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A TEST OF THE NEW VARIANT FAMINE HYPOTHESIS:
PANEL SURVEY EVIDENCE FROM ZAMBIA

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NICOLE MARIE MASON

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A TEST OF THE NEW VARIANT FAMINE HYPOTHESIS: PANEL SURVEY EVIDENCE FROM ZAMBIA

By

Nicole Marie Mason

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ABSTRACT

A TEST OF THE NEW VARIANT FAMINE HYPOTHESIS:
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Nicole Marie Mason

The new variant famine (NVF) hypothesis suggests, *inter alia*, that HIV/AIDS is causing a decline in agrarian livelihoods and that the epidemic is making agrarian communities more vulnerable and less resilient to drought and other transitory shocks. The NVF hypothesis has become an important part of the conventional wisdom surrounding the relationship between HIV/AIDS and food crises in southern Africa; however, there is a dearth of empirical evidence to support the NVF hypothesis and, to date, no studies have been specifically designed to test the NVF hypothesis. This thesis uses econometric analysis of nationally-representative district-level panel data from 1991/2 to 2002/3 to examine two main questions with the goal of 'testing' the NVF hypothesis in Zambia: (1) Is HIV/AIDS having a negative independent effect on various indicators of agricultural production? And (2) Is HIV/AIDS indirectly affecting agricultural production by exacerbating the impacts of drought and other shocks? Estimation results for the most drought-prone and highly HIV/AIDS-afflicted agroecological region of the country suggest statistically significant negative effects of HIV/AIDS on agricultural production and support the NVF hypothesis that HIV/AIDS exacerbates the impacts of drought. Results from the other agroecological regions suggest much weaker impacts of HIV/AIDS and do not provide strong support for the NVF hypothesis as it relates to agricultural production at the district level.

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LIST OF ACRONYMS

AER	Agroecological region
AIC	Akaike Information Criteria
AIDS	Acquired immune deficiency syndrome
CGAIHS	Collaborative Group on AIDS Incubation and HIV Survival including the CASCADE EU Concerted Action
CSO	Central Statistical Office
FAO	Food and Agriculture Organization of the United Nations
FEGLS	Fixed effects (feasible) generalized least squares
FRA	Food Reserve Agency
FSP	Food Security Pack
FSRP	Food Security Research Project
ha	hectare
HIV	Human immunodeficiency virus
IFPRI	International Food Policy Research Institute
kg	kilogram
MACO	Ministry of Agriculture and Cooperatives
MSU	Michigan State University
NGO	Non-governmental organization
NVF	New variant famine
PA	Prime age
PAM	Programme Against Malnutrition
PHS	Post-harvest survey
PPI	Producer price index
SADC	South African Development Community
SAHIMS	Southern African Humanitarian Information Network
SCF	Save the Children Foundation
SIDA	Swedish International Development Agency
UNAIDS	Joint United Nations Programme on HIV/AIDS
WHO	World Health Organization
ZMK	Zambia kwacha

CHAPTER 1: INTRODUCTION

The 'new variant famine' (NVF) hypothesis has become an important part of the conventional wisdom surrounding the relationship between HIV/AIDS and food crises in southern Africa, and has begun to shape HIV/AIDS mitigation and food security policies and programs of governments and development agencies (de Waal and Tumushabe, 2003). The NVF hypothesis suggests, *inter alia*, that HIV/AIDS is causing a decline in agrarian livelihoods and that the epidemic is making agrarian communities more vulnerable and less resilient to drought and other transitory shocks (de Waal and Whiteside, 2003; de Waal, 2004). Although a growing body of literature suggests a decline in agricultural productivity and productive assets among HIV/AIDS-afflicted households compared to non-afflicted households[1] (reviewed in Gillespie and Kadiyala, 2005; and Barnett and Whiteside, 2002), there remains a dearth of empirical evidence to support the NVF hypothesis (de Waal, 2004), which emphasizes how HIV/AIDS compounds the effects of other exogenous shocks on agrarian household and community livelihoods. To date, no studies have been specifically designed to test the predictions of the NVF hypothesis (de Waal, 2007).

This study represents a first step towards testing the predictions of NVF. I estimate the impact of AIDS-related morbidity and mortality on indicators of agricultural production in Zambia. I focus specifically on the impact of HIV/AIDS on district-level crop output, output per hectare, and area cultivated (henceforth referred to as 'agricultural

[1] This thesis uses the terminology of Barnett and Whiteside (2002): the term "afflicted" is used to refer to households that have incurred an HIV/AIDS-related death and to households with an HIV positive household member. Households that are not afflicted but have otherwise been indirectly affected by the impacts of HIV/AIDS on the broader community are referred to as "affected'.

production indicators'). The study is based on econometric analysis of district-level panel data derived from nationally representative household surveys from 1991 to 2003. The analysis is designed to: (1) understand the potential lagged effects of AIDS morbidity and mortality on current agricultural production indicators; (2) measure the extent to which HIV/AIDS may exacerbate the impacts of other factors affecting agricultural production, such as drought and agricultural sector policy changes; and (3) determine whether these trends and impacts are consistent with the predictions of the NVF hypothesis. The study aims to strengthen the empirical foundation of food security policies and programs responding to the HIV/AIDS crisis in southern Africa.

In addition to the availability of nationally representative longitudinal district level data, Zambia is a suitable test case of the NVF hypothesis because agrarian communities in the country are experiencing the ravages of HIV/AIDS as well as recurrent droughts. In 2006, UNAIDS estimated that the HIV prevalence rate among adults (aged 15-49) was 17%, placing Zambia among the six most-highly afflicted countries in the world (UNAIDS, 2006). Drought has also plagued the country, with five droughts occurring between 1991 and 2003 (Govereh and Wamulume, 2006; Del Ninno and Marini, 2005). In addition to being faced with recurrent drought and HIV/AIDS, smallholder farmers in Zambia have had to adapt to structural adjustment reforms implemented in the 1990s. These reforms included large reductions in government fertilizer subsidies, the withdrawal of marketing boards infrastructure, and the elimination of pan-territorial pricing for maize, the main staple food crop in the country (World Bank, 2004). Understanding the impact of HIV/AIDS on agrarian communities requires controlling for these other exogenous shocks facing the agricultural sector, as well as accounting for potential interaction effects between these processes.

The remainder of this thesis is organized as follows: Chapter 2 describes the predictions of the new variant famine hypothesis and reviews the evidence to date in support of NVF. Chapter 3 presents the methods and data used in the study. Chapter 4 describes the results and Chapter 5 outlines the conclusions and policy implications of the thesis.

CHAPTER 2: BACKGROUND ON THE NEW VARIANT FAMINE HYPOTHESIS

2.1 The new variant famine hypothesis and its predictions

The background discussed below is drawn from papers by de Waal and Whiteside, 2003, de Waal and Tumushabe, 2003, and de Waal, 2003. The NVF framework predicts two main trends over time due to the HIV/AIDS epidemic in southern Africa: (1) declining agrarian livelihoods; and (2) increasing sensitivity and decreasing resilience of agrarian communities to drought and other external shocks. The rationale for the first trend is that the burden of care giving, lost labor, money, and lost social and emotional support are all eroding agrarian livelihoods. Care is expensive in terms of time (e.g., caring for the sick and orphans, attending funerals) and money (e.g., paying for medical and funeral expenses) for both afflicted and non-afflicted households in farming communities. Furthermore, HIV/AIDS-related mortality among prime-age adults, particularly women, reduces the number of productive adults that provide for dependents while also increasing the number of dependents. This results in high effective dependency ratios[2] and potential labor shortages.

The rationale for the second trend predicted by the NVF hypothesis is that longstanding coping strategies used by households to mitigate the impacts of drought and other shocks may no longer be effective since the onset of AIDS. For example, even in the absence of other shocks, households may sell assets to pay for AIDS-related medical or funeral expenses. Such asset depletion may undermine the households' and communities' ability to cope with drought-related shortfalls in crop production. In

[2] The effective dependency ratio is defined as the number of dependents (children, the elderly, and the ill) divided by the number of productive adults (de Waal and Whiteside, 2003).

addition, AIDS-related morbidity and mortality can disrupt the intergenerational transfer of knowledge related to famine coping strategies (e.g., gathering wild foods or income generating activities) on which households rely to reduce the impacts of drought and other shocks. According to de Waal and Whiteside (2003), a common coping strategy historically in times of drought was for adults to reduce their food consumption; however, in the era of HIV/AIDS, such a strategy is dangerous because poor nutrition accelerates the progression from HIV to AIDS and also increases the susceptibility of non-afflicted individuals to HIV infection. De Waal and Whiteside (2003) argue that kinship networks are also being stressed by AIDS-related illness and deaths with the result that kinship networks may be less able to absorb the impacts of other shocks. Finally, de Waal suggests that the burden of care described above forces households and communities to adopt less productive and less resilient farming practices.

2.2 Evidence for the new variant famine hypothesis

The two broad predictions of the NVF hypothesis described above grow out of three NVF 'sub-hypotheses': that HIV/AIDS leads to (1) "new patterns of vulnerability to destitution and hunger"; (2) "new trajectories of destitution during crisis"; and (3) changes in the "ecology of nutrition and infection, and thereby the pattern and level of child mortality" (de Waal, 2007). In his chapter on NVF in the 2007 book, *The New Famines* (Devereux, 2007), de Waal outlines the evidence to date in support of each of these NVF sub-hypotheses. The majority of this evidence is either indirect or circumstantial. de Waal acknowledges that no studies have been designed specifically to test the predictions of NVF (de Waal, 2007) – this study is the first to do so. Few of the papers cited as evidence of NVF control for other factors affecting agrarian livelihoods nor do they attempt to empirically test the hypothesis that HIV/AIDS is exacerbating the effects of other shocks on agricultural livelihoods. Furthermore, most of the works cited as evidence are from limited geographic areas or are based on a 'snapshot' of the epidemic's impact rather than trends over a number of years. Given the 'long-wave' nature of HIV/AIDS, it is important to consider the immediate *and* delayed impacts of the epidemic (Gillespie, 2006; Barnett and Whiteside, 2002). Moreover, case studies based on localities known to be hard-hit by the disease may generate conclusions that do not accurately reflect broader community- or national-level impacts.

In terms of evidence for the NVF sub-hypothesis that HIV/AIDS is creating "new patterns of vulnerability to destitution and hunger" (de Waal, 2007), de Waal points to several small-scale studies (Barnett and Blaikie, 1992; Webb and Mutangadura, 1999; and Baylies, 2002) that have explored the impacts of HIV/AIDS on household and community food security in rural Africa. While these studies provide valuable insights into the social and economic impacts of HIV/AIDS on rural households and communities, all three of the studies focus on relatively limited geographic areas, often with high HIV prevalence rates, and so are not nationally representative or easily generalized. The work by Barnett and Blaikie (1992) and Baylies (2002) is largely qualitative and so does not permit measurement of the magnitude of the HIV/AIDS impact on households relative to other shocks and factors affecting agrarian livelihoods. The work by Webb and Mutangadura (1999) has a quantitative component and includes comparisons between afflicted and non-afflicted households with respect to various socio-economic indicators; however, it is not clear if differences in income and other indicators are statistically significant or if there are other differences between the afflicted and non-afflicted households that could be responsible for the income differential. Nonetheless, these and a plethora of other household-level studies (see Gillespie and Kadiyala, 2005 for a thorough review) suggest that HIV/AIDS is negatively affecting afflicted households' incomes, asset levels, and agricultural production.

None of the aforementioned papers allows comparison of the impact of drought on highly HIV-afflicted or affected households and communities versus those where the epidemic has had less of an impact. However, a pilot study in Tanzania which examined the impacts of the 2002/3 drought on households experiencing adult morbidity and mortality versus non-afflicted households found, contrary to the predictions of NVF, that afflicted households were actually better off than non-afflicted households in the face of drought (Tumushabe, 2005). One reason cited for this counter-intuitive finding is that the households with chronically ill adults and households incurring a prime-age adult death tended to be better off to begin with, underscoring the importance of controlling for other factors in order to isolate the impact of HIV/AIDS on rural livelihoods (Jayne et al. 2005).

While HIV/AIDS has undoubtedly had a devastating impact on many of the households it has touched, de Waal cites several papers that call attention to the effectiveness of household coping strategies in many instances. One such coping strategy is so-called "replacement" in which households experiencing a prime-age death attract new household members, thereby mitigating the labor force impact of the death (Yamano and Jayne, 2004; Mather et al., 2003). de Waal suggests that households that use the replacement coping strategy might be more vulnerable to subsequent shocks; however, to date, no studies have empirically tested this hypothesis (de Waal, 2007).

A weakness in much of the evidence presented by de Waal is that it consists of facts and figures on how HIV/AIDS is affecting afflicted households but gives little ground for comparison with non-afflicted households, nor does it directly support the claim that HIV/AIDS exacerbates the effects of drought and other shocks on agrarian livelihoods. For example, de Waal cites a study from rural South Africa (Steinberg et al., 2002) that indicates that half of the AIDS-afflicted households in the sample "reported that their children were going hungry as a result" (de Waal, 2007: 93). But to what extent were children going hungry in the non-afflicted households in the study area? Were there factors other than HIV/AIDS that were contributing to the child malnutrition problem?

In several other papers on the NVF hypothesis, de Waal lists among the evidence for NVF increased cassava cultivation in several southern African countries (de Waal and Whiteside, 2003; de Waal, 2004). While this upward trend is striking, other factors such as agricultural policy changes, including dismantling of marketing boards infrastructure and reductions in maize and fertilizer subsidies are likely to be as, if not more, important than HIV/AIDS in influencing this shift (Jayne et al., 2005; Chapoto, 2006).

While the evidence presented by de Waal in support of the NVF sub-hypothesis of "new patterns of vulnerability to destitution and hunger" shows that HIV/AIDS often has a negative effect at the household level, none of the evidence directly supports the claim that afflicted households are harder hit by drought and other shocks than non-afflicted households. While it is certainly plausible that such households are more vulnerable to shocks, as their ability to cope is worn down by the impacts of the epidemic, to date no explicit empirical evidence supports this claim.

In terms of the NVF sub-hypothesis that afflicted and affected households and communities will follow "new trajectories of destitution during crisis", de Waal states that "this prediction has yet to be tested" (de Waal, 2007: 95). The two main sources of circumstantial evidence for this NVF sub-hypothesis are a report by the Southern African Development Community (SADC) Food and Natural Resource Vulnerability Assessment Committee (SADC, 2003) and a paper on AIDS, child malnutrition, and drought in southern Africa by John Mason and colleagues (Mason et al., 2005). Similar limitations to those outlined above recur for this evidence for the NVF hypothesis. de Waal points to a finding in the SADC report that 57% of households with a chronically ill adult (used as a proxy for AIDS-afflicted households) had not eaten for entire days (de Waal, 2007: 95). Although this is higher than the percentage of non-afflicted households using this coping strategy (46%), there were no significant differences in income between afflicted and non-afflicted households and other socio-economic differences were not controlled for between the two groups (SADC, 2003).

The Mason et al. (2005) paper is one of the few sources of evidence cited by de Waal that is based on regression analysis. It is also the only study other than this thesis of which I am aware that has explicitly tested for an interaction effect between HIV/AIDS and drought on a food security- or rural livelihoods-related outcome variable. Using pooled time-series and cross-sectional data from Zambia (1996-2001/2) and Zimbabwe (1999-2002), Mason et al. (2005) regressed change in child underweight prevalence (a measure of malnutrition) on a drought year dummy variable, HIV prevalence, and an interaction term between drought and HIV prevalence. The coefficients on the HIV prevalence and drought variables were statistically insignificant but the interaction term was statistically significant and positive, indicating that the effect of drought is exacerbated by high HIV prevalence and vice versa. However, the parameter estimates from this regression analysis may be biased because no other factors affecting change in child underweight were controlled for in the model (omitted variables bias).

de Waal also points to anecdotes of increased engagement in transactional sex by women during food crises as evidence in support of the NVF hypothesis (SCF, 2002; SAHIMS, 2003; and Semu-Banda, 2003, cited in de Waal, 2007). While such practices may indeed be occurring, there is very little evidence to indicate whether it has increased in recent years (as opposed to people simply becoming more aware of it). Furthermore, even it if is a widespread practice, increased engagement in transactional sex lends credence to the idea that food crises are exacerbating the spread of HIV/AIDS (Bryceson and Fonseca, 2006), rather than HIV/AIDS worsening the effects of food crises as postulated by NVF.

de Waal presents no evidence in support of the third and final NVF sub-hypothesis that the ecology of nutrition and infection changes in poor, vulnerable populations in the presence of a generalized HIV/AIDS epidemic (de Waal, 2007).

Overall, the evidence in support of the various components of the NVF hypothesis is weak at best. This is not to say that the theory is invalid, only that it has yet to be tested empirically in any rigorous way. In this study the use of econometric analysis is a critical contribution, as it allows us (subject to the constraints of the data available) to control for the effects of other processes and identify the *ceteris paribus* effects of HIV/AIDS, rainfall and other shocks, and their interactions, on agrarian livelihoods as proxied by district-level crop output, output per hectare and cultivated area.[3] Furthermore, this analysis is based on nationally representative survey data and considers a 13-year period rather than being based on a limited geographic area or short time period.

[3] Other aspects of agrarian livelihoods that would have been interesting to examine include consumption or expenditure, income (farm and off-farm), and nutrition-related outcomes (e.g., anthropometrics); however, the district-level panel data required for such analyses are not available for Zambia.

CHAPTER 3: METHODS & DATA

3.1 Theoretical Framework

The goal of this thesis is to empirically test the NVF hypothesis. The NVF hypothesis predicts a "downward spiral" in the well being of HIV/AIDS-afflicted agrarian communities due to the interactions between the epidemic, drought and other shocks. This implies dynamic responses and impacts over time, and hence reasonably long time-series data is required to measure and detect such dynamics.

I test the NVF hypothesis using data on agricultural production from the Zambia Post-Harvest Surveys (PHS) for agricultural years 1991/1992 to 2002/2003. The PHS is a nationally representative longitudinal survey of smallholder agriculture in 52 districts.[4] Approximately 7,000 small and medium scale farming households[5] are included in the PHS each year; however, the specific households interviewed are not the same from year to year. The data set can therefore be considered a panel data set over 12 years, in which the cross-sectional unit of observation is the district (not the household). (For more details about the PHS survey design and samplings procedures, see Megill (2004).) The methodology used to go from household- to district-level measures of agricultural production is discussed in further detail in section 3.2 below.

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[4] Since the 2000 census, the nine provinces of Zambia have been divided into 72 districts; however, at the time of the 1990 census, the country was divided into 57 districts. PHS data for five (5) of these districts is not complete for one or more years during the period 1991/2-2002/3 so I use in the analysis the 52 "old" districts for which I do have complete data.

[5] Small and medium-scale farming households are defined as those households that cultivate fewer than 20 hectares of land and produce crops, raise livestock or poultry, or farm fish. I refer to these households as 'smallholder' households throughout the text.

I base my model on a supply response framework.[6] Supply response models (e.g., Nerlove models) are used to study the effects of changes in prices and other exogenous factors of interest on agricultural production at some aggregate level (community, region, country, etc.). Such models are of the general form:

$$y = y(p^e, p_x, Z) \qquad [1]$$

where y is a measure of agricultural output; p^e is the expected output price; p_x is a vector of input prices; and Z is a vector of other exogenous factors that affect supply (Nerlove, 1958; Askari and Cummings, 1977). Input prices of potential relevance to agrarian communities in sub-Saharan Africa include the prices of fertilizer, seed, pesticides, labor (human and draft animal), and credit (i.e., interest rates).

In the supply response literature on crop production, the dependent variable in [1] is usually crop output, output per hectare or total acreage. Askari and Cummings (1977) suggest that acreage is preferable to output (tonnage) or output per hectare (yield) as the dependent variable in supply response models because acreage is under farmers' control while output and yield are affected by factors beyond farmers' control.

In many supply response models, Z includes factors such as rainfall, infrastructure, and technology. Smallholder agriculture in Zambia is predominately rainfed so rainfall is expected to have an important effect on agricultural production, and so is included in the supply response model (*RAIN*). Beyond these 'standard' variables, researchers commonly add other relevant explanatory variables to [1] depending on the particular research question (Askari and Cummings, 1977). I add four such explanatory variables. First, to examine the effects of HIV/AIDS on agrarian communities in Zambia,

[6] Although I adopt an output supply function approach in this essay, a production function approach would have provided additional insights as to the *pathways* through which HIV/AIDS is affecting smallholder agricultural production. Data limitations prevent me from adopting a production function approach here.

I add the district-level HIV prevalence rate or AIDS-related mortality rate (*AIDS*). Second, I add the community's asset base (*ASSET*). The asset base is a potentially important determinant of farm supply decisions because with imperfect credit markets, the ability to finance input purchases and invest in productive assets will be constrained by available resources. Third, I add the percentage of female-headed households in a district (*FEM*). Women are disproportionately affected by the epidemic (Gillespie and Kadiyala, 2005; UNAIDS, 2006) and widow-headed households often cultivate less area than non-afflicted households or households in which the deceased prime-age adult member is not the male head of household (Chapoto et al., 2007). Furthermore, descriptive studies suggest that AIDS-related mortality exacerbates gender inequalities (Mutangadura, 2005). For these reasons, I want to control for the number of female-headed households in communities. Finally, I add the quantity of government-subsidized fertilizer acquired by the community (*SUB*) to control for the effects of structural adjustment-related reductions in government fertilizer subsidies on agricultural production. With the addition of these variables, [1] becomes:

$$y = y(p_y^e, p_x, Z^*, AIDS) \text{ where } Z^* = (RAIN, ASSET, FEM, SUB) \qquad [2]$$

Another consideration is how to model p_y^e, the expected output price. The prevailing market price for agricultural output at harvest time is not observable at planting time; however, expected crop output prices are a major influence on farmers' planting decisions (Nerlove, 1958). Two reasonable models of price expectations in the Zambian smallholder sector are naïve expectations and adaptive expectations. Rational expectations is unlikely to be an appropriate model of price expectations in this context because it requires that smallholders have information about the demand curve they face for their output. Such information is typically not available to Zambian smallholders. The naïve and adaptive models of price expectations assume less information is available to the decision makers. In the naïve expectations framework, expected output price (p_{yt}^{e}) is defined as:

$$p_{yt}^{e} = p_{yt-1} \qquad [3]$$

where $p_{y\,t-1}$ is the observed output price in the previous period. In the adaptive expectations framework, expected output price is defined as:

$$p_{yt}^{e} = \alpha p_{yt-1}^{e} + (1-\alpha) p_{yt-1} \qquad [4]$$

where $0 < \alpha < 1$. This assumes that current price expectations adjust partially to the difference between last period's expectation and the actual price realization last period.

3.2 Empirical model

Model specification

To test the predictions of the NVF hypothesis that HIV/AIDS: (1) negatively affects agrarian livelihoods (as proxied here by various agricultural production indicators); and (2) exacerbates the impacts of drought and other shocks on agricultural production, I consider the estimation of an agricultural supply response model based on equation [2]. I hypothesize the following linear panel data econometric model:

$$y_{it} = \alpha + \gamma p_{y_{it}}^{e} + p_{x_{it}}\psi + AIDS_{it}\delta + Z_{it}^{*}\omega + T_t\theta + \lambda_i + \varepsilon_{it} \qquad [5]$$
$$\text{and } Z^{*} = (RAIN_{it}, ASSET_{it}, FEM_{it}, SUB_{it})$$

where i indexes the district; t indexes the year; y is the agricultural production indicator; p_y^e is the expected crop output price; p_x is a vector of input prices; *AIDS* is a measure of the current productivity effect of the HIV/AIDS epidemic and is a function of the estimated district HIV prevalence or AIDS-related mortality rate (this is discussed further below); *RAIN* is a vector of positive and negative rainfall deviations (in percentage terms) from the 20-year district mean rainfall level (following Hoddinott, 2006); *ASSET* is an index of the mean household livestock and productive asset base; *SUB* is the mean household acquisition of government-subsidized fertilizer (kg/ha); *FEM* is the percentage of female-headed households; *T* is a vector of year dummies intended to capture the effects on agricultural production of unobserved factors that change over time, such as infrastructure or agricultural technology; λ_i is the time invariant district-level unobserved effects; and ε_{it} is the idiosyncratic error term. Assumptions made about the nature of the relationships among the explanatory variables, λ_i and ε_{it} are described in detail in section 3.3.

The agricultural production indicators used as dependent variables (y) in the analysis are mean household cultivated area, mean household crop output, and mean household crop output per hectare, in both level and per capita terms. (I henceforth refer to these six different dependent variables collectively as 'agricultural production indicators'.) For models in which the dependent variable is in per capita terms, the *ASSET* variable is also specified in per capita terms. I use mean household averages in each district rather than district totals for the dependent variables (as well as for *ASSET* and *SUB*) in order to control for changes in the number of households (or number of members in each household) in each district over time. In the case of cultivated area, the total area cultivated by each household for 17 different crops[7] included in the PHS was computed. The household-level data were then weighted and mean household cultivated area was calculated for each district and year.

In the case of crop output, a household-level crop output index (C_{hit}) was computed as $C_{hit} = \sum_{j=1}^{17} \bar{p}_{jk} c_{jhit}$ where $\bar{p}_{jk} = T^{-1} \sum_{t=1}^{T} p_{jkt}$, c_{jhit} is the kilograms of crop j (j=1, ..., 17) produced by household h, in district i in year t, and p_{jkt} is the real median price for crop j in year t in province k (k=1,...,9). Thus, the household-level crop output index is a weighted sum of the physical quantities of 17 crops produced by the household, where the weights are the average median provincial crop prices over the period 1991/2 to 2002/3.[8] To get a measure of household crop output per hectare, the household crop output index (C_{hit}) was divided by the household's total area planted (ha) in those 17 crops. Mean household crop output and mean household output per hectare were then computed by weighting the household-level data and taking means for each district and year.

In this analysis, p_y=*PPI*, where *PPI* is an agricultural producer price index. I use the *PPI* as the output price rather than individual crop prices because the dependent variable in [5] is mean household area planted or crop output (total or per hectare) for 17 crops potentially cultivated by the household. I calculate the *PPI* from PHS survey data

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[7] These 17 crops are: maize, sorghum, rice, millet, sunflower, groundnuts, soybeans, seed cotton, Irish potatoes, Virginia tobacco, burley tobacco, mixed beans, cowpeas, velvet beans, coffee, sweet potatoes, and cassava.

[8] Other quantity indexes, such as the Divisia, Laspeyres, or Paasche quantity indexes, could also have been used. The indexing method used in the thesis is similar to the Laspeyres quantity index in that prices are held at base year levels; however, rather than choosing a single year as the base year, I computed average crop prices over the entire period of analysis and used those prices as the 'base year prices'. For the crop output dependent variable, I am interested in changes over time in the *physical* quantities produced of the 17 different crops. Crop prices are used as weights to enable aggregation of physical quantities of different crops. By using the average crop prices as weights, I am holding the weights constant over time.

for each district and year (PPI_{it}) as $PPI_{it} = \sum_{j=1}^{17} s_{ijt} p_{jkt}$ where $s_{ijt} = \frac{p_{jkt} * \sum_{h=1}^{H_{it}} c_{jhit}}{\sum_{j=1}^{17} \left[p_{jkt} * \sum_{h=1}^{H_{it}} c_{jhit} \right]}$,

c_{jhit} and p_{jkt} are defined as above, and s_{ijt} is the share of crop j in the total value of crop output in district i in year t. Thus, PPI_{it} is a weighted combination of real crop output prices, where the weights are based on the relative importance of each crop to total agricultural production in the district in each year.[9] In the analysis, I model expected crop output price using naïve expectations (the model became overparameterized when adaptive expectations were used); therefore, $p^e_{y_{it-1}} = PPI_{it-1}$ in [5].

The input prices included in the p_x vector include the real provincial fertilizer price per kilogram and the lagged real national interest rate. Ideally, I would also have included other input prices such as prices for seed and pesticides, rental rates for draught animals, and wage rates (agricultural and non-agricultural); however, such data were not available. I include input prices in the model to control for other factors that influence supply so that I can get good estimates of the effects of HIV/AIDS and other shocks on agricultural production. It is likely that fertilizer prices and interest rates are correlated with the prices of inputs for which I do not have data; therefore, including fertilizer prices and interest rates should adequately control for other input prices that affect farm supply.

The *SUB* variable (mean household acquisition of government-subsidized fertilizer (kg/ha)) was computed from the PHS data as follows. Prior to the 1997/8 crop year, the PHS does not identify the channel used by households to acquire fertilizer,

[9] As discussed above in the context of quantity indexes, alternative price indexes, such as the Divisia, Laspeyres, Paasche or Fisher's Ideal price indexes, could also have been used here.

reflecting the dominant role of the government in fertilizer importation, sales, and distribution during that period. As described in detail in Jayne et al. (2002), prior to 1997/8 it was either illegal or legal but unprofitable in most cases for private firms to participate in fertilizer marketing unless they were contracted by the government to do so. Thus, in the analysis, I assume that all fertilizer acquired by households during crop years 1991/2 to 1996/7 was from government channels. For years 1997/8 through 2002/3, PHS data on household fertilizer acquisitions are disaggregated by channel and these channels were identified as either government-subsidized or commercial/private sector. Table A1 in the Appendix details the specific government-subsidized and commercial/private sector channels in each year during the period 1997/8 to 2002/3, and provides additional information on specific government fertilizer subsidy programs. Fertilizer acquisitions through government-subsidized channels were computed for each household (kg/ha); these data were then weighted and the mean household government-subsidized fertilizer acquisition was computed for each year and district.

In the empirical specification of the model, I add squared terms of *RAIN* and *AIDS* to equation [5] to allow for the possibility of non-linear relationships between these variables and the agricultural production indicators. I also add interaction terms between *AIDS* and all elements of the Z^* vector. This allows the elements of the Z^* vector to have differential effects on agricultural supply depending on the levels of HIV/AIDS. It also enables us to test the key prediction of the NVF hypothesis: that HIV/AIDS exacerbates the effects of drought and exogenous shocks (i.e., the variables in Z^*) on agrarian livelihoods as proxied here by various indicators of agricultural production. (Smallholders' responsiveness to input and output prices might also be sensitive to

HIV/AIDS but this is not a prediction of the NVF hypothesis, so such relationships are not explored in this thesis.) Together these additions to [5] give:

$$y_{it} = \alpha + \gamma p_{y_{it-1}} + p_{x_{it}}\psi + AIDS_{it}\delta_1 + AIDS_{it}^2\delta_2 + RAIN_{it}\omega_1 + RAIN_{it}^2\omega_2$$
$$+\omega_3 ASSET_{it} + \omega_4 FEM_{it} + \omega_5 SUB_{it} + AIDS_{it} * RAIN_{it}\varphi_1 + AIDS_{it} * RAIN_{it}^2\varphi_2 \quad [6]$$
$$+AIDS_{it} * ASSET_{it}\varphi_3 + AIDS_{it} * FEM_{it}\varphi_4 + AIDS_{it} * SUB_{it}\varphi_5 + T_t\theta + \lambda_i + \varepsilon_{it}$$

Modeling the dynamic relationship between HIV/AIDS and agricultural production indicators

I use two different variables to model the severity of the HIV/AIDS epidemic in a given district and year: 1) the estimated HIV prevalence rate; and 2) the estimated AIDS-related mortality rate, defined as the number of AIDS-related deaths divided by the total population. The HIV prevalence rate can be thought of as an advanced indicator of the AIDS-related mortality rate, as there is typically a lag of 8-10 years between seroconversion and death in the absence of antiretroviral treatment (Morgan et al., 2002; CGAIHS, 2000; Zaba, Whiteside and Boerma, 2004).[10] The HIV prevalence rate is the estimated percentage of the population currently living with HIV/AIDS, and I expect it to reflect the effects of HIV/AIDS-related illness and morbidity on agricultural production indicators. I expect the AIDS-related mortality rate to reflect the effects of AIDS-related deaths on such indicators.

There is often a significant time lag between seroconversion and the onset of symptomatic illness and death, as well as a lag between illness and death and the socio-

[10] HIV prevalence rates are measured without reference to when people became HIV positive. Based on epidemiological estimates that the mean period between seroconversion and death is 8-10 years, it is likely that the HIV prevalence rates are computed based on people that have been HIV positive for the mean of this period (4-5 years). Therefore, it is likely that HIV prevalence rates are an advance predictor of AIDS deaths with a lag of roughly 4-5 years.

economic impacts of the epidemic. This 'long-wave' nature of HIV/AIDS (Gillespie, 2006; Barnett and Whiteside, 2002) implies that both current and past HIV/AIDS-related morbidity and mortality may be affecting agricultural production. To model both the immediate and delayed impacts of HIV/AIDS-related illness and morbidity, I estimate models including the contemporaneous HIV prevalence rate as well as models including contemporaneous and lagged HIV prevalence. I estimate similar models using the AIDS-related mortality rate instead of HIV prevalence to test the relationships between AIDS-related deaths and agricultural production.

Including numerous lags of the HIV/AIDS variables creates potential problems with multicollinearity and degrees of freedom. To address this issue, I estimate models using a polynomial distributed (Almon) lag structure for the HIV/AIDS variables in addition to models with a traditional distributed lag structure. To identify an appropriate number of years to lag the HIV/AIDS variables (J), I follow the recommendations in Pindyck and Rubinfeld (1997) and Gujarati (2003) and add additional lags until the Akaike Information Criteria (AIC) stops declining. In the Almon lag structures, I impose a second-degree (quadratic) form on the polynomial. That is, I assume in

$\sum_{j=0}^{J} \alpha_j HIV_{it-j}$, that α_j can be approximated by $\alpha_j = a_o + a_1 j + a_2 j^2$, where HIV_{it} is the HIV prevalence rate or AIDS-related mortality rate in district i in year t, and j is the length of the lag. Substituting in for α_j, we obtain:

$$HIV_{it}^{*} = \sum_{j=0}^{J} \alpha_j HIV_{it-j} = a_0 \sum_{j=0}^{J} HIV_{it-j} + a_1 \sum_{j=0}^{J} jHIV_{it-j} + a_2 \sum_{j=0}^{J} j^2 HIV_{it-j}$$

or $HIV_{it}^{*} = a_0 Almon_{1it} + a_1 Almon_{2it} + a_2 Almon_{3it}$

where $Almon_{1it} = \sum_{j=0}^{J} HIV_{it-j}$, $Almon_{2it} = \sum_{j=0}^{J} jHIV_{it-j}$,

$Almon_{3it} = \sum_{j=0}^{J} j^2 HIV_{it-j}$

Such a lag structure allows the impact of the HIV prevalence rate in year t to grow over time to a peak (as the disease progresses and ultimately results in the death of the HIV-positive individuals reflected in that HIV prevalence rate in year t) and then for the effect to eventually diminish as the households and communities affected by that wave of illness and death eventually recover.[11] The implications of such a lag structure on the AIDS-related mortality variable are similar.

Zambia is divided into three agroecological regions (AERs): AER I covers the southern border of the country and receives less than 800 mm of rainfall per year; AER II covers western and central Zambia and receives 800 to 1,000 mm of rainfall; and AER III covers the northern part of the country and receives in excess of 1,000 mm of rainfall per annum (see Figure A1 in the Appendix for a map of the AERs in Zambia). Some districts' borders encompass parts of both AERs II and III so I define four "agrozone" categories and assign districts to each of them: districts in AER I are assigned to agrozone 1 (lowest rainfall); districts entirely in AER II are assigned to agrozone 2 (lower rainfall); districts with area in both AERs II and III are assigned to agrozone 3 (higher rainfall); and districts in AER III only are assigned to agrozone 4 (highest rainfall). The

[11] Note that this lag structure allows for any quadratic lag weight path, i.e., either concave or convex. The pattern described above is the intuitively expected result.

impacts of HIV/AIDS and other explanatory variables on agricultural production indicators may vary by agrozone. To determine if it is appropriate to pool agrozones, I conduct a series of Chow Tests. The results of the Chow Tests suggest that the impacts of HIV/AIDS and other regressors do indeed vary by agrozone, indicating that I should run separate regressions for each agrozone.

For each agrozone and dependent variable combination, I compute the AIC value for various finite distributed lag and Almon lag structures on HIV/AIDS (HIV prevalence or AIDS-related mortality rate). The 'preferred' lag structure for each model (agrozone-dependent variable combination) is that with the lowest AIC value; it is these 'preferred' models (summarized in Table A2 in the Appendix) that I estimate and analyze throughout the remainder of the thesis.

3.3 Estimation

I take advantage of the panel-nature of the data and use an estimation technique that allows us to difference out the time invariant district-level unobserved effects (λ_i). Under strict exogeneity of the explanatory variables conditional on λ_i (assumption FE.1) and the assumption that $rank[E(\ddot{X}_i'\ddot{X}_i)] = K$, where T is the number of years, K is the number of explanatory variables, and $\ddot{X}_i$ is the TxK matrix for district i of time-demeaned data on the explanatory variables in all T years (assumption FE.2), the fixed effects (FE) estimator is consistent (Wooldridge, 2002: 269). (Under these assumptions, λ_i may be correlated with the observed explanatory variables and with the idiosyncratic error term, ε_{it} .) I find evidence of heteroskedasticity and serial correlation in the ε_{it} . In this case, the fixed-effects estimator is not the most efficient estimator (ibid). Therefore, I assume that $E(\varepsilon_i \varepsilon_i' \mid x_i, \lambda_i) = \Lambda$, where Λ is a *TxT* positive definite matrix, $\varepsilon_i \equiv (\varepsilon_{i1}, \varepsilon_{i2}, ..., \varepsilon_{iT})$ and $x_i \equiv (x_{i1}, x_{i2}, ..., x_{iT})$ (assumption FEGLS.3), which relaxes the assumptions of homoskedasticity and no serial correlation (Wooldridge, 2002: 276). Under FE.1, FEGLS.3 and an additional assumption, FEGLS.2, the fixed-effects (feasible) generalized least squares (FEGLS) estimator is consistent and is the most efficient estimator (Wooldridge, 2002: 278). FEGLS.2 is the assumption that $rank[E(\breve{X}_i' \Omega^{-1} \breve{X}_i)] = K$ where $\Omega \equiv E(\breve{\varepsilon}_i \breve{\varepsilon}_i')$, $\breve{\varepsilon}_i$ is the *(T-1)x1* vector of time-demeaned errors, and $\breve{X}_i$ is the *(T-1)xK* matrix of time-demeaned data on the explanatory variables. I use the FEGLS estimator in the analysis (Wooldridge, 2002: 278).

3.4 Data

District-level indicators of agricultural production (mean household crop output, output per hectare, and cultivated area), government fertilizer subsidies, producer price indexes, and asset base indexes used in the analysis are drawn from PHS data. Median provincial fertilizer prices are based on data from the Ministry of Agriculture and Cooperatives (MACO) Agricultural Marketing Information Center. Real interest rates are from *World Development Indicators, 2005* (World Bank, 2005). Rainfall data are from 36 rainfall stations throughout Zambia. Estimates of district HIV prevalence and AIDS-related mortality rates are drawn from the report, *Zambia: HIV/AIDS Epidemiological Projections, 1985-2010* (CSO, 2005) and the Zambian population censuses from 1980, 1990, and 2000 (CSO, 1975; CSO, 1985; CSO, 1994; CSO, 2003). The *Epidemiological Projections* report includes estimates of the HIV prevalence rate and of the number of

AIDS-related deaths in each district in Zambia. The HIV prevalence estimates are based on sentinel surveillance site (ante-natal clinic) data and the projections are computed using the cohort component method. The AIDS-related deaths figures in the report are generated by a mathematical model of the relationship between HIV prevalence and AIDS-related deaths under assumptions about the life expectancy rate, fertility rate, and the percentage of pregnant women on treatment to prevent mother-to-child-transmission of HIV/AIDS (Chewe, 2006). The *Epidemiological Projections* report lists estimated HIV prevalence rates and numbers of AIDS-related deaths for each district for the years 1985, 1990, 1995, and 2000-2010; extrapolation was required to estimate the HIV prevalence and AIDS deaths in the years for which no values were reported. To control the number of AIDS deaths for population growth, I computed a variable for the "AIDS-related mortality rate", defined as the number of AIDS-related deaths divided by the total population. As with the HIV prevalence and AIDS deaths figures, some extrapolation was required to estimate population figures for the years in the intercensal periods. Summary statistics, correlation matrices and other information on the variables used in the analysis are included in the Appendix.

Given the methodology used to generate the district-level estimates of the HIV prevalence rates, AIDS-related deaths, and AIDS-related mortality rates, there are multiple sources of potential measurement error in these estimates. First, not all districts have a sentinel surveillance site; the Zambia Central Statistical Office (CSO) generated estimates of the HIV prevalence rates in districts without sentinel surveillance sites by assuming that the HIV prevalence rates in districts with similar socio-economic characteristics are the same (Chewe, 2006). In other words, CSO assumed that the HIV prevalence rate in a district without a sentinel surveillance site was the same as the HIV prevalence rate in a district with similar socio-economic characteristics that did have a sentinel surveillance site. There will clearly be measurement error in such estimates. Second, even for districts with sentinel surveillance sites, estimates of HIV prevalence in the sexually active adult population of men (aged 15-59) and women (aged 15-49) in those districts are based on the estimated HIV prevalence among pregnant women visiting antenatal clinics (sentinel surveillance sites). This can be problematic for two main reasons: (i) pregnant women who visit antenatal clinics may not be representative of all pregnant women (those who do and do not visit antenatal clinics); and (ii) HIV prevalence among pregnant women may not be a good proxy for HIV prevalence among the sexually-active adult population of men and women (WHO & UNAIDS, 2003). Third, since the AIDS-related adult death estimates are derived from the HIV prevalence estimates using a mathematical model, there will be measurement error in these estimates. Fourth, in order to estimate the AIDS-related mortality rate, population estimates had to be made for years in the intercensal period using extrapolation/interpolation – another source of measurement error. Fifth, there is also measurement error due to extrapolation/interpolation in the estimates of AIDS-related deaths and HIV prevalence for the years for which no figures were published in the *Epidemiological Projections* report (CSO, 2005). Finally, the HIV/AIDS estimates in the *Epidemiological Projections* report (CSO, 2005) are for the combined rural and urban populations of each district but the agricultural production data analyzed in this thesis is predominately for rural households.

One important result to note in the data on HIV/AIDS is the high sample correlation ($\rho = 0.90$) between the estimated district level HIV prevalence and the contemporaneous estimated AIDS-related mortality rate. Because of the lag between seroconversion and AIDS-related death, the correlation between the AIDS-related mortality rate and HIV prevalence increases as I lag HIV prevalence (see Table A8 in the Appendix for a table of these correlations). This correlation is highest ($\rho \approx 0.95$) between the AIDS-related mortality rate in year t and the HIV prevalence rate from three to five years earlier.

These relationships between HIV prevalence and lagged AIDS-related mortality are consistent with *a priori* expectations and the epidemiology of HIV/AIDS. In general, the time from seroconversion to death is 8-10 years. So, for any given HIV-positive population, on average, individuals have been living with HIV for 4-5 years. The high correlation in the Zambia data between HIV prevalence from 3-5 years ago and AIDS-related deaths today roughly corresponds with the average time period for an HIV-positive individual to die of AIDS-related causes.

CHAPTER 4: RESULTS

4.1 Independent effects of HIV/AIDS on agricultural production indicators

I estimate models of the form

$$y_{it} = \alpha + \gamma p_{y_{it-1}} + p_{x_{it}} \psi + AIDS_{it}\delta_1 + AIDS_{it}^2\delta_2 + RAIN_{it}\omega_1 + RAIN_{it}^2\omega_2 + \omega_3 ASSET_{it} + \omega_4 FEM_{it} + \omega_5 SUB_{it} + T_t\theta + \lambda_i + \varepsilon_{it} \quad [7]$$

using an appropriate AIC-minimizing lag structure on *AIDS* and $AIDS^2$ to get an initial measure of the effects of HIV/AIDS on mean household crop output, output per hectare, and cultivated area (levels and per capita). Note that in these models I exclude the interactions of HIV/AIDS with drought and other exogenous factors.

To determine the long-run partial effect of a one percentage point increase in the HIV prevalence rate or AIDS-related mortality rate on the dependent variable of interest, I take the partial derivative of equation [7] (which may include dynamics) with respect to *AIDS.* I evaluate this partial derivative at mean HIV prevalence or AIDS-related mortality and then at the 90^{th} percentile of these HIV/AIDS measures. The long-run partial effects of a one percentage point increase in HIV prevalence or the AIDS-related mortality rate on each dependent variable are reported by agrozone in Tables 1a and 1b below. The short-run partial effects of HIV/AIDS and the partial effects of HIV/AIDS at each lag are reported in tables A11 to A22 in the Appendix.[12] Because of

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[12] The short-run partial effect estimates show us the 'shape' of the Almon lag structure for each outcome variable and agrozone combination (see Table A23 in the Appendix). A priori, I expected the Almon lag estimates of the partial effects of HIV/AIDS on agricultural production outcomes to be zero, then increasingly negative, and eventually zero again as agrarian communities recover from the HIV/AIDS shock, i.e., a ∪ shape. This was the estimated shape in 10 of 31 models where the preferred lag structure was an Almon lag; the estimated shape in the other 21 Almon lag models was ∩ contrary to a priori expectations. One possibility for further research in this area would be to impose the ∪ shape rather than allowing 'the data to decide' the shape (i.e., either ∪ or ∩) and compare the long-run partial effect estimates to those reported in this chapter.

multicollinearity, these short-run effects are imprecisely measured; however, the long-run partial effects reported in Tables 1a and 1b should be more reliable. (Due to the large number of models estimated and space limitations, I report only the parameter estimates for the key variables of interest, rather than the full regression results. In the Appendix, Table A24, I include one full set of regression results that are consistent with the implications of many of the other models estimated in the analysis.)[13]

Consider first the long-run partial effect of an increase in the HIV prevalence rate on agricultural production indicators in agrozone 1, the lowest rainfall zone. When evaluated at mean HIV prevalence (17.33%), there is a negative and statistically significant long-run partial effect of HIV prevalence on all six indicators ($p<0.10$). (Refer to Tables A9 and A10 in the Appendix for summary statistics of contemporaneous and lagged HIV prevalence and AIDS-related mortality rates for each agrozone.) For four of the six agricultural production indicators, the negative impact of HIV/AIDS is more negative at high levels of HIV/AIDS relative to mean levels. The results are similar for agrozone 1 when I use the AIDS-related mortality rate instead of HIV prevalence.

[13] In general the parameter estimates on the covariates (i.e., those variables that are not interacted with HIV/AIDS) are as follows: the coefficient on lagged agricultural PPI is either positive and statistically significant ($p<0.10$), as I would expect, or not statistically different from zero. I expect the coefficients on the provincial fertilizer price and lagged national interest rate variables to be negative and significant; however, in all models but one (area cultivated in agrozone 2 with AIDS-related mortality as the HIV/AIDS measure), the estimated coefficient is either positive and significant or not statistically different from zero. These counter-intuitive findings may be because these variables are correlated with other input price variables that I was unable to include in the model due to data limitations. However, the parameter estimates on these variables are not the key results of interest in this essay – I only include the lagged PPI, lagged interest rate and fertilizer price variables in the models as controls.

Table 1a. Long-run partial effects of a one-percentage point increase in HIV prevalence on selected agricultural production indicators

Agro-zone	Evaluated at ___ HIV prevalence	Output	Output per capita	Output/ha	Output/ha per capita	Area cultivated	Area cultivated per capita
1	Mean	-11.3%	-7.3%	-1.0%	-12.4%	-3.8%	-2.3%
	(17.33%)	(2.75)**	(1.85)+	(2.64)**	(3.08)**	(2.08)*	(2.20)*
	High	-16.5%	-7.0%	-1.1%	-5.5%	-4.3%	-2.4%
	(25.00%)	(2.87)**	(1.29)	(2.24)*	(1.10)	(1.71)+	(1.36)
2	Mean	4.9%	7.4%	-0.2%	12.9%	-9.6%	8.8%
	(11.77%)	(2.40)*	(1.53)	(0.52)	(2.22)*	(2.62)**	(2.71)**
	High	4.3%	6.6%	-0.4%	8.8%	-3.8%	9.2%
	(18.78%)	(3.78)**	(1.88)+	(1.02)	(2.08)*	(1.41)	(2.69)**
3	Mean	-3.5%	-41.6%	-9.8%	-105.5%	-7.7%	-38.9%
	(8.56%)	(0.84)	(1.48)	(5.30)**	(4.02)**	(0.21)	(0.85)
	High	4.7%	-24.6%	-3.5%	-50.9%	0.3%	-8.0%
	(12.00%)	(0.54)	(1.47)	(3.52)**	(3.46)**	(0.02)	(0.45)
4	Mean	-1.1%	-3.5%	-1.0%	-10.3%	3.5%	0.8%
	(10.43%)	(0.53)	(1.51)	(3.22)**	(2.85)**	(1.22)	(0.31)
	High	5.2%	3.8%	0.5%	6.0%	-6.2%	-5.1%
	(21.03%)	(1.82)+	(1.25)	(1.99)*	(1.97)*	(2.64)**	(2.12)*

Table 1b. Long-run partial effects of a one-percentage point increase in the AIDS-related mortality rate on selected agricultural production indicators

Agro-zone	Evaluated at ___ AIDS-related mortality	Output	Output per capita	Output/ha	Output/ha per capita	Area cultivated	Area cultivated per capita
1	Mean	-11.1%	-5.5%	-1.3%	-4.2%	8.1%	10.8%
	(6.87%)	(1.99)*	(0.95)	(2.24)*	(0.88)	(2.12)*	(2.96)**
	High	-17.8%	-15.5%	-1.2%	-5.3%	-1.6%	-5.4%
	(12.34%)	(4.61)**	(4.11)**	(3.12)**	(1.38)	(0.64)	(2.10)*
2	Mean	6.1%	-1.5%	0.3%	-3.2%	18.3%	8.8%
	(3.66%)	(1.59)	(0.34)	(0.85)	(0.89)	(1.92)+	(2.25)*
	High	3.8%	-0.3%	0.0%	-2.1%	21.9%	8.8%
	(7.23%)	(1.79)+	(0.13)	(0.22)	(1.11)	(3.18)**	(2.49)*
3	Mean	-56.7%	-92.0%	9.7%	103.8%	9.7%	-5.7%
	(2.66%)	(1.20)	(1.92)+	(3.49)**	(2.82)**	(0.12)	(0.29)
	High	-56.0%	-65.0%	4.2%	57.9%	-11.2%	7.9%
	(5.07%)	(1.32)	(1.59)	(2.58)**	(3.23)**	(0.35)	(0.76)
4	Mean	-4.2%	-0.5%	-1.4%	-13.2%	14.9%	12.4%
	(4.63%)	(1.37)	(0.21)	(5.06)**	(2.56)**	(4.11)**	(3.31)**
	High	-0.4%	0.0%	-1.1%	1.9%	4.7%	5.6%
	(13.73%)	(0.15)	(0.00)	(5.27)**	(0.54)	(1.86)+	(2.14)*

Source: Author's calculations

Notes: Absolute value of z statistics in parentheses under partial effect estimates. + significant at 10%; * significant at 5%; ** significant at 1%. Mean = partial derivative with respect to HIV/AIDS evaluated at mean HIV prevalence or AIDS-related mortality for the agrozone. High = partial derivative with respect to HIV/AIDS evaluated at the 90^{th} percentile of HIV prevalence or AIDS-related mortality for the agrozone.

In agrozone 2, the next lowest rainfall zone, the picture is dramatically different. For only one of the dependent variables (area cultivated) is there a negative and statistically significant long-run partial effect of mean HIV prevalence (-9.6%, $p<0.01$); however this effect becomes less negative in magnitude and is not statistically significant ($p>0.10$) when evaluated at high HIV prevalence. I find no evidence of significant negative impacts of AIDS-related mortality on any of the six indicators. Compared to agrozone 1, the mean HIV prevalence rate in agrozone 2 is substantially lower (11.77%), which might explain why I find little evidence of a negative impact of HIV/AIDS on agricultural production in agrozone 2. The findings, in some cases, of positive long-run partial effects of HIV/AIDS in agrozone 2 (and in the other agrozones) are counterintuitive. I discuss and analyze the cases of positive long-run partial effects in further detail at the end of this section.

In agrozone 3, the second highest rainfall zone, there is no statistically significant long-run partial effect of HIV prevalence on output (levels and per capita) or area cultivated (levels and per capita). The results are similar when I use AIDS-related mortality. For output per hectare (in both levels and per capita terms), the long-run partial effect of HIV prevalence is negative and highly significant ($p<0.01$); however, the magnitude of the negative effect is less negative when evaluated at the 90^{th} percentile than it is when evaluated at the mean. (Also, the finding of a 105.5% decrease in output/ha per capita when HIV prevalence is at the 90^{th} percentile, is unreasonable as it suggests total crop failure.) On the contrary, the estimated long-run partial effects of AIDS-related mortality on output per hectare (in both levels and per capita terms) are positive and statistically significant ($p<0.01$), again with an unreasonably large estimated partial effect (103.8%) of mean AIDS-related mortality. Given these contradictions and the weak evidence of any statistically significant effect whatsoever of HIV/AIDS on output or area cultivated, I conclude that there is no robust relationship between HIV/AIDS and agricultural production indicators in agrozone 3. Of the four agrozones, zone 3 has the lowest average HIV prevalence and AIDS-related mortality rates (8.56% and 2.66%, respectively).

In agrozone 4, the highest rainfall zone, the results are also inconclusive. Neither HIV prevalence nor AIDS-related mortality has a statistically strong long-run partial effect on output or output per capita (all p-values are greater than 0.10). There is some evidence of a decline in output/ha in both levels and per capita terms when the partial effect of HIV/AIDS is evaluated at mean levels. However, the results also suggest, contrary to *a priori* expectations, that the long-run partial effect of HIV prevalence is positive and significant when evaluated at the 90th percentile. The opposite is true of the relationship between HIV prevalence and area cultivated: the long-run partial effect of mean HIV prevalence is not statistically significant ($p>0.10$) but the long-run partial effect of HIV prevalence is statistically significant ($p<0.05$) and negative when evaluated at the 90th percentile. As in agrozone 2, I find a significant positive effect of increased AIDS-related mortality on area cultivated in agrozone 4.

On balance, only in agrozone 1 do I consistently find evidence of a significant negative direct effect of HIV/AIDS on agricultural production. This agrozone is characterized by the lowest mean annual rainfall levels and the highest mean HIV prevalence and AIDS-related mortality rates of the four agrozones. This finding of a weak relationship between HIV/AIDS and agricultural production at the district level is consistent with other community and aggregate level evidence from Zambia. For HIV/AIDS impacts on cultivated area, Larson et al. (2004) find that, for the entire sample of cotton farming households in their study, an increase in prime-age (PA) deaths was associated with a decline in area cultivated of less than 1%. Similarly, Jayne et al. (2006) find a decrease of only 6% in area cultivated at the community level when adult mortality rates in Zambia increase from 0 to 24.4%; furthermore, this effect is short-lived, as it becomes statistically insignificant after 3-8 years. These studies also find weak or non-existent impacts of AIDS-related mortality on crop output: increases in PA deaths in Zambia reduce aggregate crop output by less than 1% (Larson et al., 2004) and there is no independent effect of increases in the adult mortality rate on gross value of crop output or output per hectare (Jayne et al., 2006). Likewise, despite incurring 52 AIDS related-deaths between 1993 and 2005, 35 clusters studied in Mpongwe, Zambia were able to increase maize production over the period (Drinkwater et al., 2006).

Table 2 summarizes the signs and significance levels of the long-run partial effects of HIV/AIDS on agricultural production indicators in each agrozone.

Table 2. Summary of model results by agrozone according to their estimated long-run partial effects of HIV/AIDS on selected agricultural production indicators

Agrozone	% of total model specifications according to their estimated long-run partial effect of HIV/AIDS on agricultural production indicators			
	Negative, significant at 5% level	Not statistically different from zero at the 5% level		Positive, significant at 5% level
		Negative	Positive	
1	54.2%	37.5%	0%	8.3%
2	4.2%	29.2%	29.2%	37.5%
3	33.3%	33.3%	16.7%	16.7%
4	29.2%	20.8%	29.2%	20.8%
Overall	30.2%	30.2%	18.8%	20.8%

Source: Author's calculations (based on Tables 1a and 1b)
Notes: Percentages indicate the percentage of the 24 total models estimated for each agrozone where the estimated long-run partial effect of HIV/AIDS on agricultural production indicators was negative and significant at the 5% level, positive and significant at the 5% level, and not statistically different from zero at the 5% level.

Table 2 indicates that the counterintuitive findings, in some cases, of positive and statistically significant (p<0.05) long-run partial effects of HIV/AIDS are most prevalent in agrozone 2. In each of the other agrozones, approximately 80% of the estimated long-run partial effects of HIV/AIDS on agricultural production indicators area either negative and statistically significant at the 5% level or not statistically different from zero at the 5% level (as expected *a priori*). Using a 5% significance level, we can expect to make Type I errors 5% of the time.

Disaggregating the counterintuitive positive long-run partial effects results by the agricultural production indicator (rather than by the agrozone) reveals additional insights (Table 3).

Table 3. Summary of model results by agricultural production indicator according to their estimated long-run partial effects of HIV/AIDS on selected agricultural production indicators

Agricultural production indicator	% of total model specifications according to their estimated long-run partial effect of HIV/AIDS on agricultural production indicators			
	Negative, significant at 5% level	Not statistically different from zero at the 5% level		Positive, significant at 5% level
		Negative	Positive	
Output	25.0%	37.5%	25.0%	12.5%
Output per capita	6.3%	68.8%	25.0%	0%
Output/ha	56.3%	12.5%	12.5%	18.8%
Output/ha per capita	31.3%	31.3%	6.3%	31.3%
Cultivated area	18.8%	31.3%	31.3%	18.8%
Cultivated area per capita	18.8%	25.0%	12.5%	43.8%

Source: Author's calculations (based on Tables 1a and 1b)
Notes: Percentages indicate the percentage of the 16 total models estimated for each agricultural production indicator where the estimated long-run partial effect of HIV/AIDS was negative and significant at the 5% level, positive and significant at the 5% level, and not statistically different from zero at the 5% level.

Table 3 indicates that the findings of positive and statistically significant (p<0.05) long-run partial effects of HIV/AIDS are most prevalent when the agricultural production indicator used is cultivated area per capita or output/ha per capita. In the case of cultivated area per capita, if a household member dies and the household continues to cultivate the same total area of land (and does not attract new household members), cultivated area per capita must increase, ceteris paribus. Thus, there is a plausible explanation for what initially appears to be a counterintuitive finding. In the case of output/ha per capita, a similar explanation applies. If total output/ha is held constant and the number of household members decreases due to an AIDS-related death, per capita output/ha must increase, ceteris paribus. A reduction in household size as a result of an AIDS-related death in the household is consistent with empirical evidence from Zambia. Chapoto and Jayne (2008) find that households incurring the prime-age death of a long-time resident household member other than the household head or spouse experience a reduction in household size of 2.21 members in the case of a male adult death and a reduction of 1.47 household members in the case of a female adult death.

For the other agricultural production indicators, over 80% of the estimated long-run partial effects are either negative and statistically significant at the 5% level or not statistically different from zero at the 5% level. The finding of negative and significant long-run partial effects of HIV/AIDS on output/ha at the district level in 56% of the models estimated is consistent with findings of household-level studies that suggest that prime-age male deaths (Yamano & Jayne, 2004) and male head of household deaths (Chapoto and Jayne, 2008) are associated with a decrease in production of cash (high-value) crops, and that the (HIV/AIDS-related) death of the head of household or his/her spouse adversely affects the value of crop production per hectare (Yamano & Jayne, 2004).

4.2 How HIV/AIDS affects the impacts of exogenous shocks on agricultural production indicators

In the previous section, I examined the independent impacts of HIV/AIDS on selected agricultural production indicators. This section analyzes how the impacts on agricultural production indicators of drought and other exogenous factors are affected by HIV/AIDS, namely: policy changes such as those that occurred as part of structural adjustment reforms, gender inequalities, and shocks to communities' productive asset base.

In this section I detail the estimation results from models as specified in equation [6] with an appropriate AIC-minimizing lag structure. To determine the long-run partial effect of a one unit increase in the rainfall shock, fertilizer subsidy, female-headed household, or productive asset base variables on the dependent variable of interest, I take the partial derivative of equation [6] (which may include dynamics) with respect to *RAIN*, *SUB, FEM,* or *ASSET*. I evaluate the partial derivative at mean HIV prevalence or AIDS-related mortality and then at the 90th percentile of these HIV/AIDS measures.

Evidence that HIV/AIDS exacerbates the effects of drought?

Tables 4a and 4b present the results for the partial effects of a one-percentage point increase in high (i.e., 90th percentile) negative rainfall shocks (droughts) evaluated at mean and high levels of HIV/AIDS. As in the case of the long-run partial effects of HIV/AIDS on agricultural production indicators, of all the agrozones, the results from agrozone 1 are most consistent with *a priori* expectations with respect to the impacts of negative rainfall shocks. In agrozone 1 models where I use the HIV prevalence as the measure of the severity of the HIV/AIDS epidemic in a district, I find negative and statistically significant ($p<0.10$) partial effects of negative rainfall shocks (droughts) on five of the six indicators when the partial effect is evaluated at mean HIV prevalence, and on four of the six indicators when evaluated at the 90th percentile of HIV prevalence. For crop output and output/ha, the negative impact of drought is more negative when HIV prevalence is high. This finding is consistent with the prediction of the NVF hypothesis. However, when I use the AIDS-related mortality rate instead of the HIV prevalence, there is no robust relationship between drought and the agricultural production indicators used in the analysis.

In agrozone 2, whether I use the HIV prevalence or AIDS-related mortality rate, I consistently find a statistically significant negative partial effect of drought on output and output per hectare. In HIV prevalence models, the relationship between the partial effects evaluated at mean and high HIV prevalence is consistent with NVF for three of the agricultural production indicators. In AIDS models, the magnitude of the negative impact of drought becomes more negative when evaluated at high AIDS-related mortality; however, in some cases the partial effects evaluated at the 90th percentile are imprecisely measured and are not statistically significant at the 10% level. In general, in agrozone 2 I find some support for the NVF hypothesis that HIV/AIDS exacerbates the negative impacts of drought, particularly those effects on crop output and output/ha.

In agrozone 3, output, output per capita, and cultivated area per capita are negatively impacted by drought ($p<0.10$) in both HIV prevalence and AIDS models. The negative impact of drought on output and cultivated area per capita is exacerbated by high HIV prevalence rates and AIDS-related mortality rates as predicted by the NVF hypothesis; and the negative impact of drought on output per capita is more negative at high AIDS-related mortality rate levels but not at high HIV prevalence levels. There is no robust relationship between drought and the other agricultural production indicators in both the HIV prevalence and AIDS-related mortality models. As in agrozones 1 and 2, in agrozone 3 I find some evidence to support the NVF hypothesis, but only for a subset of the agricultural production indicators examined.

In agrozone 4, the highest rainfall zone, there is little statistically significant impact of negative rainfall shocks on agricultural production indicators when I use HIV prevalence to model the HIV/AIDS epidemic. In models using the AIDS-related mortality rate instead, I find a weak negative impact of drought on crop output and cultivated area (both in levels and per capita terms) but this impact is small in magnitude (less than 2%) and only in the case of output per capita is the negative effect of drought exacerbated by AIDS-related mortality.

These results provide some support for the NVF hypothesis in agrozones 1, 2 and 3, and particularly for the effects of drought on crop output and output per hectare (both in levels and per capita terms). In many cases, the negative impact of drought is at least twice as negative when HIV/AIDS is high relative to when HIV/AIDS is held at its mean. However, NVF-like phenomena are far from universal even within these agrozones, and the results are sensitive to the HIV/AIDS variable used.

Table 4a. Partial effects of a one-percentage point increase in the negative rainfall shock on selected agricultural production indicators (evaluated at mean and high HIV prevalence)

Agro-zone	Evaluated at ___ HIV prevalence	Dependent Variable					
		Output	Output per capita	Output/ha	Output/ha per capita	Area cultivated	Area cultivated per capita
1	Mean	-1.4%	-1.0%	-0.2%	-2.4%	-0.9%	-78.6%
	(17.33%)	(2.22)*	(1.52)	(3.65)**	(3.70)**	(2.22)*	(1.77)+
	High	-2.7%	-2.1%	-0.3%	-4.3%	1.8%	-97.7%
	(25.00%)	(2.60)**	(2.17)*	(3.27)**	(4.30)**	(0.46)	(1.58)
2	Mean	-1.6%	-2.0%	-0.2%	-2.7%	0.7%	-0.3%
	(11.77%)	(2.36)*	(2.53)*	(2.67)**	(4.09)**	(1.49)	(0.58)
	High	-0.4%	-3.8%	-0.4%	-7.2%	4.3%	1.8%
	(18.78%)	(0.32)	(1.90)+	(2.81)**	(3.84)**	(3.39)**	(1.43)
3	Mean	-2.1%	-8.3%	0.1%	0.5%	-2.7%	-3.9%
	(8.56%)	(2.25)*	(6.11)**	(0.60)	(0.26)	(1.60)	(2.35)*
	High	-3.4%	-8.0%	0.5%	6.2%	-8.7%	-18.9%
	(12.00%)	(2.01)*	(1.79)+	(1.48)	(1.41)	(1.45)	(3.11)**
4	Mean	-0.5%	-0.5%	0.0%	0.0%	-0.2%	-0.3%
	(10.43%)	(1.70)+	(1.73)+	(1.07)	(0.15)	(0.57)	(0.92)
	High	0.4%	-0.2%	0.0%	-1.0%	1.1%	0.4%
	(21.03%)	(0.79)	(0.26)	(0.39)	(1.11)	(1.36)	(0.46)

Table 4b. Partial effects of a one-percentage point increase in the negative rainfall shock on selected agricultural production indicators (evaluated at mean and high AIDS-related mortality)

Agro-zone	Evaluated at ___ AIDS-related mortality	Dependent Variable					
		Output	Output per capita	Output/ha	Output/ha per capita	Area cultivated	Area cultivated per capita
1	Mean	-0.3%	-0.9%	-0.1%	-0.2%	-0.3%	-0.6%
	(6.87%)	(0.46)	(1.66)+	(1.42)	(0.26)	(0.68)	(1.52)
	High	1.1%	-0.7%	-0.1%	0.1%	-0.8%	-0.2%
	(12.34%)	(0.68)	(1.23)	(0.56)	(0.11)	(0.76)	(0.25)
2	Mean	-2.6%	-2.1%	-0.3%	-2.7%	0.4%	0.6%
	(3.66%)	(3.08)**	(2.64)**	(4.79)**	(3.56)**	(0.81)	(1.23)
	High	-3.3%	-3.1%	-0.7%	-6.9%	2.2%	2.3%
	(7.23%)	(1.62)	(1.64)	(4.17)**	(3.79)**	(1.01)	(1.06)
3	Mean	-8.7%	-16.2%	0.2%	2.2%	5.4%	-4.4%
	(2.66%)	(4.60)**	(7.46)**	(1.36)	(0.90)	(0.58)	(2.64)**
	High	-21.0%	-41.8%	0.3%	4.4%	3.3%	-10.1%
	(5.07%)	(3.63)**	(6.29)**	(0.68)	(0.91)	(0.16)	(1.90)+
4	Mean	-0.8%	-0.8%	0.0%	1.1%	-1.3%	-0.9%
	(4.63%)	(2.58)**	(2.72)**	(0.74)	(1.88)+	(2.50)*	(1.75)+
	High	-1.4%	-1.8%	0.0%	1.7%	-1.6%	-1.3%
	(13.73%)	(1.56)	(2.28)*	(0.34)	(1.49)	(1.56)	(1.20)

Source: Author's calculations

Notes: Absolute value of z statistics in parentheses under partial effect estimates. + significant at 10%; * significant at 5%; ** significant at 1%. Mean = partial derivative with respect to high negative rainfall shocks evaluated at mean HIV prevalence or AIDS-related mortality for the agrozone. High = partial derivative with respect to high negative rainfall shocks evaluated at the 90th percentile of HIV prevalence or AIDS-related mortality for the agrozone.

Evidence that HIV/AIDS exacerbates the effects of other shocks?

In much of the literature on the NVF hypothesis, de Waal suggests that HIV/AIDS may be exacerbating the effects of other shocks in addition to drought. To test this hypothesis, I consider 'other shocks' such as changes in fertilizer subsidies and communities' asset bases, and gender inequality embodied in the effect of female household headship on agricultural production indicators.

Tables 5a and 5b present the results of the simulations for the partial effects of a 1 kg/ha (4%) increase in the fertilizer subsidy per household evaluated at mean and high levels of HIV/AIDS. (Fertilizer subsidies did not have a statistically nor a practically significant effect on cultivated area or area per capita and so the *SUB* variable was dropped from these models. For this reason, no partial effects of *SUB* results are reported for cultivated area and area per capita.)

Table 5a. Partial effects of a one-kg/ha (4%) fertilizer subsidy increase on selected agricultural production indicators (evaluated at mean and high HIV prevalence)

Agro-zone	Evaluated at ___ HIV prevalence	Dependent Variable			
		Output	Output per capita	Output/ha	Output/ha per capita
1	Mean (17.33%)	0.1% (0.52)	0.0% (0.26)	0.0% (0.60)	0.0% (0.33)
	High (25.00%)	0.2% (1.49)	0.1% (0.68)	0.0% (1.53)	0.1% (0.40)
2	Mean (11.77%)	0.1% (0.72)	-0.2% (0.84)	0.0% (2.40)*	0.2% (0.98)
	High (18.78%)	0.0% (0.13)	-1.1% (2.01)*	0.1% (1.82)+	-0.3% (0.77)
3	Mean (8.56%)	0.0% (0.31)	0.5% (2.90)**	0.0% (1.03)	0.5% (2.15)*
	High (12.00%)	-0.6% (3.18)**	-0.1% (0.33)	0.0% (0.95)	0.5% (1.25)
4	Mean (10.43%)	0.5% (7.53)**	0.4% (5.47)**	0.0% (2.00)*	0.1% (0.88)
	High (21.03%)	0.3% (5.43)**	0.2% (3.30)**	0.0% (0.63)	0.1% (0.32)

Table 5b. Partial effects of a one-kg/ha (4%) fertilizer subsidy increase on selected agricultural production indicators (evaluated at mean and high AIDS-related mortality)

Agro-zone	Evaluated at ___ AIDS-related mortality	Dependent Variable			
		Output	Output per capita	Output/ha	Output/ha per capita
1	Mean (6.87%)	0.7% (0.52)	0.1% (1.18)	0.0% (1.40)	0.0% (0.14)
	High (12.34%)	0.4% (1.34)	0.0% (0.16)	0.0% (0.87)	0.0% (0.26)
2	Mean (3.66%)	-0.1% (0.56)	-0.2% (0.91)	0.0% (1.51)	0.1% (0.83)
	High (7.23%)	-0.3% (0.78)	-0.6% (1.33)	0.0% (1.41)	0.2% (0.65)
3	Mean (2.66%)	12.1% (3.73)**	16.8% (5.26)**	0.0% (0.13)	0.1% (0.36)
	High (5.07%)	-0.7% (1.34)	-0.3% (0.60)	0.0% (1.06)	-0.2% (0.51)
4	Mean (4.63%)	0.2% (1.40)	0.2% (2.13)*	0.0% (1.08)	0.0% (0.10)
	High (13.73%)	-0.6% (1.74)+	-0.4% (1.23)	0.0% (0.55)	0.1% (0.17)

Source: Author's calculations

Notes: Absolute value of z statistics in parentheses under partial effect estimates. + significant at 10%; * significant at 5%; ** significant at 1%. Mean = partial derivative with respect to fertilizer subsidy shocks evaluated at mean HIV prevalence or AIDS-related mortality for the agrozone. High = partial derivative with respect to fertilizer subsidy shocks evaluated at the 90^{th} percentile of HIV prevalence or AIDS-related mortality for the agrozone.

In agrozone 1, I find no statistically significant ($p>0.10$) partial effect of fertilizer subsidies on agricultural production indicators after controlling for other exogenous shocks. This is the case for both the HIV prevalence and AIDS-related mortality models. Similarly for agrozone 2, there is no robust relationship between fertilizer subsidies and agricultural production indicators. However, when HIV prevalence is high I do find a weak, negative impact (-1.1%, $p<0.05$) on output per capita and a practically small, positive impact on output/ha (+0.1%, $p<0.10$).

In agrozone 3 for mean HIV prevalence models, the impact of increased fertilizer subsidies is positive and statistically significant ($p<0.05$) on both output per capita and output/ha, but these partial effects are practically small (+0.5%). However, when I evaluate the partial effects at the 90th percentile of HIV prevalence, the positive partial effects of increased fertilizer subsidies are eliminated. This is in line with what I would expect under the predictions of the NVF hypothesis, but the results are quite weak. I find a similar pattern in agrozone 3 for AIDS-related mortality models. In both HIV prevalence and AIDS-related mortality models for agrozone 3, I find results that are consistent with the NVF hypothesis for two of the four agricultural production indicators.

In agrozone 4 for mean HIV prevalence models I find statistically significant ($p<0.01$) but practically small increases in output, output per capita, and output/ha associated with an increase in the fertilizer subsidy. The magnitude of the positive effect on output and output per capita is smaller when these partial effects are evaluated at the 90th percentile of HIV prevalence; in the case of output/ha, the positive partial effect is no longer statistically significant ($p>0.10$) when evaluated at high HIV prevalence. For mean AIDS-related mortality models, the partial effect of fertilizer subsidies is only statistically significant ($p<0.05$) on output per capita, and this effect is practically small (+0.2%).

Overall, increases in fertilizer subsidies have a practically small, if any, positive effect on output and output/ha (in both levels and per capita terms). In all cases but one where there is a statistically significant, positive partial effect of fertilizer subsidies at mean HIV/AIDS levels, this effect is less positive in magnitude when evaluated at high HIV/AIDS levels. This is consistent with the predictions of the NVF hypothesis, but occurs mainly in agrozones 3 and 4, and only for a subset of the agricultural production indicators analyzed.

Tables 6a and 6b present the results of the simulations for the partial effects (evaluated at mean and high levels of HIV/AIDS) of a one percentage point increase in female-headed households in a district.

Table 6a. Partial effects of a one-percentage point increase in female-headed households on selected agricultural production indicators (evaluated at mean and high HIV prevalence)

Agro-zone	Evaluated at ___ HIV prevalence	Dependent Variable					
		Output	Output per capita	Output/ha	Output/ha per capita	Cultivated area	Cultivated area per capita
1	Mean	-1.1%	-0.4%	-0.1%	-0.7%	-0.4%	-26.9%
	(17.33%)	(2.65)**	(1.02)	(2.96)**	(1.58)	(1.36)	(0.92)
	High	-0.4%	-0.1%	-0.1%	-1.0%	-1.0%	-13.5%
	(25.00%)	(0.59)	(0.10)	(1.48)	(1.79)+	(2.30)*	(0.29)
2	Mean	-0.9%	-0.1%	0.0%	0.9%	-0.5%	-0.8%
	(11.77%)	(2.44)*	(0.25)	(0.15)	(2.29)*	(2.10)*	(2.91)**
	High	0.2%	0.1%	-0.1%	-0.9%	0.4%	0.6%
	(18.78%)	(0.34)	(0.06)	(1.43)	(1.20)	(0.83)	(1.18)
3	Mean	-0.4%	1.5%	0.0%	0.6%	-0.3%	1.1%
	(8.56%)	(1.09)	(2.75)**	(1.33)	(1.32)	(0.14)	(0.51)
	High	-1.7%	0.3%	0.1%	1.9%	1.0%	1.5%
	(12.00%)	(2.33)*	(0.37)	(1.26)	(1.98)*	(0.80)	(1.23)
4	Mean	0.0%	0.5%	0.0%	0.5%	-0.7%	-0.7%
	(10.43%)	(01.4)	(1.67)+	(0.74)	(1.67)+	(1.15)	(1.20)
	High	0.4%	0.7%	0.1%	1.5%	-0.2%	0.2%
	(21.03%)	(0.75)	(0.99)	(1.77)+	(2.78)**	(0.54)	(0.55)

Table 6b. Partial effects of a one-percentage point increase in female-headed households on selected agricultural production indicators (evaluated at mean and high AIDS-related mortality)

Agro-zone	Evaluated at ___ AIDS-related mortality	Dependent Variable					
		Output	Output per capita	Output/ha	Output/ha per capita	Cultivated area	Cultivated area per capita
1	Mean	-0.3%	-0.6%	-0.1%	0.1%	-0.5%	0.3%
	(6.87%)	(0.22)	(1.70)+	(2.34)*	(0.24)	(1.79)+	(0.36)
	High	0.0%	-0.6%	0.0%	0.2%	-0.9%	-0.6%
	(12.34%)	(0.03)	(0.85)	(0.06)	(0.34)	(1.57)	(1.25)
2	Mean	-0.1%	0.3%	0.0%	0.7%	-0.6%	-0.9%
	(3.66%)	(0.23)	(0.64)	(0.52)	(1.85)+	(2.54)*	(3.58)**
	High	0.8%	1.4%	0.0%	0.2%	-1.6%	-1.8%
	(7.23%)	(1.11)	(1.76)+	(0.48)	(0.34)	(2.29)*	(2.54)*
3	Mean	12.6%	17.3%	0.0%	-0.6%	-1.8%	0.6%
	(2.66%)	(4.10)**	(5.44)**	(0.74)	(1.44)	(0.55)	(1.23)
	High	2.7%	3.8%	0.0%	-2.2%	3.8%	0.6%
	(5.07%)	(2.06)*	(3.14)**	(0.42)	(1.77)+	(0.65)	(0.54)
4	Mean	0.0%	0.6%	0.0%	0.5%	-0.2%	0.2%
	(4.63%)	(0.09)	(2.02)*	(0.58)	(2.19)*	(1.14)	(1.10)
	High	0.4%	0.6%	0.1%	0.1%	-0.5%	0.0%
	(13.73%)	(0.59)	(0.89)	(1.46)	(0.13)	(1.26)	(0.11)

Source: Author's calculations

Notes: Absolute value of z statistics in parentheses under partial effect estimates. + significant at 10%; * significant at 5%; ** significant at 1%. Mean = partial derivative with respect to female headship shocks evaluated at mean HIV prevalence or AIDS-related mortality for the agrozone. High = partial derivative with respect to female headship shocks evaluated at the 90th percentile of HIV prevalence or AIDS-related mortality for the agrozone.

In agrozone 1 for HIV prevalence models, the sign of the partial effect of a one-percentage point increase in female-headed households is consistently negative, as expected *a priori*. When evaluated at mean HIV prevalence, this negative effect is only statistically significant ($p<0.01$) on output (-1.1%) and output/ha (-0.1%). For these two agricultural production indicators, the negative effect of female headship shocks is not statistically different from zero ($p>0.10$) when evaluated at the 90^{th} percentile of HIV prevalence. This finding is contrary to what I would expect under the NVF hypothesis. For output/ha per capita and cultivated area, however, while female headship shocks don't have a significant effect when HIV prevalence is at its mean, the effect is more negative and significant ($p<0.10$) at high HIV prevalence levels, as predicted by NVF. When I model HIV/AIDS using the AIDS-related mortality rate, partial effects of female headship shocks that are negative and significant at mean AIDS-related mortality become statistically insignificant at high AIDS-related mortality rates, contrary to NVF.

In agrozone 2, I again have conflicting results with respect to the hypothesis that HIV/AIDS exacerbates the impact of female headship shocks on agricultural production indicators. In HIV prevalence models, none of the findings support this hypothesis and for three of the indicators (output, cultivated area and cultivated area per capita), the results are opposite of what NVF would predict: the negative impacts of female headship shocks are less negative at high HIV prevalence relative to mean HIV prevalence. For AIDS-related mortality models, NVF is only supported for the effects of female headship shocks on cultivated area and cultivated area per capita.

In agrozone 3, the findings are similarly weak. Although I do not find direct contradictory evidence against NVF, in only two of the twelve models (6 models each for

HIV prevalence and AIDS-related mortality) do I find evidence to support the NVF hypothesis. In the case of HIV prevalence, NVF is supported for the negative effects of female headship shocks on output, and in the case of AIDS-related mortality, NVF is supported for output/ha per capita.

In agrozone 4 there is no evidence to support the NVF hypothesis as it relates to female headship shocks and the agricultural production indicators analyzed, nor do I find evidence to unequivocally reject the NVF hypothesis in this agrozone.

Overall, there is little evidence to support the NVF prediction that the negative impacts of female headship shocks will be exacerbated by HIV/AIDS. Of the 48 simulations done, the results of only 6 of them are consistent with the predictions of the NVF hypothesis as it relates to female headship shocks.

Tables 7a and 7b present the results of the simulations for the partial effects (evaluated at mean and high levels of HIV/AIDS) of a 100,000 ZMK increase in the mean household productive asset base (or mean productive asset base per capita for models in which the dependent variable is in per capita terms). This 100,000 ZMK increase corresponds to a 10% increase for models in which the dependent variable is in levels, and to a 67% increase for models in which the dependent variable is in per capita terms.

Table 7a. Partial effects of a 100,000 ZMK productive asset base increase on selected agricultural production indicators (evaluated at mean and high HIV prevalence)

Agro-zone	Evaluated at ___ HIV prevalence	Output	Output per capita	Output/ha	Output/ha per capita	Cultivated area	Cultivated area per capita
1	Mean	0.4%	0.3%	0.1%	1.2%	0.0%	233.1%
	(17.33%)	(1.38)	(0.14)	(2.93)**	(0.65)	(0.20)	(1.62)
	High	1.5%	6.6%	0.1%	0.6%	0.4%	357.0%
	(25.00%)	(2.74)**	(2.02)*	(1.41)	(0.18)	(1.18)	(1.80)+
2	Mean	0.7%	-1.0%	0.0%	-6.0%	0.7%	-0.1%
	(11.77%)	(2.43)*	(0.48)	(1.21)	(2.87)**	(3.78)**	(0.04)
	High	0.6%	-3.1%	0.0%	-5.5%	1.0%	0.0%
	(18.78%)	(1.27)	(0.68)	(0.19)	(1.35)	(2.91)**	(0.02)
3	Mean	1.3%	23.0%	0.2%	18.9%	-0.2%	17.7%
	(8.56%)	(1.29)	(3.56)**	(2.01)*	(2.70)**	(0.06)	(2.13)*
	High	-0.5%	-3.0%	-0.1%	-21.4%	1.9%	0.8%
	(12.00%)	(0.32)	(0.29)	(0.83)	(1.76)+	(0.87)	(0.06)
4	Mean	3.5%	14.8%	0.0%	-0.1%	3.2%	13.6%
	(10.43%)	(4.00)**	(3.23)**	(0.42)	(0.02)	(4.15)**	(3.96)**
	High	2.2%	3.5%	-0.2%	-7.9%	4.1%	9.3%
	(21.03%)	(1.19)	(0.41)	(1.30)	(0.90)	(2.30)*	(1.37)

Table 7b. Partial effects of a 100,000 ZMK productive asset base increase on selected agricultural production indicators (evaluated at mean and high AIDS-related mortality)

Agro-zone	Evaluated at ___ AIDS-related mortality	Output	Output per capita	Output/ha	Output/ha per capita	Cultivated area	Cultivated area per capita
1	Mean	2.0%	-0.7%	0.1%	0.8%	-0.3%	-2.0%
	(6.87%)	(1.46)	(0.37)	(3.72)**	(0.36)	(1.15)	(1.14)
	High	1.6%	4.2%	0.1%	0.5%	0.2%	3.9%
	(12.34%)	(2.07)*	(0.85)	(3.20)**	(0.19)	(0.43)	(0.86)
2	Mean	0.7%	-0.4%	0.0%	-3.0%	0.7%	0.8%
	(3.66%)	(2.61)**	(0.18)	(0.83)	(1.75)+	(4.36)**	(0.70)
	High	0.6%	-4.7%	0.0%	-3.1%	1.2%	2.8%
	(7.23%)	(1.22)	(1.48)	(0.97)	(0.88)	(2.86)**	(0.87)
3	Mean	9.3%	-30.3%	0.0%	13.7%	2.7%	11.8%
	(2.66%)	(2.38)*	(2.20)*	(0.10)	(1.62)	(0.39)	(1.96)*
	High	-2.5%	-5.4%	0.0%	14.0%	6.3%	-29.1%
	(5.07%)	(1.43)	(0.46)	(0.07)	(0.58)	(0.62)	(2.37)*
4	Mean	2.6%	14.3%	-0.1%	6.3%	3.8%	14.9%
	(4.63%)	(2.83)**	(2.98)**	(1.97)*	(1.44)	(5.66)**	(4.60)**
	High	-3.6%	8.0%	-1.1%	2.6%	6.9%	27.9%
	(13.73%)	(1.26)	(0.72)	(4.81)**	(0.22)	(3.62)**	(2.99)**

Source: Author's calculations

Notes: Absolute value of z statistics in parentheses below partial effect estimates. + significant at 10%; * significant at 5%; ** significant at 1%. Mean = partial derivative with respect to productive asset base shocks evaluated at mean HIV prevalence or AIDS-related mortality for the agrozone. High = partial derivative with respect to productive asset base shocks evaluated at the 90th percentile of HIV prevalence or AIDS-related mortality for the agrozone.

In agrozone 1, I find little evidence for the NVF prediction that the positive effects of increases in the mean household productive asset base are reduced by HIV/AIDS. In HIV prevalence models, this NVF scenario is only observed for output/ha and I find evidence contrary to NVF for output and output per capita. I find no support for NVF in the AIDS-related mortality models and find evidence of effects contrary to the NVF prediction in the case of crop output.

In agrozone 2, the results lend very little support to the NVF hypothesis. Only for crop output do I find that the positive effects of productive asset base increases are decreased by HIV/AIDS, and these declines are minimal: from +0.7% to +0.6%. And contrary to the NVF prediction, positive productive asset base partial effects on cultivated area are more positive when HIV/AIDS is high relative to when it is at its mean.

Findings from agrozone 3 are most consistent with the predictions of the NVF hypothesis. In HIV prevalence models, for four of the six indicators (output per capita, output/ha, output/ha per capita, and cultivated area per capita), the statistically significant positive effects of productive asset base increases are less positive (and in some cases negative and significant) when the HIV prevalence is at the 90th percentile, compared to when it is held at its mean. In AIDS-related mortality models, there is less evidence of NVF-like phenomena, but I do find that high AIDS-related mortality reduces the positive partial effect of productive asset base increases on output and cultivated area per hectare.

In agrozone 4, results from the HIV prevalence models support the NVF hypothesis for output, output per capita, and cultivated area per capita, but the results from the cultivated area models contradict the predictions of NVF. Results from the AIDS-related mortality models are inconclusive.

Overall, only in agrozone 3 do I consistently find weak evidence that HIV/AIDS reduces the positive impacts of productive asset base increases, as would be expected under the NVF hypothesis. In mean household terms, the productive asset base in agrozone 3 is lower than the other three agrozones; in per capita terms, the productive asset base is the second lowest in agrozone 3 after agrozone 4). Perhaps because communities in agrozone 3 have fewer productive assets to begin with, those few assets are more important for their agricultural production but are also more vulnerable to being liquidated as HIV/AIDS puts more stress on the communities.

CHAPTER 5: CONCLUSIONS & POLICY IMPLICATIONS

The new variant famine hypothesis posits that HIV/AIDS is eroding rural livelihoods and exacerbating the impacts of drought and other shocks on agrarian communities. In southern Africa, where HIV prevalence rates are among the highest in the world and there are recurrent droughts, the NVF hypothesis has become an important framework for understanding the relationship between HIV/AIDS and food crises. The NVF hypothesis has also begun to influence the HIV/AIDS mitigation and food security policies and programs of development agencies and governments.

Despite this influence, the empirical evidence base for the NVF hypothesis is weak for several reasons. First, many of the studies cited as evidence in support of NVF are based on case studies or data collected from relatively small (and often highly afflicted) geographic areas or only for a short period of time. Second, few of the studies cited as evidence of NVF control for factors other than HIV/AIDS that affect rural livelihoods. And third, none of these studies directly tests the central tenet of NVF: that HIV/AIDS exacerbates the effects of drought. Indeed, this thesis is the first study to test the NVF hypothesis econometrically using nationally representative panel survey data from an extended period of time. Given the scarcity of development resources for HIV/AIDS mitigation and food security initiatives, it is important that such interventions be based, to the extent possible, on a solid empirical foundation. With this thesis, I aim to strengthen the evidence base concerning the NVF hypothesis specifically and the relationship between HIV/AIDS and smallholder agricultural production more generally.

In the thesis, I use nationally-representative district-level panel data from Zambia from 1991/2 to 2002/3 and econometrically estimate several supply response models to examine two main questions with the goal of 'testing' the NVF hypothesis in Zambia: (1) Is HIV/AIDS having a negative independent effect on agricultural production (a proxy for agrarian livelihoods)? And (2) Is HIV/AIDS indirectly affecting agricultural production by exacerbating the impacts of drought and other shocks?

The analysis generates a number of findings that may help evaluate the validity of the new variant famine hypothesis as an analytical framework in the context of agrarian livelihoods and food security in Zambia. First, only in agrozone 1 do I consistently find evidence of a significant negative independent effect of HIV/AIDS on mean household agricultural production at the district level. This agrozone is characterized by the lowest mean annual rainfall levels and the highest mean HIV prevalence and AIDS-related mortality rates of the four agrozones. In agrozone 1, a one-percentage point increase in the district HIV prevalence rate is estimated to result (in the long-run) in a 1% decrease in mean household crop output/ha and an 11% to 17% decrease in mean household crop output. In the other three agrozones, the estimated partial effects of HIV/AIDS on several agricultural production indicators are negative but imprecisely measured. Crop output/ha is the agricultural production indicator for which statistically significant (at the 5% level) negative partial effects of HIV/AIDS are most commonly found. This finding of a weak relationship between HIV/AIDS and agricultural production at the district level is consistent with other community and aggregate level evidence from Zambia (e.g., Larson et al., 2004; Jayne et al., 2006; and Drinkwater et al., 2006).

Second, for the key NVF prediction that HIV/AIDS exacerbates the impacts of drought on agrarian livelihoods, the results of this study lend some support to this prediction for agrozones 1, 2 and 3, particularly when the outcome variable is crop output or output per hectare (both in levels and in per capita terms). In many cases, the negative impact of drought is at least doubled when HIV/AIDS is high relative to when HIV/AIDS is held at its mean. For example, a one-percentage point increase in a negative rainfall shock in agrozone 1 results in a 1.4% decrease in crop output when the HIV prevalence rate is 17.33% (the mean), but a 2.7% decrease in crop output when the HIV prevalence rate is 25.00% (the 90th percentile). However, NVF-like phenomena are far from universal even within agrozones 1, 2 and 3, and the results are sensitive to whether the HIV prevalence rate or the AIDS-related mortality rate is used to measure the severity of the HIV/AIDS epidemic.

Third, increases in fertilizer subsidies have a practically small, if any, positive effect on output and output/ha (in both levels and per capita terms). In all cases but one where there is a statistically significant, positive partial effect of fertilizer subsidies at mean HIV/AIDS levels, this effect is less positive in magnitude when evaluated at high HIV/AIDS levels. This is consistent with the predictions of the NVF hypothesis, but occurs mainly in agrozones 3 and 4, and only for a subset of the agricultural production indicators analyzed.

Fourth, there is little evidence to support the NVF prediction that the negative impacts of female headship shocks will be exacerbated by HIV/AIDS. Of the 48 simulations done, the results of only six of them are consistent with the predictions of the NVF hypothesis as it relates to female headship shocks. While I find some evidence of negative impacts of female-household headship on agricultural production indicators (a result that is consistent with household-level studies that find a negative impact of PA male head of household deaths on agricultural production (Yamano and Jayne, 2004; Chapoto and Jayne, 2005) and widows' access to land (Chapoto et al., 2007; Mather et al., 2004)), the results do not suggest a differential impact of female household headship shocks depending on the severity of the HIV/AIDS epidemic.

And fifth, only in agrozone 3 do I consistently find weak evidence that HIV/AIDS reduces the positive impacts of productive asset base increases as would be expected under the NVF hypothesis. In mean household terms, the productive asset base in agrozone 3 is lower than the other three agrozones (although in per capita terms, the productive asset base is the second lowest in agrozone 3 after agrozone 4). Perhaps because communities in agrozone 3 have fewer productive assets to begin with, those few assets are more important for their agricultural production but are also more vulnerable to being liquidated as HIV/AIDS puts more stress on the communities.

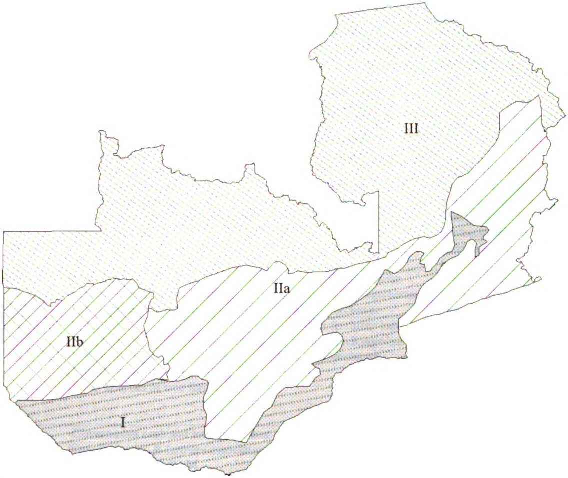
None of these findings lend unequivocal support to the NVF hypothesis in Zambia. There is some evidence that in low rainfall areas, HIV/AIDS exacerbates the effects of drought on crop output and output per hectare – a finding that is consistent with the predictions of the NVF hypothesis. The evidence is much weaker that HIV/AIDS exacerbates the impacts of other shocks on agricultural production (such as reductions in fertilizer subsidies, a rise in the percentage of households that are female-headed, and a reduction in productive farm assets). Furthermore, the results vary by agrozone, by the agricultural production outcome analyzed, and by the HIV/AIDS measure used. Thus, as is the case with household level analyses, it is important not to lump all highly afflicted districts (or agrozones) into one category and overgeneralize as to the effects of HIV/AIDS (and its interaction with other shocks) on agrarian communities.

The findings of this study suggest that efforts to target assistance toward communities that are drought-prone (have low annual rainfall) or have a weak productive asset base and are also highly AIDS-afflicted may be an important aspect of food security and HIV/AIDS mitigation programs and policies. Efforts to improve social protection and safety nets in communities whose asset bases have been eroded may also be an effective way to mitigate the impacts of the epidemic. The finding of no robust negative effect of HIV/AIDS on district level agricultural production except in the lowest rainfall areas suggests that agrarian communities may be more resilient in the face of HIV/AIDS than predicted. Therefore, it will be important for governments, donors and NGOs to continue to invest in AIDS mitigation and rural development, broadly defined, to bolster resilient livelihood strategies in HIV/AIDS-afflicted agrarian communities.

Future research to further test the NVF hypothesis as it relates to agricultural production could explore the impacts of HIV/AIDS, drought, and their interaction on the median or variance of household agricultural production at the community level. This thesis focuses on the effects of HIV/AIDS and drought on mean household agricultural production indicators, but the impacts on the median or variance may tell a different story. Furthermore, studies to assess the extent to which HIV/AIDS is exacerbating the effects of drought on aspects of agrarian livelihoods other than agricultural production, such as non-farm income; health, nutrition, and anthropometrics; and consumption/ expenditure among agrarian households, are also needed to further evaluate whether empirical evidence supports the NVF hypothesis in Zambia and other countries in southern Africa.

APPENDIX

Figure A1. Agroecological regions of Zambia



Agro-Ecological Zones & Average Annual Rainfall

- I: less than 800 mm
- IIa: 800 - 1000 mm (clay soils)
- IIb: 800 - 1000 mm (sandy soils)
- III: greater than 1000 mm

Source: Food Security Research Project, Lusaka, Zambia

Table A1. Government-subsidized and commercial/private sector channels for fertilizer acquisition by Zambian smallholders in the Post-Harvest Surveys for years 1997/8-2002/3

Crop year	Government-subsidized channels	Commercial/ private sector channels	Description of selected government subsidy programs
1997/8	-Co-op union -Credit coordinator -Fellow farmer	-NGO -Private trader -Out-growers	
1998/9	-Co-op union -Credit coordinator -Fellow farmer	-NGO -Private trader -Out-growers	
1999/2000	-Food Reserve Agency (FRA) through farmers association -Farmers association -Government agent - FRA/Omnia -Fellow farmers	-NGO -Private trader -Out-growers	-FRA: subsidized fertilizer distributed on credit to smallholders -FRA/Omnia: FRA contracts private firm Omnia to distribute fertilizer
2000/1	-FRA loan -Free government fertilizer -Other sources of free fertilizer	-Other fertilizer loan -Direct exchange/barter -Cash purchases	-FRA: subsidized fertilizer distributed on credit to smallholders
2001/2	-FRA loan -Government Food Security Pack-Programme Against Malnutrition (FSP-PAM) -Other sources of free fertilizer	-Other fertilizer loan -Direct exchange/barter -Cash purchases	-FRA: subsidized fertilizer distributed on credit to smallholders -FSP-PAM: free fertilizer (grant); targeted at relatively poor smallholders
2002/3	-Government cash and loan programs through co-ops & farmers associations -Government FSP-PAM -Other sources of free fertilizer	-Direct exchange/barter -Commercial cash purchase	-FSP-PAM: free fertilizer (grant); targeted at relatively poor smallholders

Sources: Post-Harvest Surveys, 1997/8-2002/3, Central Statistical Office, Lusaka; Jayne et al. (2002); World Bank (n.d.)

Table A2. Preferred lag structure on HIV/AIDS for each dependent variable and agrozone

HIV/AIDS measure	Agro-zone	Dependent Variable					
		Output	Output per capita	Output/ha	Output/ha per capita	Area cultivated	Area cultivated per capita
HIV	1	At-5	At-5	At-5	At-5	At-6	t only
	2	t only	At-6	At-3	At-6	At-6	At-3
	3	t only	Dt-2	At-3	At-3	At-7	At-7
	4	t only	t only	At-6	At-6	At-7	At-7
AIDS	1	At-7	At-6	At-6	t only	At-6	At-7
	2	Dt-1	Dt-1	t only	t only	At-7	At-7
	3	At-7	At-7	At-5	At-4	t only	Dt-1
	4	At-3	Dt-1	At-4	At-7	At-7	At-7

Source: Author's calculations

Notes: HIV = HIV prevalence rate; AIDS = AIDS-related mortality rate; D t-j = finite distributed lag with maximum lag length of j years; A t-j = Almon lag with maximum lag length of j years; t only = contemporaneous only.

Table A3. Agrozone 1 - Summary statistics for dependent and explanatory variables

Variable	Obs.	Mean	Std. Dev.	Min	Max	90th percentile
OUTPUT	156	1186.81	767.04	0	3976.22	2114.52
OUTPUTPC	144	196.80	117.83	0	554.94	363.95
YIELD	156	852.76	442.74	0	2190.32	1429.14
YIELDPC	144	169.62	95.35	0	490.68	285.99
AREA	156	14.69	6.63	1.70	37.25	24.56
AREAPC	144	2.59	0.93	0.39	5.60	3.80
HIV	156	17.33	7.65	3.05	34.51	25.00
AIDS	156	6.87	4.22	0.32	17.69	12.34
POS	156	11.05	16.34	0	70.13	37.75
NEG	156	9.56	13.67	0	51.63	31.95
PPI	144	11.22	6.24	4.30	48.26	19.52
FERT	156	2048.41	816.84	747.43	3708.02	3489.62
IR	156	-1.17	24.08	-48.09	25.12	21.14
SUB	144	33.51	71.89	0	594.68	86.92
FEM	156	22.34	7.32	0	42.67	31.33
ASST	144	21.80	13.17	1.66	67.59	37.97
ASPC	144	3.14	1.85	0.27	10.38	5.35

Source: Based on raw data from PHS surveys, 1991/2-2002/3, Central Statistical Office, Lusaka.

Where:

Variable	Description	Units	Level	Years
OUTPUT	Mean household crop output	'000 ZMK	District	Agric
OUTPUTPC	Mean household crop output per capita	'000 ZMK	District	Agric
YIELD	Mean household crop output per hectare	'000 ZMK/ha	District	Agric
YIELDPC	Mean household crop output per hectare per capita	'000 ZMK/ha	District	Agric
AREA	Mean household cultivated area	0.1 ha	District	Agric
AREAPC	Mean household cultivated area per capita	0.1 ha	District	Agric
HIV	Estimated HIV prevalence rate	%	District	Calen
AIDS	Estimated AIDS-related mortality rate	%	District	Calen
POS	Positive rainfall shock, deviation from 20-year district avg.	%	District	Agric
NEG	Negative rainfall shock, deviation from 20-year district avg.	%	District	Agric
PPI	Real agricultural producer price index in year t-1	'00 ZMK/kg	District	Agric
FERT	Real price of fertilizer	ZMK/kg	Provincial	Calen
IR	Real interest rate in year t-1	%	National	Calen
SUB	Mean household fertilizer subsidy	kg/ha	District	Agric
FEM	Percentage of female-headed households	%	District	Agric
ASST	Mean household productive asset base	'00,000 ZMK	District	Agric
ASPC	Mean household productive asset base per capita	'00,000 ZMK	District	Agric

Notes: Agric=Agricultural years (October through September) 1991/2-2002/3; Calen=Calendar years 1991-2002.

Table A4. Agrozone 2 - Summary statistics for dependent and explanatory variables

Variable	Obs.	Mean	Std. Dev.	Min	Max	90th percentile
OUTPUT	130	1686.57	814.93	331.25	3876.07	2720.91
OUTPUTPC	120	305.11	130.43	48.40	634.87	484.89
YIELD	130	1030.35	347.45	150.34	1938.95	1494.18
YIELDPC	120	228.03	75.01	27.41	404.49	335.36
AREA	130	15.98	4.53	6.43	29.40	22.22
AREAPC	120	3.16	0.78	1.39	5.54	4.17
HIV	130	11.77	5.01	3.21	23.10	18.78
AIDS	130	3.66	2.43	0.36	11.76	7.23
POS	130	10.68	15.48	0	79.73	34.68
NEG	130	8.64	11.46	0	45.88	27.03
PPI	120	12.90	5.15	4.27	37.35	20.73
FERT	130	2100.57	809.15	747.43	3708.02	3489.62
IR	130	-1.17	24.10	-48.09	25.12	21.14
SUB	120	23.79	34.87	0.00	167.24	69.53
FEM	130	24.83	6.70	12.35	40.74	34.84
ASST	120	17.15	10.62	4.33	69.41	29.60
ASPC	120	2.66	1.33	0.66	7.43	4.51

Source: Based on raw data from PHS surveys, 1991/2-2002/3, Central Statistical Office, Lusaka.

Table A5. Agrozone 3 - Summary statistics for dependent and explanatory variables

Variable	Obs.	Mean	Std. Dev.	Min	Max	90th percentile
OUTPUT	91	1201.14	589.04	316.90	3574.74	1790.47
OUTPUTPC	84	242.40	108.01	79.85	553.09	355.42
YIELD	91	1064.35	334.66	354.00	1895.76	1428.07
YIELDPC	84	241.39	76.73	80.04	461.84	327.12
AREA	91	11.45	3.44	5.10	22.24	15.29
AREAPC	84	2.41	0.69	1.35	4.87	3.20
HIV	91	8.56	2.81	2.23	13.00	12.00
AIDS	91	2.66	1.72	0.24	7.13	5.07
POS	91	6.89	10.78	0	36.70	24.73
NEG	91	8.24	11.40	0	64.10	25.23
PPI	84	11.32	4.52	6.30	26.28	18.49
FERT	91	2120.43	804.51	747.43	3777.15	3489.62
IR	91	-1.17	24.14	-48.09	25.12	21.14
SUB	84	33.55	51.96	0	187.34	129.59
FEM	91	27.65	8.02	12.15	55.08	38.89
ASST	84	4.24	4.81	0	21.01	12.66
ASPC	84	0.70	0.82	0	3.79	1.92

Source: Based on raw data from PHS surveys, 1991/2-2002/3, Central Statistical Office, Lusaka.

Table A6. Agrozone 4 - Summary statistics for dependent and explanatory variables

Variable	Obs.	Mean	Std. Dev.	Min	Max	90th percentile
OUTPUT	299	1254.11	537.33	222.46	3585.52	2008.50
OUTPUTPC	276	254.83	108.72	49.35	681.32	399.00
YIELD	299	1139.22	428.98	446.75	4533.39	1618.33
YIELDPC	276	258.96	103.31	86.73	1071.70	368.38
AREA	299	11.88	4.04	2.92	30.38	17.31
AREAPC	276	2.51	0.79	0.57	5.44	3.55
HIV	299	10.43	7.27	1.53	29.53	21.03
AIDS	299	4.63	5.09	0.14	21.05	13.73
POS	299	2.45	5.70	0	30.74	9.84
NEG	299	10.87	10.64	0	42.38	24.71
PPI	276	12.21	4.83	5.16	29.94	19.25
FERT	299	2166.43	787.14	747.43	3777.15	3489.62
IR	299	-1.17	24.04	-48.09	25.12	21.14
SUB	276	21.03	35.64	0	424.58	59.71
FEM	299	20.77	6.95	0	46.15	29.00
ASST	276	2.69	3.19	0	17.42	6.86
ASPC	276	0.49	0.58	0	3.16	1.35

Source: Based on raw data from PHS surveys, 1991/2-2002/3, Central Statistical Office, Lusaka.

Table A7. Correlation matrix of explanatory variables (data from all agrozones pooled)

	HIV	AIDS	POS	NEG	PPI	FERT	IR	SUB	FEM	ASST	ASPC
HIV	1.00										
AIDS	0.90	1.00									
POS	0.05	0.02	1.00								
NEG	0.05	0.05	-0.46	1.00							
PPI	-0.18	-0.23	-0.12	0.03	1.00						
FERT	-0.18	-0.28	-0.06	-0.13	0.48	1.00					
IR	0.23	0.29	0.13	-0.18	-0.71	-0.34	1.00				
SUB	0.04	-0.05	-0.07	0.05	0.39	0.23	-0.42	1.00			
FEM	-0.22	-0.24	0.17	-0.08	-0.10	0.00	0.03	-0.21	1.00		
ASST	0.16	0.06	0.16	0.06	0.04	0.00	-0.08	0.06	0.00	1.00	
ASPC	0.13	0.03	0.18	0.02	0.03	0.02	-0.08	0.02	0.06	0.96	1.00

Source: Author's calculations

Table A8. Correlation between HIV prevalence and AIDS-related mortality (all agrozones)

HIV prevalence in year	Correlation with AIDS-related mortality	AIDS-related mortality in year	Correlation with HIV prevalence
t-1	0.923	t-1	0.879
t-2	0.938	t-2	0.854
t-3	0.948	t-3	0.827
t-4	0.952	t-4	0.797
t-5	0.950	t-5	0.765
t-6	0.939	t-6	0.728
t-7	0.920	t-7	0.701

Source: Based on raw data from *Zambia: HIV/AIDS Epidemiological Projections: 1985-2010* (CSO, 2005) and Zambian population census data (CSO, 1975; CSO, 1985; CSO, 1994; CSO, 2003).

Table A9. Mean and 90th Percentile of HIV prevalence by agrozone and lag

Lag	Zone 1 Mean	Zone 1 90th	Zone 2 Mean	Zone 2 90th	Zone 3 Mean	Zone 3 90th	Zone 4 Mean	Zone 4 90th
t	17.33	25.00	11.77	18.78	8.56	12.00	10.43	21.03
t-1	16.85	25.00	10.96	18.73	7.93	12.00	9.92	21.03
t-2	16.27	24.98	10.08	18.46	7.25	11.73	9.35	20.90
t-3	15.55	24.78	9.13	17.76	6.51	11.28	8.69	20.80
t-4	14.72	24.38	8.11	16.81	5.73	10.37	7.95	20.80
t-5	13.77	23.28	7.08	15.35	4.94	9.86	7.12	19.90
t-6	12.71	21.83	6.06	14.00	4.18	9.10	6.23	18.40
t-7	12.22	21.45	5.47	12.22	3.72	8.35	5.79	17.01

Source: Based on raw data from *Zambia: HIV/AIDS Epidemiological Projections: 1985-2010* (CSO, 2005).

Table A10. Mean and 90th Percentile of AIDS-related mortality by agrozone and lag

Lag	Zone 1 Mean	Zone 1 90th	Zone 2 Mean	Zone 2 90th	Zone 3 Mean	Zone 3 90th	Zone 4 Mean	Zone 4 90th
t	6.87	12.34	3.66	7.23	2.66	5.07	4.63	13.73
t-1	6.42	12.09	3.21	6.56	2.31	4.72	4.19	12.85
t-2	5.92	11.77	2.78	5.78	1.96	4.34	3.73	11.75
t-3	5.40	11.25	2.36	5.06	1.64	3.64	3.25	10.37
t-4	4.86	10.60	1.97	4.24	1.34	3.19	2.79	8.83
t-5	4.32	9.78	1.62	3.62	1.07	2.74	2.35	7.24
t-6	3.78	8.92	1.31	3.12	0.84	2.22	1.93	5.74
t-7	3.49	8.52	1.11	2.73	0.70	1.77	1.68	5.51

Source: Based on raw data from *Zambia: HIV/AIDS Epidemiological Projections: 1985-2010* (CSO, 2005) and Zambian population census data (CSO, 1975; CSO, 1985; CSO, 1994; CSO, 2003).

Table A11. Short-run partial effects of a one-percentage point increase in HIV prevalence on crop output ('000 ZMK)

	Zone 1 At-5	Zone 1 At-5	Zone 2 t only	Zone 2 t only	Zone 3 t only	Zone 3 t only	Zone 4 t only	Zone 4 t only
Evaluated at HIV prev.	Mean	High	Mean	High	Mean	High	Mean	High
$\partial y/\partial HIV_t$	-346.575	-469.407	82.462	73.222	-42.607	55.989	-14.396	64.832
	(2.76)**	(3.04)**	(2.40)*	(3.78)**	(0.84)	(0.54)	(0.53)	(1.82)+
$\partial y/\partial HIV_{t-1}$	17.355	2.427						
	(0.98)	(0.11)						
$\partial y/\partial HIV_{t-2}$	197.971	250.794						
	(2.91)**	(3.04)**						
$\partial y/\partial HIV_{t-3}$	203.536	274.367						
	(2.76)**	(3.04)**						
$\partial y/\partial HIV_{t-4}$	47.044	75.992						
	(1.84)+	(2.50)*						
$\partial y/\partial HIV_{t-5}$	-254.230	-329.998						
	(2.92)**	(3.21)**						
$\partial y/\partial HIV_{t-6}$								
$\partial y/\partial HIV_{t-7}$								
$\partial y/\partial HIV$ (long-run effect)	-134.418	-195.825	82.462	73.222	-42.607	55.989	-14.396	64.832
	(2.75)**	(2.87)**	(2.40)*	(3.78)**	(0.84)	(0.54)	(0.53)	(1.82)+

Source: Author's calculations

Notes: Zone refers to agrozone. High=90th percentile. Absolute value of z statistics in parentheses. + significant at 10%; * significant at 5%; ** significant at 1%. HIV = HIV prevalence rate; At-j = Almon lag with maximum lag length of j years; t only = contemporaneous only.

Table A12. Short-run partial effects of a one-percentage point increase in HIV prevalence on crop output per capita ('000 ZMK/capita)

	Zone 1 At-5	Zone 1 At-5	Zone 2 At-6	Zone 2 At-6	Zone 3 Dt-2	Zone 3 Dt-2	Zone 4 t only	Zone 4 t only
Evaluated at ___ HIV prev.	Mean	High	Mean	High	Mean	High	Mean	High
$\partial y/\partial HIV_t$	-40.692	-53.214	58.084	-1.696	-1168.392	-721.447	-8.869	9.679
	(2.04)*	(2.18)*	(1.84)+	(0.06)	(3.79)**	(2.42)*	(1.51)	(1.25)
$\partial y/\partial HIV_{t-1}$	6.993	7.804	27.787	22.278	1789.529	920.347		
	(2.42)*	(2.13)*	(4.58)**	(4.21)**	(3.31)**	(1.58)		
$\partial y/\partial HIV_{t-2}$	29.388	38.243	-3.101	30.869	-722.046	-258.428		
	(2.68)**	(2.88)**	(0.20)	(2.26)*	(2.08)*	(0.71)		
$\partial y/\partial HIV_{t-3}$	27.591	37.916	-27.511	22.198				
	(2.34)*	(2.63)**	(1.24)	(1.17)				
$\partial y/\partial HIV_{t-4}$	3.331	7.250	-37.092	1.276				
	(0.82)	(1.51)	(2.10)*	(0.09)				
$\partial y/\partial HIV_{t-5}$	-41.116	-51.788	-22.207	-22.174				
	(2.91)**	(3.13)**	(4.09)**	(4.75)**				
$\partial y/\partial HIV_{t-6}$			26.572	-32.649				
			(0.78)	(1.27)				
$\partial y/\partial HIV_{t-7}$								
$\partial y/\partial HIV$ (long-run effect)	-14.455	-13.789	22.532	20.100	-100.908	-59.529	-8.869	9.679
	(1.85)+	(1.29)	(1.53)	(1.88)+	(1.48)	(1.47)	(1.51)	(1.25)

Source: Author's calculations

Notes: Zone refers to agrozone. High=90th percentile. Absolute value of z statistics in parentheses. + significant at 10%; * significant at 5%; ** significant at 1%. HIV = HIV prevalence rate; Dt-j = finite distributed lag with maximum lag length of j years; At-j = Almon lag with maximum lag length of j years; t only = contemporaneous only.

Table A13. Short-run partial effects of a one-percentage point increase in HIV prevalence on crop output per hectare ('000 ZMK/ha)

	Zone 1 At-5	Zone 1 At-5	Zone 2 At-3	Zone 2 At-3	Zone 3 At-3	Zone 3 At-3	Zone 4 At-6	Zone 4 At-6
Evaluated at ___ HIV prev.	Mean	High	Mean	High	Mean	High	Mean	High
$\partial y/\partial HIV_t$	-20.058	-18.183	-37.765	-19.726	-197.603	-171.920	-9.759	9.969
	(2.61)**	(1.97)*	(1.38)	(0.65)	(3.06)**	(2.76)**	(2.09)*	(2.53)*
$\partial y/\partial HIV_{t-1}$	.850	-.369	22.880	-1.006	189.255	216.772	-2.146	3.707
	(0.73)	(0.26)	(1.13)	(0.04)	(3.37)**	(3.00)**	(1.92)+	(2.84)**
$\partial y/\partial HIV_{t-2}$	11.967	9.126	33.587	9.599	166.233	184.150	3.301	-.506
	(2.95)**	(1.84)+	(1.52)	(0.35)	(3.02)**	(2.99)**	(1.83)+	(0.33)
$\partial y/\partial HIV_{t-3}$	12.980	10.345	-21.156	6.530	-262.051	-265.955	5.940	-2.638
	(2.92)**	(1.91)+	(1.05)	(0.24)	(3.79)**	(3.18)**	(2.15)*	(1.24)
$\partial y/\partial HIV_{t-4}$	3.400	3.137					4.919	-2.906
	(2.11)*	(1.69)+					(2.17)*	(1.69)+
$\partial y/\partial HIV_{t-5}$	-17.403	-13.139					-.844	-1.251
	(3.39)**	(2.13)*					(1.01)	(1.98)*
$\partial y/\partial HIV_{t-6}$							-12.666	-.213
							(2.97)**	(0.08)
$\partial y/\partial HIV_{t-7}$								
$\partial y/\partial HIV$ (long-run effect)	-8.273	-9.082	-2.454	-4.603	-104.166	-36.952	-11.255	6.163
	(2.64)**	(2.24)*	(0.52)	(1.02)	(5.30)**	(3.52)**	(3.22)**	(1.99)*

Source: Author's calculations

Notes: Zone refers to agrozone. High=90th percentile. Absolute value of z statistics in parentheses. + significant at 10%; * significant at 5%; ** significant at 1%. HIV = HIV prevalence rate; At-j = Almon lag with maximum lag length of j years.

Table A14. Short-run partial effects of a one-percentage point increase in HIV prevalence on crop output per hectare per capita ('000 ZMK/ha per capita)

	Zone 1	Zone 1	Zone 2	Zone 2	Zone 3	Zone 3	Zone 4	Zone 4
	At-5	At-5	At-6	At-6	At-3	At-3	At-6	At-6
Evaluated at ___ HIV prev.	Mean	High	Mean	High	Mean	High	Mean	High
$\partial y/\partial HIV_t$	-53.246	-34.834	69.125	27.155	-663.542	-487.393	-12.734	26.739
	(3.24)**	(1.82)+	(2.46)*	(1.15)	(3.12)**	(2.31)*	(1.00)	(2.74)**
$\partial y/\partial HIV_{t-1}$	5.479	5.987	17.174	11.864	444.694	414.961	-3.905	9.945
	(2.18)*	(1.97)*	(2.88)**	(2.32)*	(2.47)*	(1.75)+	(1.26)	(2.94)**
$\partial y/\partial HIV_{t-2}$	36.471	26.333	-21.837	-.381	513.731	427.070	2.785	-1.517
	(4.16)**	(2.51)*	(1.69)+	(0.03)	(2.89)**	(2.08)*	(0.54)	(0.37)
$\partial y/\partial HIV_{t-3}$	38.213	26.416	-43.150	-10.839	-549.583	-477.599	6.193	-7.532
	(4.00)**	(2.32)*	(2.24)*	(0.68)	(2.53)*	(1.76)+	(0.81)	(1.38)
$\partial y/\partial HIV_{t-4}$	8.343	5.636	-41.143	-16.194			4.815	-8.499
	(2.44)*	(1.48)	(2.59)**	(1.31)			(0.78)	(1.94)+
$\partial y/\partial HIV_{t-5}$	-56.255	-38.85	-9.331	-9.900			-3.276	-4.307
	(4.96)**	(2.95)**	(1.87)+	(2.08)*			(1.39)	(2.69)**
$\partial y/\partial HIV_{t-6}$			58.637	18.419			-20.424	.666
			(2.01)*	(0.84)			(1.69)+	(0.09)
$\partial y/\partial HIV_{t-7}$								
$\partial y/\partial HIV$ (long-run effect)	-21.067	-9.317	29.473	20.122	-254.701	-122.961	-26.547	15.495
	(3.08)**	(1.10)	(2.22)*	(2.08)*	(4.02)**	(3.46)**	(2.85)**	(1.97)*

Source: Author's calculations

Notes: Zone refers to agrozone. High=90th percentile. Absolute value of z statistics in parentheses. + significant at 10%; * significant at 5%; ** significant at 1%. HIV = HIV prevalence rate; At-j = Almon lag with maximum lag length of j years; t only = contemporaneous only.

Table A15. Short-run partial effects of a one-percentage point increase in HIV prevalence on cultivated area (0.1 ha)

	Zone 1 At-6	Zone 1 At-6	Zone 2 At-6	Zone 2 At-6	Zone 3 At-7	Zone 3 At-7	Zone 4 At-7	Zone 4 At-7
Evaluated at ___ HIV prev.	Mean	High	Mean	High	Mean	High	Mean	High
$\partial y/\partial HIV_t$	-1.014	-1.878	-2.938	-2.972	-.361	-3.017	.650	-.377
	(1.99)*	(2.81)**	(2.34)*	(2.81)**	(0.08)	(0.92)	(1.84)+	(1.30)
$\partial y/\partial HIV_{t-1}$	.111	-.0635	.198	.290	1.675	.649	.127	-.236
	(0.85)	(0.39)	(0.71)	(1.22)	(0.82)	(0.35)	(1.02)	(1.96)*
$\partial y/\partial HIV_{t-2}$	.695	1.015	1.981	2.170	2.371	2.896	-.261	-.132
	(3.18)**	(3.37)**	(3.48)**	(3.90)**	(2.50)*	(1.88)+	(3.16)**	(1.47)
$\partial y/\partial HIV_{t-3}$	.777	1.347	2.425	2.661	1.976	3.577	-.487	-.0677
	(2.62)**	(3.27)**	(2.84)**	(3.66)**	(1.00)	(2.18)*	(2.92)**	(0.50)
$\partial y/\partial HIV_{t-4}$	.420	.938	1.546	1.774	.795	2.664	-.517	-.0331
	(1.82)+	(3.00)**	(2.17)*	(3.22)**	(0.30)	(1.56)	(2.79)**	(0.23)
$\partial y/\partial HIV_{t-5}$	-.291	-.175	-.636	-.478	-.819	.751	-.308	-.0473
	(2.99)**	(1.90)+	(2.68)**	(2.09)*	(0.32)	(0.43)	(2.44)*	(0.50)
$\partial y/\partial HIV_{t-6}$	-1.249	-1.816	-4.103	-4.055	-2.502	-2.085	.196	-.0139
	(3.16)**	(3.60)**	(3.19)**	(4.05)**	(1.35)	(1.03)	(2.46)*	(0.27)
$\partial y/\partial HIV_{t-7}$					-4.010	-5.404	1.018	.173
					(1.14)	(1.71)+	(3.24)**	(0.84)
$\partial y/\partial HIV$ (long-run effect)	-.551	-.632	-1.527	-.610	-.876	.0307	.419	-.733
	(2.08)*	(1.71)+	(2.62)**	(1.41)	(0.21)	(0.02)	(1.22)	(2.64)**

Source: Author's calculations

Notes: Zone refers to agrozone. High=90th percentile. Absolute value of z statistics in parentheses. + significant at 10%; * significant at 5%; ** significant at 1%.
HIV = HIV prevalence rate; At-j = Almon lag with maximum lag length of j years.

Table A16. Short-run partial effects of a one-percentage point increase in HIV prevalence on cultivated area per capita (0.1 ha/capita)

	Zone 1 t only	Zone 1 t only	Zone 2 At-3	Zone 2 At-3	Zone 3 At-7	Zone 3 At-7	Zone 4 At-7	Zone 4 At-7
Evaluated at ___ HIV prev.	Mean	High	Mean	High	Mean	High	Mean	High
$\partial y/\partial HIV_t$	-.0590	-.0623	1.763	.436	-.237	-1.003	.169	-.0279
	(2.20)*	(1.36)	(2.54)*	(0.52)	(0.20)	(1.14)	(2.56)*	(0.46)
$\partial y/\partial HIV_{t-1}$			-.924	.433	.589	.324	.0355	-.0252
			(1.68)+	(0.59)	(1.06)	(0.64)	(1.52)	(0.98)
$\partial y/\partial HIV_{t-2}$			-1.511	-.0105	.912	1.121	-.0632	-.0237
			(2.63)**	(0.01)	(3.64)**	(2.67)**	(3.62)**	(1.23)
$\partial y/\partial HIV_{t-3}$			.950	-.568	.805	1.346	-.122	-.0238
			(1.75)+	(0.78)	(1.50)	(3.09)**	(3.74)**	(0.85)
$\partial y/\partial HIV_{t-4}$					.361	.986	-.134	-.0233
					(0.49)	(2.17)*	(3.76)**	(0.81)
$\partial y/\partial HIV_{t-5}$					-.313	.230	-.0901	-.0270
					(0.44)	(0.49)	(3.76)**	(1.41)
$\partial y/\partial HIV_{t-6}$					-1.108	-.907	.0213	-.0145
					(2.16)*	(1.62)	(1.22)	(1.28)
$\partial y/\partial HIV_{t-7}$					-1.946	-2.290	.205	.0366
					(2.03)*	(2.65)**	(3.25)**	(0.88)
$\partial y/\partial HIV$ (long-run effect)	-.0590	-.0623	.278	.290	-.938	-.193	.0209	-.129
	(2.20)*	(1.36)	(2.71)**	(2.69)**	(0.85)	(0.45)	(0.31)	(2.12)*

Source: Author's calculations

Notes: Zone refers to agrozone. High=90th percentile. Absolute value of z statistics in parentheses. + significant at 10%; * significant at 5%; ** significant at 1%. HIV = HIV prevalence rate; At-j = Almon lag with maximum lag length of j years; t only = contemporaneous only.

Table A17. Short-run partial effects of a one-percentage point increase in the AIDS-related mortality rate on crop output ('000 ZMK)

	Zone 1 At-7	Zone 1 At-7	Zone 2 Dt-1	Zone 2 Dt-1	Zone 3 At-7	Zone 3 At-7	Zone 4 At-3	Zone 4 At-3
Evaluated at ___ AIDS deaths	Mean	High	Mean	High	Mean	High	Mean	High
$\partial y/\partial AIDS_t$	-409.217	-642.544	933.389	802.307	-1455.360	-1520.646	-781.013	-179.926
	(3.28)**	(5.32)**	(2.20)*	(2.54)*	(3.27)**	(2.75)**	(3.08)**	(1.02)
$\partial y/\partial AIDS_{t-1}$	-60.522	-148.842	-830.668	-737.764	33.303	-198.847	801.503	230.627
	(1.91)+	(3.79)**	(1.85)+	(2.23)*	(0.26)	(1.02)	(3.74)**	(1.22)
$\partial y/\partial AIDS_{t-2}$	156.809	178.723			1026.637	737.978	824.477	316.744
	(3.55)**	(4.73)**			(3.58)**	(1.92)+	(3.46)**	(2.06)*
$\partial y/\partial AIDS_{t-3}$	251.972	341.550			1475.090	1271.162	-897.976	-371.869
	(3.06)**	(5.29)**			(3.45)**	(3.12)**	(3.70)**	(1.94)+
$\partial y/\partial AIDS_{t-4}$	236.372	346.136			1338.275	1267.305		
	(2.67)**	(5.02)**			(3.14)**	(3.52)**		
$\partial y/\partial AIDS_{t-5}$	122.652	205.514			580.853	696.950		
	(2.14)*	(4.14)**			(2.32)*	(2.25)*		
$\partial y/\partial AIDS_{t-6}$	-76.626	-58.771			-821.117	-515.198		
	(2.56)**	(2.50)*			(2.88)**	(1.40)		
$\partial y/\partial AIDS_{t-7}$	-352.890	-433.297			-2859.024	-2411.634		
	(2.43)**	(4.92)**			(3.08)**	(3.33)**		
$\partial y/\partial AIDS$ (long-run effect)	-131.451	-211.530	102.721	64.543	-681.343	-672.929	-53.009	-4.425
	(1.99)*	(4.61)**	(1.59)	(1.79)+	(1.20)	(1.32)	(1.37)	(0.15)

Source: Author's calculations

Notes: Zone refers to agrozone. High=90th percentile. Absolute value of z statistics in parentheses. + significant at 10%; * significant at 5%; ** significant at 1%. AIDS = AIDS-related mortality rate; Dt-j = finite distributed lag with maximum lag length of j years; At-j = Almon lag with maximum lag length of j years.

Table A18. Short-run partial effects of a one-percentage point increase in the AIDS-related mortality rate on crop output per capita ('000 ZMK/capita)

	Zone 1 At-6	Zone 1 At-6	Zone 2 Dt-1	Zone 2 Dt-1	Zone 3 At-7	Zone 3 At-7	Zone 4 Dt-1	Zone 4 Dt-1
Evaluated at AIDS deaths	Mean	High	Mean	High	Mean	High	Mean	High
$\partial y/\partial AIDS_t$	-63.412	-115.950	152.428	179.276	-247.866	-261.868	-79.281	-16.302
	(2.49)*	(4.90)**	(1.81)+	(2.69)**	(2.42)*	(2.28)*	(1.53)	(0.39)
$\partial y/\partial AIDS_{t-1}$	-3.641	-13.904	-157.134	-180.239	30.842	-30.837	77.934	16.324
	(0.89)	(2.38)*	(1.69)+	(2.53)*	(1.11)	(0.71)	(1.56)	(0.45)
$\partial y/\partial AIDS_{t-2}$	28.568	46.675			217.236	140.362		
	(2.21)*	(4.51)**			(3.41)**	(1.85)+		
$\partial y/\partial AIDS_{t-3}$	36.969	66.866			296.809	244.947		
	(1.94)+	(4.57)**			(3.01)**	(2.89)**		
$\partial y/\partial AIDS_{t-4}$	25.948	50.265			257.647	245.647		
	(1.67)+	(4.10)**			(2.60)**	(2.98)**		
$\partial y/\partial AIDS_{t-5}$	.248	2.828			89.406	132.884		
	(0.06)	(0.57)			(1.55)	(1.83)+		
$\partial y/\partial AIDS_{t-6}$	-35.450	-67.220			-214.860	-116.009		
	(1.25)	(3.88)**			(3.44)**	(1.61)		
$\partial y/\partial AIDS_{t-7}$					-652.187	-512.762		
					(3.06)**	(3.39)**		
$\partial y/\partial AIDS$ (long-run effect)	-10.770	-30.442	-4.705	-.963	-222.9731	-157.638	-1.347	.0218
	(0.95)	(4.11)**	(0.34)	(0.13)	(1.92)+	(1.59)	(0.21)	(0.00)

Source: Author's calculations

Notes: Zone refers to agrozone. High=90th percentile. Absolute value of z statistics in parentheses. + significant at 10%; * significant at 5%; ** significant at 1%. AIDS = AIDS-related mortality rate; Dt-j = finite distributed lag with maximum lag length of j years; At-j = Almon lag with maximum lag length of j years.

Table A19. Short-run partial effects of a one-percentage point increase in the AIDS-related mortality rate on crop output per hectare ('000 ZMK/ha)

	Zone 1 At-6	Zone 1 At-6	Zone 2 t only	Zone 2 t only	Zone 3 At-5	Zone 3 At-5	Zone 4 At-4	Zone 4 At-4
Evaluated at ___ AIDS deaths	Mean	High	Mean	High	Mean	High	Mean	High
$\partial y/\partial AIDS_t$	-26.535	-41.913	2.597	.348	58.259	17.852	-55.266	-46.431
	(2.52)*	(4.10)**	(0.85)	(0.22)	(1.17)	(0.45)	(4.44)**	(5.32)**
$\partial y/\partial AIDS_{t-1}$	-.242	-6.570			-29.548	-13.455	28.130	17.664
	(0.14)	(2.54)*			(2.39)*	(0.55)	(6.69)**	(3.67)**
$\partial y/\partial AIDS_{t-2}$	14.682	15.412			-74.835	-37.523	55.440	42.779
	(2.76)**	(3.44)**			(1.68)+	(1.07)	(5.33)**	(6.00)**
$\partial y/\partial AIDS_{t-3}$	18.759	24.090			-62.128	-41.664	24.189	23.196
	(2.37)*	(3.86)**			(1.22)	(1.34)	(3.83)**	(5.71)**
$\partial y/\partial AIDS_{t-4}$	12.651	19.788			22.043	4.179	-68.189	-49.411
	(1.95)+	(3.80)**			(1.18)	(0.16)	(6.27)**	(6.74)**
$\partial y/\partial AIDS_{t-5}$	-2.904	3.217			189.047	115.586		
	(1.76)+	(1.45)			(2.35)*	(2.63)**		
$\partial y/\partial AIDS_{t-6}$	-27.168	-24.371						
	(2.32)*	(3.46)**						
$\partial y/\partial AIDS_{t-7}$								
$\partial y/\partial AIDS$ (long-run effect)	-10.758	-10.347	2.597	.348	102.838	44.975	-15.695	-12.203
	(2.24)*	(3.12)**	(0.85)	(0.22)	(3.49)**	(2.58)**	(5.06)**	(5.27)**

Source: Author's calculations

Notes: Zone refers to agrozone. High=90th percentile. Absolute value of z statistics in parentheses. + significant at 10%; * significant at 5%; ** significant at 1%. AIDS = AIDS-related mortality rate; At-j = Almon lag with maximum lag length of j years; t only = contemporaneous only.

Table A20. Short-run partial effects of a one-percentage point increase in the AIDS-related mortality rate on crop output per hectare per capita ('000 ZMK/ha per capita)

	Zone 1 t only	Zone 1 t only	Zone 2 t only	Zone 2 t only	Zone 3 At-4	Zone 3 At-4	Zone 4 At-7	Zone 4 At-7
Evaluated at AIDS deaths	Mean	High	Mean	High	Mean	High	Mean	High
$\partial y/\partial AIDS_t$	-7.094	-9.070	-7.295	-4.876	494.802	225.067	-54.016	63.439
	(0.88)	(1.38)	(0.89)	(1.11)	(2.42)*	(1.66)+	(2.78)**	(3.12)**
$\partial y/\partial AIDS_{t-1}$					-268.693	-121.712	-20.951	-10.286
					(3.01)**	(1.01)	(3.53)**	(1.91)+
$\partial y/\partial AIDS_{t-2}$					-555.290	-295.604	9.680	-40.359
					(2.49)*	(2.20)*	(1.27)	(3.93)**
$\partial y/\partial AIDS_{t-3}$					-232.990	-168.094	32.523	-35.153
					(1.64)	(1.70)+	(2.46)*	(2.89)**
$\partial y/\partial AIDS_{t-4}$					812.793	500.137	41.377	-10.362
					(2.92)**	(3.03)**	(2.97)**	(1.00)
$\partial y/\partial AIDS_{t-5}$							30.495	13.760
							(3.39)**	(1.96)*
$\partial y/\partial AIDS_{t-6}$							-5.366	17.215
							(0.77)	(2.77)**
$\partial y/\partial AIDS_{t-7}$							-68.019	6.591
							(2.66)**	(0.37)
$\partial y/\partial AIDS$ (long-run effect)	-7.094	-9.070	-7.295	-4.876	250.623	139.793	-34.277	4.845
	(0.88)	(1.38)	(0.89)	(1.11)	(2.82)**	(3.23)**	(2.56)**	(0.54)

Source: Author's calculations

Notes: Zone refers to agrozone. High=90^{th} percentile. Absolute value of z statistics in parentheses. + significant at 10%; * significant at 5%; ** significant at 1%. AIDS = AIDS-related mortality rate; At-j = Almon lag with maximum lag length of j years; t only = contemporaneous only.

Table A21. Short-run partial effects of a one-percentage point increase in the AIDS-related mortality rate on cultivated area (0.1 ha)

	Zone 1 At-6	Zone 1 At-6	Zone 2 At-7	Zone 2 At-7	Zone 3 t only	Zone 3 t only	Zone 4 At-7	Zone 4 At-7
Evaluated at AIDS deaths	Mean	High	Mean	High	Mean	High	Mean	High
$\partial y/\partial AIDS_t$	2.831	-.815	6.226	7.437	1.112	-1.282	1.394	-.630
	(2.30)*	(0.78)	(5.12)**	(6.54)**	(0.12)	(0.35)	(2.28)*	(0.93)
$\partial y/\partial AIDS_{t-1}$	.270	.0513	.959	.649			.393	.252
	(1.46)	(0.18)	(3.34)**	(1.60)			(2.25)*	(1.55)
$\partial y/\partial AIDS_{t-2}$	-1.651	.310	-2.228	-3.261			-.404	.498
	(2.62)**	(0.70)	(3.94)**	(4.57)**			(1.61)	(1.57)
$\partial y/\partial AIDS_{t-3}$	-2.593	.0686	-3.578	-4.703			-.898	.268
	(2.76)**	(0.11)	(3.73)**	(5.58)**			(2.09)*	(0.68)
$\partial y/\partial AIDS_{t-4}$	-2.167	-.327	-3.327	-4.028			-.974	-.142
	(2.84)**	(0.58)	(3.41)**	(5.02)**			(2.19)*	(0.42)
$\partial y/\partial AIDS_{t-5}$	.0443	-.325	-1.676	-1.719			-.527	-.360
	(0.23)	(1.31)	(3.07)**	(2.79)**			(1.91)+	(1.61)
$\partial y/\partial AIDS_{t-6}$	4.454	.804	1.222	2.029			.539	-.0206
	(3.12)**	(1.03)	(1.83)+	(2.97)**			(2.40)*	(0.11)
$\partial y/\partial AIDS_{t-7}$			5.331	7.102			2.250	.697
			(2.37)*	(4.23)**			(2.69)**	(1.21)
$\partial y/\partial AIDS$ (long-run effect)	1.188	-.232	2.930	3.504	1.112	-1.282	1.773	.562
	(2.12)*	(0.64)	(1.92)+	(3.18)**	(0.12)	(0.35)	(4.11)**	(1.86)+

Source: Author's calculations

Notes: Zone refers to agrozone. High=90th percentile. Absolute value of z statistics in parentheses. + significant at 10%; * significant at 5%; ** significant at 1%. AIDS = AIDS-related mortality rate; At-j = Almon lag with maximum lag length of j years; t only = contemporaneous only.

Table A22. Short-run partial effects of a one-percentage point increase in the AIDS-related mortality rate on cultivated area per capita (0.1 ha/capita)

	Zone 1 At-7	Zone 1 At-7	Zone 2 At-7	Zone 2 At-7	Zone 3 Dt-1	Zone 3 Dt-1	Zone 4 At-7	Zone 4 At-7
Evaluated at AIDS deaths	Mean	High	Mean	High	Mean	High	Mean	High
$\partial y/\partial AIDS_t$	.410	-.143	.930	1.188	.818	1.329	.211	-.0327
	(2.35)*	(0.76)	(3.03)**	(4.76)**	(0.36)	(0.73)	(1.61)	(0.22)
$\partial y/\partial AIDS_{t-1}$	.0897	.00421	.0653	.0881	-.956	-1.139	.0208	.0349
	(2.05)*	(0.07)	(0.92)	(0.88)	(0.38)	(0.59)	(0.55)	(0.97)
$\partial y/\partial AIDS_{t-2}$	-.178	.0600	-.451	-.566			-.118	.0309
	(2.81)**	(0.97)	(3.20)**	(3.66)**			(2.16)*	(0.44)
$\partial y/\partial AIDS_{t-3}$	-.353	.0331	-.647	-.819			-.190	-.0195
	(3.03)**	(0.33)	(2.61)**	(4.32)**			(2.06)*	(0.23)
$\partial y/\partial AIDS_{t-4}$	-.390	-.0402	-.551	-.706			-.180	-.0712
	(3.14)**	(0.38)	(2.15)*	(3.57)**			(1.87)+	(0.96)
$\partial y/\partial AIDS_{t-5}$	-.239	-.0996	-.188	-.293			-.0706	-.0682
	(2.96)**	(1.32)	(1.31)	(1.85)+			(1.18)	(1.41)
$\partial y/\partial AIDS_{t-6}$	.150	-.0574	.424	.393			.151	.0427
	(3.40)**	(1.41)	(2.54)*	(2.61)**			(3.02)**	(1.01)
$\partial y/\partial AIDS_{t-7}$	.791	.104	1.272	1.335			.488	.224
	(3.87)**	(0.80)	(2.17)*	(3.34)**			(2.70)**	(1.77)+
$\partial y/\partial AIDS$ (long-run effect)	.281	-.139	.853	.620	-.138	.190	.312	.141
	(2.96)**	(2.10)*	(2.25)*	(2.49)*	(0.29)	(0.76)	(3.31)**	(2.14)*

Source: Author's calculations

Notes: Zone refers to agrozone. High=90th percentile. Absolute value of z statistics in parentheses. + significant at 10%; * significant at 5%; ** significant at 1%. AIDS = AIDS-related mortality rate; Dt-j = finite distributed lag with maximum lag length of j years; At-j = Almon lag with maximum lag length of j years.

Table A23. Summary of Almon lag estimates for the short-run partial effects of HIV/AIDS on select agricultural production outcomes

Agrozone	1		2		3		4	
HIV/AIDS variable	HIV	AIDS	HIV	AIDS	HIV	AIDS	HIV	AIDS
Crop output	∩	∩	NA	NA	NA	∩	NA	∩
Crop output per capita	∩	∩	∪	NA	NA	∩	NA	NA
Crop output/ha	∩	∩	∩	NA	∩	∪	∩	∩
Crop output/ha per capita	∩	NA	∪	NA	∩	∪	∩	Ambig
Cultivated area	∩	Ambig	∩	∪	∩	NA	∩	∪
Cultivated area per capita	NA	Ambig	∪	∪	∩	NA	∪	∪

Source: Summarized from tables A10-A21

Notes: HIV = HIV prevalence; AIDS = AIDS-related mortality rate; ∩ = lagged partial effects are negative/zero, then positive, then negative/zero again; ∪ = lagged partial effects are positive/zero, then negative, then positive/zero again; NA = not applicable – preferred lag structure was not an Almon lag for that combination of outcome variable and agrozone; Ambig = ambiguous 'shape', i.e., not clearly ∩ or ∪. A priori, I expected the Almon lag estimates to be zero, then increasingly negative, and eventually zero again as agrarian communities recover from the HIV/AIDS shock, i.e., a ∪ shape. This was the estimated shape in 10 of 31 models where the preferred lag structure was an Almon lag; the estimated shape in the other 21 Almon lag models was ∩ contrary to a priori expectations.

Table A24. Regression results from Agrozone 1 models using HIV prevalence and including interaction terms

Explanatory Variables	Dependent variable [units] (lag structure for HIV/AIDS variable)					
	Output ['000 ZMK] (At-5)	Output per capita ['000 ZMK] (At-5)	Output/ha ['000 ZMK/ha] (At-5)	Output/ha per capita ['000 ZMK/ha] (At-5)	Cultivated area [0.1 ha] (At-6)	Cultivated area/capita [0.1 ha] (t only)
HIV prevalence (t)						0.028
						(0.00)
HIV prevalence, squared (t)						-0.118
						(0.51)
$Almon_1$	-241.886	-57.515+	-36.254*	-126.653**	-0.247	
	(1.12)	(1.77)	(2.31)	(3.62)	(0.19)	
$Almon_2$	430.829	92.631*	58.514**	170.783**	0.761	
	(1.58)	(2.30)	(3.08)	(4.06)	(0.61)	
$Almon_3$	-93.908+	-19.526*	-12.306**	-34.079**	-0.156	
	(1.79)	(2.52)	(3.41)	(4.26)	(0.79)	
$Almon_1$, squared	-5.624	-0.562	-0.084	1.648*	-0.028	
	(1.20)	(0.79)	(0.24)	(2.21)	(1.08)	
$Almon_2$, squared	5.869	0.737	0.088	-1.766*	0.023	
	(1.07)	(0.90)	(0.21)	(2.04)	(0.89)	
$Almon_3$, squared	-1.027	-0.139	-0.011	0.331*	-0.003	
	(1.00)	(0.91)	(0.14)	(2.05)	(0.81)	
Positive rainfall shock, % deviation from district mean	6.083	0.828	2.082+	3.212	-0.291+	1.513
	(0.39)	(0.33)	(1.91)	(1.23)	(1.88)	(0.62)
Positive rainfall shock, % deviation from district mean, squared	0.060	0.005	-0.022	-0.035	0.005+	-0.003
	(0.23)	(0.11)	(1.09)	(0.76)	(1.75)	(0.08)
Negative rainfall shock, % deviation from district mean	29.231	4.571	4.935**	8.324**	-0.075	7.727*
	(1.38)	(1.38)	(3.50)	(2.64)	(0.37)	(2.32)
Negative rainfall shock, % deviation from district mean, squared	-0.356	-0.071	-0.096**	-0.173**	0.004	-0.135+
	(0.77)	(1.04)	(3.19)	(2.67)	(0.93)	(1.96)
Agricultural producer price index (t-1) ('00 ZMK)	32.597**	3.407*	0.367	0.875	0.066	3.965*
	(3.08)	(2.12)	(0.51)	(0.55)	(0.77)	(2.56)

Table A24. continued

Explanatory Variables	Dependent variable [units] (lag structure for HIV/AIDS variable)					
	Output ['000 ZMK] (At-5)	Output per capita ['000 ZMK] (At-5)	Output/ha ['000 ZMK/ha] (At-5)	Output/ha per capita ['000 ZMK/ha] (At-5)	Cultivated area [0.1 ha] (At-6)	Cultivated area/capita [0.1 ha] (t only)
Median provincial fertilizer price ('00 ZMK/kg)	220.132**	26.680*	18.568**	34.858**	1.545**	17.234+
	(3.24)	(2.57)	(3.93)	(3.30)	(3.22)	(1.69)
Real interest rate (2000=100) (t-1)	77.820**	9.952**	7.307**	15.257**	0.449**	5.114
	(3.45)	(2.83)	(4.58)	(4.27)	(2.75)	(1.55)
Mean fertilizer subsidy (kg/ha/household)	-0.149	0.213	-0.161	-0.620		
	(0.04)	(0.34)	(0.54)	(0.92)		
Female-headed households in district (%)	8.303	1.700	1.147	3.341+	-0.018	-1.479
	(0.68)	(0.97)	(1.36)	(1.94)	(0.15)	(0.79)
Mean household productive assets ('00,000 ZMK) †	-3.732	-6.314	0.852	4.348	-0.081	-1.211
	(0.47)	(0.91)	(1.59)	(0.68)	(1.02)	(0.16)
Positive rainfall shock*HIV prevalence						-0.021
						(0.14)
Positive rainfall shock squared*HIV prevalence						-0.000
						(0.03)
Positive rainfall shock*$Almon_1$	9.293	2.804	3.468**	6.698**	-0.010	
	(0.67)	(1.34)	(3.74)	(3.19)	(0.19)	
Positive rainfall shock*$Almon_2$	-12.231	-3.702	-4.867**	-9.248**	0.013	
	(0.63)	(1.29)	(3.81)	(3.20)	(0.21)	
Positive rainfall shock*$Almon_3$	2.333	0.705	0.950**	1.794**	-0.002	
	(0.62)	(1.26)	(3.82)	(3.19)	(0.19)	
Positive rainfall shock squared*$Almon_1$	-0.432	-0.100*	-0.082**	-0.171**	-0.000	
	(1.47)	(2.32)	(4.25)	(3.96)	(0.35)	
Positive rainfall shock squared*$Almon_2$	0.574	0.134*	0.114**	0.235**	0.000	
	(1.41)	(2.27)	(4.30)	(3.98)	(0.30)	
Positive rainfall shock squared*$Almon_3$	-0.110	-0.026*	-0.022**	-0.046**	-0.000	
	(1.39)	(2.24)	(4.30)	(3.97)	(0.30)	

Table A24. continued

Explanatory Variables	Dependent variable [units] (lag structure for HIV/AIDS variable)					
	Output ['000 ZMK] (At-5)	Output per capita ['000 ZMK] (At-5)	Output/ha ['000 ZMK/ha] (At-5)	Output/ha per capita ['000 ZMK/ha] (At-5)	Cultivated area [0.1 ha] (At-6)	Cultivated area/capita [0.1 ha] (t only)
Negative rainfall shock*HIV prevalence						-0.325
						(1.61)
Negative rainfall shock squared*HIV prevalence						0.004
						(0.93)
Negative rainfall shock*Almon$_1$	-7.070	1.273	0.765	1.506	0.045	
	(0.55)	(0.64)	(0.90)	(0.76)	(0.76)	
Negative rainfall shock*Almon$_2$	13.496	-1.657	-1.217	-2.631	-0.054	
	(0.70)	(0.56)	(0.96)	(0.89)	(0.76)	
Negative rainfall shock*Almon$_3$	-2.940	0.309	0.245	0.551	0.009	
	(0.76)	(0.52)	(0.96)	(0.93)	(0.78)	
Negative rainfall shock squared*Almon$_1$	0.575*	0.015	0.017	0.017	-0.001	
	(1.97)	(0.35)	(0.88)	(0.39)	(0.97)	
Negative rainfall shock squared*Almon$_2$	-0.931*	-0.026	-0.025	-0.015	0.002	
	(2.11)	(0.40)	(0.84)	(0.23)	(0.91)	
Negative rainfall shock squared*Almon$_3$	0.192*	0.005	0.005	0.002	-0.000	
	(2.15)	(0.41)	(0.83)	(0.18)	(0.90)	
Mean fertilizer subsidy*HIV prevalence						
Mean fertilizer subsidy*Almon$_1$	1.719*	0.254*	0.113+	0.343**		
	(2.23)	(2.07)	(1.92)	(2.68)		
Mean fertilizer subsidy*Almon$_2$	-2.991**	-0.443**	-0.179*	-0.503**		
	(2.80)	(2.64)	(2.21)	(2.90)		
Mean fertilizer subsidy*Almon$_3$	0.633**	0.093**	0.037*	0.101**		
	(2.99)	(2.83)	(2.30)	(2.95)		

Table A24. continued

Explanatory Variables	Dependent variable [units] (lag structure for HIV/AIDS variable)					
	Output ['000 ZMK] (At-5)	Output per capita ['000 ZMK] (At-5)	Output/ha ['000 ZMK/ha] (At-5)	Output/ha per capita ['000 ZMK/ha] (At-5)	Cultivated area [0.1 ha] (At-6)	Cultivated area/capita [0.1 ha] (t only)
Female-headed households*HIV prevalence						0.045
						(0.42)
Female-headed households* $Almon_1$	-1.794	1.066	-0.387	-0.077	0.041	
	(0.34)	(1.32)	(1.08)	(0.10)	(1.36)	
Female-headed households* $Almon_2$	-1.570	-2.088+	0.282	-0.335	-0.047	
	(0.21)	(1.84)	(0.56)	(0.31)	(1.41)	
Female-headed households* $Almon_3$	0.622	0.454*	-0.036	0.097	0.008	
	(0.42)	(2.04)	(0.36)	(0.45)	(1.41)	
Mean household productive assets†*HIV prevalence						0.418
						(1.06)
Mean household productive assets†* $Almon_1$	-15.115*	-19.767**	-0.669	-20.863**	0.011	
	(2.50)	(3.06)	(1.63)	(3.24)	(0.35)	
Mean household productive assets†* $Almon_2$	22.303*	29.232**	1.034+	32.415**	-0.017	
	(2.49)	(2.96)	(1.68)	(3.29)	(0.46)	
Mean household productive assets†* $Almon_3$	-4.433*	-5.821**	-0.210+	-6.592**	0.003	
	(2.47)	(2.92)	(1.70)	(3.31)	(0.51)	
Observations	132	132	132	132	132	132
Number of districts	12	12	12	12	12	12

Source: Author's calculations

Notes: Absolute value of z statistics in parentheses. + significant at 10%; * significant at 5%; ** significant at 1%. $Almon_1$. $Almon_2$, and $Almon_3$ are as defined in section 3.2 of the manuscript. † = mean household productive assets are in per capita terms when the dependent variable is in per capita terms. A t-j = Almon lag with maximum lag length of j years; t only = contemporaneous only.

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