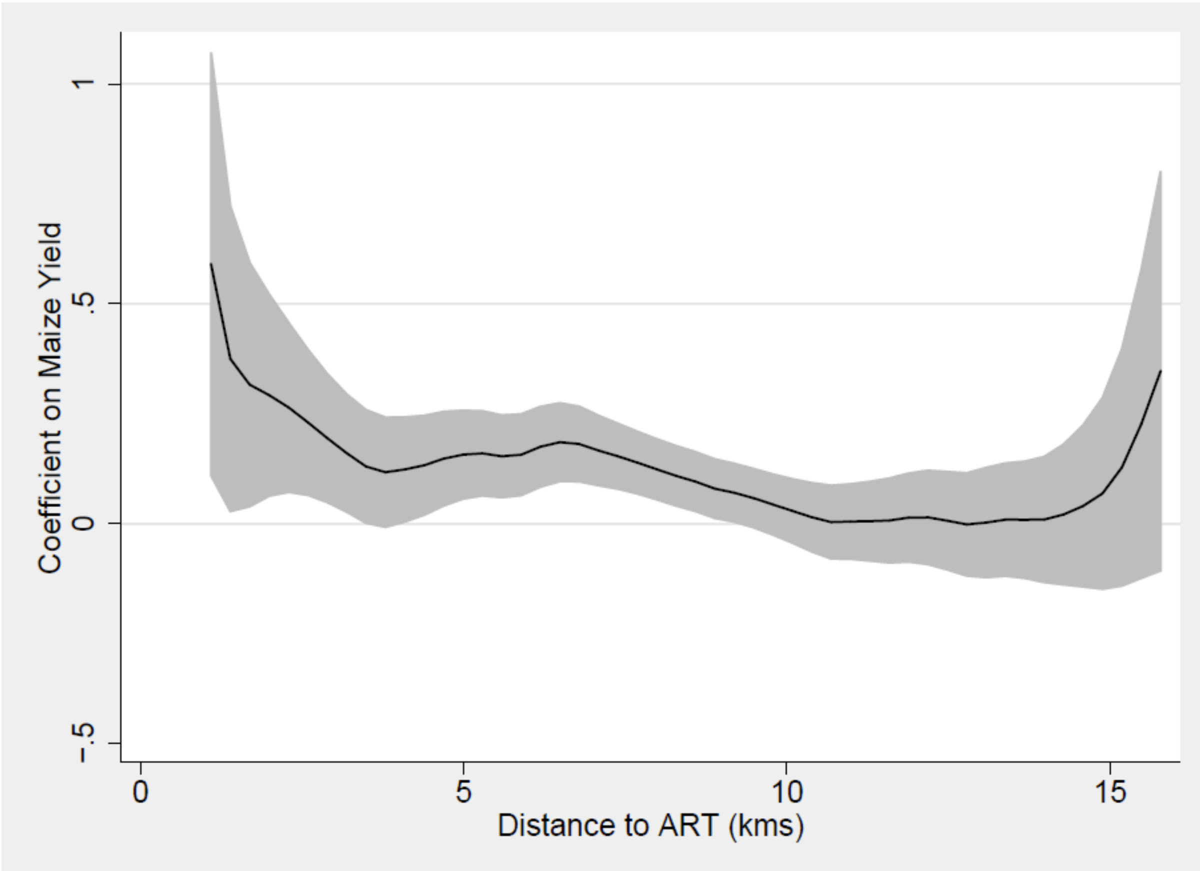


Figure 10: Local Linear Regression of Log Maize Output on ART Proximity