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EXECUTIVE SUMMARY

Since the southern African food crisis of 2001/02, the 'new-variant famine' (NVF) hypothesis first proposed by de Waal and Whiteside (2003) has become an important part of the conventional wisdom surrounding the relationship between HIV/AIDS and food crises in the region. The NVF hypothesis suggests that HIV/AIDS is eroding agrarian livelihoods and exacerbating the effects of drought and other shocks on agrarian communities. These concepts have begun to shape the HIV/AIDS mitigation and food security policies and programs of governments and development agencies. To date, however, there is a dearth of empirical evidence to support the NVF hypothesis, and there have been no studies specifically designed to tests its predictions.

This study represents a first step towards testing the predictions of NVF. We estimate the impact of AIDS-related morbidity and mortality on indicators of agrarian livelihoods in Zambia. We focus specifically on the impact of HIV/AIDS on district-level crop output, output/ha, and area cultivated (henceforth referred to as 'agrarian livelihood indicators' or 'agricultural 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 effect of AIDS morbidity and mortality on current and future agrarian livelihood indicators; (2) measure the extent to which HIV/AIDS may exacerbate the impact of other factors affecting agricultural production, such as macroeconomic structural adjustment, 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.

The analysis generates a number of findings that may help evaluate the validity of the NVF hypothesis as an analytical framework in the context of agrarian livelihoods and food security in Zambia. First, HIV prevalence rates and AIDS-related mortality rates in Zambia are highest in the lowest rainfall and most drought-prone zone of the country (agroecological region (AER) I).

Second, only in AER I do we consistently find evidence of a significant negative independent effect of HIV/AIDS on agrarian livelihoods at the district level. This region is characterized by the lowest mean annual rainfall levels and the highest mean HIV prevalence and AIDS-related mortality rates of the three AERs. 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.

Third, for the key NVF suggestion that HIV/AIDS exacerbates the impact of drought on agrarian livelihoods, the results from of this study lend some support to this prediction for AERs I and II, particularly when the outcome variable is crop output or output per ha. In many cases, the negative impact of drought is at least doubled when HIV prevalence rates are relatively high (at the 90th percentile, which corresponds to 18% to 25%, depending on the particular AER) compared to when these rates are held at mean levels for the various AERs (between 11.7% and 17.3%). However, of the various alternative model specifications, results consistent with the NVF hypothesis are far from universal even within these AERs.

Fourth, 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 AER III, and only for a subset of the agricultural production indicators analyzed.

Fifth, there is little evidence to support the NVF prediction that HIV/AIDS affects the relationship between a rise in female headship (e.g., due to male head mortality or migration) and a decline in crop cultivation or output. Of the 48 simulations done, the results of only six are consistent with the predictions of the NVF hypothesis as it relates to female headship shocks. While we find some evidence of negative impacts of female-household headship on agricultural production indicators, results do not suggest a differential impact of female household headship shocks depending on the severity of the HIV/AIDS epidemic.

Sixth, only in districts whose borders encompass both AER II and III do we consistently find evidence that HIV/AIDS reduces the contribution of productive assets to crop output and output per unit of land as would be expected under the NVF hypothesis. These communities tend to have the lowest productive asset base (in mean household terms). Perhaps because they 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 community.

None of these findings lend unequivocal support to the NVF hypothesis in Zambia. There is strong evidence that in low rainfall areas, HIV/AIDS exacerbates the effects of drought on crop output and output/ha. The evidence is much weaker that HIV/AIDS exacerbates the impact of other shocks on agricultural output (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, results vary by AER, 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 affected districts (or AERs) into one category and overgeneralize as to the effect of HIV/AIDS (and its interaction with other shocks) on rural 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-affected may be an important aspect of both food security and HIV/AIDS mitigation strategies. 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 some agrarian communities may be more resilient in the face of HIV/AIDS than earlier predicted. Nevertheless, it is likely to remain important for governments, donors, and NGOs to continue to invest in AIDS prevention and mitigation in order to reduce rural poverty, and to invest in rural development, broadly defined, to bolster resilient livelihood strategies in all HIV/AIDS affected agrarian communities.

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LIST OF ACRONYMS

AER	Agroecological region
AIC	Akaike Information Criteria
AMR	Adult mortality rate
CGAIHS	Collaborative Group on AIDS Incubation and HIV Survival including the CASCADE EU Concerted Action
CSO	Central Statistical Office
FAO	Food and Agricultural Organization
FEGLS	Fixed effects (feasible) generalized least squares
FSRP	Food Security Research Project
ha	hectare
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
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
USAID	United States Agency for International Development
ZMK	Zambia kwacha

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; Barnett and Whiteside 2002), there remains a dearth of empirical evidence to support the NVF hypothesis (de Waal 2004), which emphasizes how AIDS compounds the effect of other exogenous shocks on 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 toward testing the predictions of NVF. We estimate the impact of AIDS-related morbidity and mortality on indicators of agrarian livelihoods in Zambia. We focus specifically on the impact of HIV/AIDS on district-level crop output, output/ha, and area cultivated (henceforth referred to as 'agrarian livelihood indicators' or 'agricultural 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 effect of AIDS morbidity and mortality on current and future agrarian livelihood indicators; (2) measure the extent to which HIV/AIDS may exacerbate the impact of other factors affecting agricultural production, such as macroeconomic structural adjustment, 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.

Apart from 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 to 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

[1] This paper follows the taxonomy convention of Barnett and Whiteside (2002): "Afflicted" households are those that have incurred a prime-age death in their households and those households in which a member is currently HIV positive. Households that have not directly suffered a death and do not have a member living with HIV/AIDS but are nevertheless affected by the impact of death in the broader community is referred to in this study as "affected." Households not directly suffering a HIV/AIDS-related death or illness may be non-afflicted, but it is doubtful that there are many non-affected households in hard-hit communities of eastern and southern Africa.

communities requires controlling for these other exogenous shocks facing the agricultural sector, as well as accounting for potential interaction effects between these processes.

Section 2 describes the predictions of the NVF hypothesis and reviews the evidence to date in support of NVF. Section 3 presents the methods and data used in the study. Section 4 describes the results, and section 5 outlines the conclusions and policy implications of the study.

2. BACKGROUND ON THE NVF HYPOTHESIS

2.1. The NVF 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. The burden of 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 impact 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 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 impact 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. Kinship networks are also being stressed by AIDS-related illness and death and so social networks may be less able to absorb the impact of other shocks. Finally, de Waal (2003) 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 NVF 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 (2007) outlines the evidence to date in support of each of these NVF sub-hypotheses. The majority of this evidence is either indirect or circumstantial; in fact, de Waal acknowledges that no studies have been designed specifically to test the predictions of NVF—our paper 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

[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).

hypothesis that HIV/AIDS is exacerbating the effect 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 impact 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; Baylies 2002) that have explored the impact of HIV/AIDS on household and community food security in rural Africa. While these studies provide valuable insight into the social and economic impact 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 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 affected and non-affected 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 affected and non-affected 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 impacting afflicted households' incomes, asset levels, and agricultural production.

None of the aforementioned papers allows comparison of the impact of drought on HIV-affected households and communities versus those less affected by the epidemic. However, a pilot study in Tanzania which examined the impact of the 2002/03 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 affected by adult chronic illness and 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).[3]

While HIV/AIDS has undoubtedly had a devastating impact on many of the households it has touched, de Waal (2007) 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

[3] A major difficulty in measuring the impact of mortality attributable to AIDS is that it is caused by behavioral choices rather than by random events. Individuals and households incurring adult mortality are more likely to display certain characteristics. Especially in the early years of the epidemic in sub-Saharan Africa, evidence suggests that men and women with higher education and income were more likely to contract HIV because they tended to have more sexual partners (Ainsworth and Semali 1998; Gregson, Waddell, and Chandiwana 2001). More recently, there is some evidence to suggest that poverty is increasingly associated with HIV infection, especially among women. Regardless, a failure to control for initial household characteristics may generate biased estimates of the impact of AIDS.

strategy might be more vulnerable to subsequent shocks; however, to date, no studies have empirically tested this hypothesis.

A weakness in much of the evidence presented by de Waal (2007) is that it consists of facts and figures on how HIV/AIDS is impacting afflicted households, but gives little ground for comparison with non-afflicted households, nor does it directly support the claim that HIV/AIDS exacerbates the effect 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." 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 impact of the epidemic, to date no explicit empirical evidence supports this claim.

In terms of the NVF sub-hypothesis that affected households and communities will follow "new trajectories of destitution during crisis," de Waal (2007) states that "this prediction has yet to be tested." The two main sources of circumstantial evidence for this NVF sub-hypothesis are a report by the Southern African Development Community 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 weaknesses to those outlined above recur for this evidence for the NVF hypothesis. de Waal (2007) 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. 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 (2007) that is based on regression analysis. It is also the only study other than the current paper, of which we are aware, that has explicitly tested for an interaction effect between HIV/AIDS and drought on a food security- or rural livelihoods-related outcome variable. 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 independent effect of HIV prevalence and drought was 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 results of this regression analysis may be biased because no other factors affecting change in child underweight were controlled for in the model.

An oft-cited source of evidence for the NVF hypothesis is anecdotes of increased engagement in transactional sex by women during food crises (SCF 2002; SAHIMS 2003; 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, rather than HIV/AIDS worsening the effect of food crises as postulated by NVF (Bryceson and Fonseca 2006).

de Waal (2007) 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.

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 effect of other processes and identify the *ceteris paribus* effect of HIV/AIDS, rainfall and other shocks, and their interactions on agrarian livelihoods as measured by district-level crop output, output/ha, and cultivated area. Furthermore, our 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. METHODS AND DATA

3.1. Theoretical Framework

In this paper, our goal is to empirically test the NVF hypothesis. The NVF hypothesis predicts a "downward spiral" in the well-being of HIV/AIDS-affected 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.

We test the NVF hypothesis using data on agrarian livelihoods from the Zambia Post-Harvest Surveys (PHS) for agricultural years 1991/92 to 2002/03. The PHS is a nationally representative longitudinal survey of 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).)

We base our model on the supply response literature.[6] Supply response models (e.g., Nerlove models) are used to study the effect 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 production; 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/ha, or total acreage, and in the context of our test of the NVF hypothesis, we can think of these variables as indicators of agrarian livelihoods. Askari and Cummings (1977) suggest that acreage is preferable to output (tonnage) or output/ha (yield) as the dependent variable in supply response models because acreage is under farmers' control while output and yield are affected by factors beyond the 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

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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 of these districts is not complete for one or more years during the period 1991/92-2002/03 so we use in the analysis the 52 "old" districts for which we do have complete data.

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

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

expected to have an important effect on agricultural production, and so is included in our 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). We add four such explanatory variables. First, to examine the effect of HIV/AIDS on agrarian communities in Zambia, we add the district-level HIV prevalence rate or AIDS-related mortality rate (*AIDS*). Second, we 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, we 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, Jayne, and Mason 2007). Furthermore, descriptive studies suggest that AIDS-related mortality exacerbates gender inequalities (Mutangadura 2005). For these reasons, we want to control for the number of female-headed households in communities. Finally, we add government fertilizer subsidies to the community (*SUB*) to control for the effect of structural adjustment-related reductions in government in-kind 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 ($p_{y_t}^e$) is defined as:

$$p_{y_t}^e = p_{y_{t-1}} \qquad [3]$$

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:

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

where $0 < \alpha < 1$.

3.2. Empirical Model

3.2.1. Model Specification

To test the predictions of the NVF hypothesis that HIV/AIDS (1) negatively affects agrarian livelihoods (agricultural production), and (2) exacerbates the impact of drought and other shocks on agrarian livelihoods, we consider the estimation of an agricultural supply response model based on equation [2]. We hypothesize the following linear panel data econometric model:

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

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 government in-kind fertilizer subsidy (kg/ha); *FEM* is the percentage of female-headed households; *T* is a vector of time dummies intended to capture the effect 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 effect; and ε_{it} is the idiosyncratic error term.

The agricultural production (agrarian livelihood) indicators used as dependent variables (*y*) in the analysis are mean household cultivated area, mean household crop output, and mean household crop output/ha, in both level and per capita terms. (We henceforth refer to these six different dependent variables collectively as 'agricultural production indicators' or 'agrarian livelihood indicators'.) Note that for models in which the dependent variable is in per capita terms, the *ASSET* variable is also specified in per capita terms. We 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 data were then weighted and household means for each district and year were calculated. In the case of crop output, the physical quantity (kgs) of each of the same 17 crops potentially produced by each household was multiplied by its mean provincial crop price/kg for the period 1991/92 to 2003/04 to come up with an index of crop production. In the case of crop output/ha, this household index of crop production was divided by the total number of hectares planted in those 17 crops. For both crop output and output/ha, the data were then weighted and household means for each district and year were calculated.

In this analysis, p_y=*PPI,* where *PPI* is the agricultural producer price index. We 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 ha) for 17 crops potentially cultivated by the household. We calculate the *PPI* from PHS survey data for each district and year as a weighted combination of crop output prices, where the weights vary by district and are based on the relative importance of each crop to total agricultural production in the district. We model expected crop output price using both naïve expectations and adaptive expectations; in both models of price expectations, we use the lagged *PPI* as $p_{y\ t-1}$ in [3] and [4].

The input prices included in the p_x vector include the lagged provincial real fertilizer price/kg and the lagged national real interest rate. Ideally, we would also have included other input prices, such as prices for seed and pesticides, rental rates for draught animals, and wage rates

[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.

(agricultural and non-agricultural); however, such data were not available. We include input prices in our model to control for other factors that influence supply so that we can get good estimates of the effect of HIV/AIDS and other shocks on agricultural production. It is likely that fertilizer prices and interest rates are correlated with the price of inputs for which we do not have data; therefore, including fertilizer price and interest rate should adequately control for other input prices that affect farm supply.

In the empirical specification of the model, we 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. We also add interaction terms between *AIDS* and all elements of the Z^* vector. This allows the elements of the Z^* vector to have a differential effect on agricultural supply depending on the level of HIV/AIDS. It also enables us to test the key prediction of the NVF hypothesis: that HIV/AIDS exacerbates the effect of drought and exogenous shocks (i.e., the variables in Z^*) on agrarian livelihoods. Together these additions to [5] give:

$$\begin{aligned} y_{it} &= \alpha + \gamma p^{e}_{y_{it}} + p_{x_{it}}\psi + AIDS_{it}\delta_1 + AIDS^2_{it}\delta_2 + RAIN_{it}\omega_1 + RAIN^2_{it}\omega_2 + \omega_3 ASSET + \omega_4 FEM \\ &+ \omega_5 SUB + AIDS_{it} * RAIN_{it}\varphi_1 + AIDS_{it} * RAIN^2_{it}\varphi_2 + AIDS_{it} * ASSET_{it}\varphi_3 + AIDS_{it} * FEM_{it}\varphi_4 \\ &+ AIDS_{it} * SUB_{it}\varphi_5 + T_t\theta + \lambda_i + \varepsilon_{it} \end{aligned} \quad [6]$$

3.2.2. Modeling the Dynamic Relationship Between HIV/AIDS and Agricultural Production Indicators

We 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 eight to ten years between seroconversion and death in the absence of antiretroviral treatment (Morgan et al. 2002; CGAIHS 2000; Zaba, Whiteside, and Boerma 2004).[8] The HIV prevalence rate is the estimated percentage of the population currently living with HIV/AIDS, and we expect it to reflect the effect of HIV/AIDS-related illness and morbidity on the agricultural production indicator. We expect the AIDS-related mortality rate to reflect the effect of AIDS-related deaths on such an indicator.

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-economic impact 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 agrarian livelihoods. To model both the immediate and delayed impact of HIV/AIDS-related illness and morbidity, we estimate models including the contemporaneous HIV prevalence rate as well as models including contemporaneous and lagged HIV

[8] 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 eight to ten 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 (four to five years). Therefore, it is likely that HIV prevalence rates are an advance predictor of AIDS deaths with a lag of roughly four to five years.

prevalence. We estimate similar models using the AIDS-related mortality rate instead of HIV prevalence to test the relationship 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, we 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 in the Almon and traditional distributed lag models (*J*), we follow the recommendations in Pindyck and Rubinfeld (1997) and Guajarati (2003) and add additional lags until the Akaike Information Criteria (AIC) stops declining. In the Almon lag structures, we impose a second-degree (quadratic) form on the polynomial. That is, we 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:

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

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

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.[9] The implications of such a lag structure on the AIDS-related mortality variable are similar.

Zambia is divided into three AERs: AER I covers the southern border of the country and receives less than 800 mm of rainfall/year; AER II covers western and central Zambia and receives 800 to 1,000 mm of rainfall/year; and AER III covers the northern part of the country and receives in excess of 1,000 mm of rainfall/annum (see Figure A.1 for a map of the AERs in Zambia). Some districts' borders encompass parts of both AERs II and III so we 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 impact of HIV/AIDS and other explanatory variables on agricultural production indicators may vary by agrozone. To determine if it is appropriate to pool agrozones, we conduct a series of Chow Tests. The results of the Chow Tests suggest that the impact of HIV/AIDS and other regressors do indeed vary by agrozone, indicating that we should run separate regressions for each agrozone.

For each agrozone and dependent variable (output, output/capita, output/ha, output/ha/capita, area cultivated, and area cultivated/capita) combination, we compute the AIC value for various finite distributed lag and Almon lag structures on HIV/AIDS (HIV prevalence or

[9] 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.

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 A.1) that we estimate and analyze throughout the remainder of the paper.

3.3. Estimation

We take advantage of the panel-nature of the data and use estimation techniques that allow us to difference out the district-level unobserved effect that does not vary over time (λ_i). We report here only on the results of the models in which we assume smallholders' price expectations to be naïve. Estimation of models with multiple lags of HIV/AIDS under the adaptive expectations assumption proved problematic as this involved lagging previously lagged variables, and resulted in numerous terms being dropped due to collinearity. We find evidence of heteroskedasticity and serial correlation in the error terms of the naïve expectations models and so estimate these models using the fixed effects (feasible) generalized least squares estimator (FEGLS) described in Wooldridge (2002).

3.4. Data

District-level indicators of agrarian livelihoods (mean household crop output, output/ha, and cultivated area), government fertilizer subsidies, PPIs, and asset base indexes used in the analysis are drawn from PHS data. Median provincial fertilizer prices are based on data from the MACO Agricultural Marketing Centre. 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 census from 1980, 1990, and 2000 (CSO 1975; CSO 1985; CSO 1994; CSO 2003). The HIV/AIDS estimates in this report are based on sentinel surveillance site (ante-natal clinic) data and the projections are computed using the cohort component method. 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, we 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 death 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.

One important result to note is the high correlation ($\rho = 0.90$) in our sample 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 we lag HIV prevalence (see Table A.7 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 eight to ten years. So, for any given HIV-positive population, on average, individuals have been living with HIV for four to five years. The high correlation in the Zambia data between HIV prevalence from three to five 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.

4. RESULTS

4.1. Independent Effects of HIV/AIDS on Agrarian Livelihood Indicators

We estimate models as specified in equation [6] excluding the interaction terms to get an initial measure of the independent effect of HIV/AIDS on mean household crop output, output/ha, and cultivated area (levels and per capita). In these models, we are not exploring how HIV/AIDS interacts with drought and other exogenous factors to affect agricultural production.

To determine the partial effect of a one-percentage point increase in the HIV prevalence rate or AIDS-related mortality rate on the dependent variable of interest, we take the partial derivative of equation [6] with respect to *AIDS* (and excluding the interaction terms between *AIDS* and *RAIN* and other shocks). We evaluate this partial derivative at mean HIV prevalence or AIDS-related mortality and then at the 90th percentile of these HIV/AIDS measures. The long-run partial effect of a one-percentage point increase in HIV prevalence or the AIDS-related mortality rate on each dependent variable is reported by agrozone in Tables 1A and 1B below. (Due to the large number of models estimated and space limitations, we report only the parameter estimates for the key variables of interest, rather than the full regression results. In the Appendix, we include one full set of regression results that are consistent with the implications of many of the other models estimated in the analysis.)[10]

Consider first the 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 partial effect of HIV prevalence on all six indicators ($p<0.10$). (Refer to Tables A8 and A9 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 (those shaded in gray), 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 we use the AIDS-related mortality rate instead of HIV prevalence.

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[10] In general, the parameter estimates on the "control" variables (i.e., those variables that are not interacted with HIV/AIDS) are: the coefficient on lagged agricultural PPI is either positive and statistically significant ($p<0.10$), as we would expect, or not statistically different from zero. We 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 we were 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 paper—we only include the lagged PPI, lagged interest rate, and fertilizer price variables in the models as controls.

Table 1A. Partial Effects of a One-percentage Point Increase in HIV Prevalence on Selected Agricultural Production Indicators

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

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

Source: Authors' 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 90th percentile of HIV prevalence or AIDS-related mortality for the agrozone
Shaded = negative effect of HIV/AIDS more negative when evaluated at high relative to mean HIV/AIDS
Bold = positive and statistically significant result–contrary to *a priori* expectations

In agrozone 2, the next lowest rainfall zone, the picture is dramatically different. For only one dependent variable (area cultivated) is there a negative and statistically significant 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. We find no evidence of significant negative impact 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 we find little evidence of a negative impact of HIV/AIDS on agrarian livelihoods in agrozone 2. The findings, in some cases, of positive partial effects of HIV/AIDS are difficult to explain. In previous rounds of modeling for this paper in which we used a slightly different set of explanatory variables (e.g., previous rounds did not include time dummies) and did not estimate separate regressions by agrozone, the results of some models did suggest a positive and significant partial effect of HIV/AIDS on agricultural production indicators. The incidence of such counterintuitive results is considerably lower in the models reported in this paper, perhaps due to the inclusion of time dummies.

In agrozone 3, the second highest rainfall zone, there is no statistically significant partial effect of HIV prevalence on output (levels and per capita) or area cultivated (levels and per capita). The results are similar when we use AIDS-related mortality. For output/ha (in both levels and per capita terms), the 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 90th percentile than it is when evaluated at the mean. (Also, the finding of a 105.5% decrease in output/ha/capita when HIV prevalence is at the 90th percentile is unreasonable as it suggests total crop failure.) On the contrary, the estimated partial effect of AIDS-related mortality on output/ha (in both levels and per capita terms) is 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, we conclude that there is no robust relationship between HIV/AIDS and agricultural production indicators in agrozone 3. Of the four agrozones, agrozone 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 partial effect ($p>0.10$) on output or output/capita. There is some evidence of a decline in output/ha in both levels and per capita when the partial effect of HIV/AIDS is evaluated at mean levels. However, the results also suggest, contrary to *a priori* expectations, that the 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 partial effect of mean HIV prevalence is not statistically significant ($p>0.10$), but the partial effect of HIV prevalence is statistically significant ($p<0.05$) and negative when evaluated at the 90th percentile. As in agrozone 2, we find a significant positive effect of increased AIDS-related mortality on area cultivated in agrozone 4.

On balance, only in agrozone 1 do we consistently find evidence of a significant negative direct effect of HIV/AIDS on agrarian livelihoods. This agrozone is characterized by the lowest mean annual rainfall level 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 impact on cultivated area, Larson et al. (2004) find that, for the entire sample of cotton farming households in their study, an increase in 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 increased from 0 to 24.4%; furthermore, this effect is short-lived, as it becomes statistically insignificant after three to eight 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 AMR on gross value of crop output or output/ha (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, McEwan, and Samuels 2006).

4.2. How HIV/AIDS Affects the Impacts of Exogenous Shocks on Agrarian Livelihood Indicators

In the previous section, we examined the independent impact of HIV/AIDS on selected agricultural production indicators. This section analyzes how the impact 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 we detail the estimation results from models as specified in equation [6]. To determine the partial effect of a one unit increase in the fertilizer subsidy, female-headed household, or productive asset base variables on the dependent variable of interest, we take the partial derivative of equation [6] with respect to *RAIN*, *SUB, FEM,* or *ASSET*. We evaluate the partial derivative at mean HIV prevalence or AIDS-related mortality and then at the 90^{th} percentile of these HIV/AIDS measures.

4.2.1. Evidence that HIV/AIDS Exacerbates the Effects of Drought

Tables 2A and 2B present the results for the partial effect of a one-percentage point increase in high (i.e., 90^{th} percentile) negative rainfall shocks (droughts) evaluated at mean and high levels of HIV/AIDS.

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

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

Source: Authors' 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

Shaded = negative effect of negative rainfall shocks more negative when evaluated at high relative to mean HIV/AIDS (consistent with predictions of NVF hypothesis)

Bold = positive and statistically significant result–contrary to *a priori* expectations

As in the case of the partial effect 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 impact of negative rainfall shocks. In agrozone 1 models where we use the HIV prevalence as the measure of the severity of the HIV/AIDS epidemic in a district, we find negative and statistically significant ($p<0.10$) partial effect 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 we 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 we use the HIV prevalence or AIDS-related mortality rate, we consistently find a statistically significant negative partial effect of drought on output and output/ha. In HIV prevalence models, the relationship between the partial effect 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 we find some support for the NVF hypothesis that HIV/AIDS exacerbates the negative impact of drought, particularly those effects on crop output and output/ha.

In agrozone 3, output, output/capita, and cultivated area/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/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/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 we 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 we use HIV prevalence to model the HIV/AIDS epidemic. In models using the AIDS-related mortality rate instead, we 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/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 effect of drought on crop output and output/ha (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.

4.2.2. 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 effect of other shocks in addition to drought. To test this hypothesis, we 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 3A and 3B present the results of the simulations for the partial effect 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/capita, and so the *SUB* variable was dropped from these models. Hence, no partial effect of *SUB* results are reported for cultivated area and area/capita.)

Table 3A. 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 3B. 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: Authors' 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 90th percentile of HIV prevalence or AIDS-related mortality for the agrozone
Shaded = positive effect of fertilizer subsidy shocks less positive when evaluated at high relative to mean HIV/AIDS (consistent with predictions of NVF hypothesis)
Bold = negative and statistically significant result—contrary to *a priori* expectations

In agrozone 1, we 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, we do find a weak, negative impact (-1.1%, p<0.05) on output/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/capita and output/ha, but these partial effects are practically small (+0.5%). However, when we evaluate the partial effect at the 90th percentile of HIV prevalence, the positive partial effect of increased fertilizer subsidies is eliminated. This is in line with what we would expect under the predictions of the NVF hypothesis, but the results are quite weak. We find a similar pattern in agrozone 3 for AIDS-related mortality models. In both HIV prevalence and AIDS-related mortality models for agrozone 3, we find results consistent with the NVF hypothesis for two of the four agricultural production indicators.

In agrozone 4 for mean HIV prevalence models, we find statistically significant (p<0.01), but practically small increases in output, output/capita, and output/ha associated with an increase in the fertilizer subsidy. The magnitude of the positive effect on output and output/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/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 4A and 4B present the results of the simulations for the partial effect (evaluated at mean and high levels of HIV/AIDS) of a one-percentage point increase in female-headed households in a district.

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

Table 4B. 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 (6.87%)	-0.3% (0.22)	-0.6% (1.70)+	-0.1% (2.34)*	0.1% (0.24)	-0.5% (1.79)+	0.3% (0.36)
	High (12.34%)	0.0% (0.03)	-0.6% (0.85)	0.0% (0.06)	0.2% (0.34)	-0.9% (1.57)	-0.6% (1.25)
2	Mean (3.66%)	-0.1% (0.23)	0.3% (0.64)	0.0% (0.52)	**0.7% (1.85)+**	-0.6% (2.54)*	-0.9% (3.58)**
	High (7.23%)	0.8% (1.11)	**1.4% (1.76)+**	0.0% (0.48)	0.2% (0.34)	-1.6% (2.29)*	-1.8% (2.54)*
3	Mean (2.66%)	**12.6% (4.10)****	**17.3% (5.44)****	0.0% (0.74)	-0.6% (1.44)	-1.8% (0.55)	0.6% (1.23)
	High (5.07%)	**2.7% (2.06)***	**3.8% (3.14)****	0.0% (0.42)	-2.2% (1.77)+	3.8% (0.65)	0.6% (0.54)
4	Mean (4.63%)	0.0% (0.09)	**0.6% (2.02)***	0.0% (0.58)	**0.5% (2.19)***	-0.2% (1.14)	0.2% (1.10)
	High (13.73%)	0.4% (0.59)	0.6% (0.89)	0.1% (1.46)	0.1% (0.13)	-0.5% (1.26)	0.0% (0.11)

Source: Authors' 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 90th percentile of HIV prevalence or AIDS-related mortality for the agrozone
Shaded = negative effect of female household headship shocks more negative when evaluated at high relative to mean HIV/AIDS (consistent with predictions of NVF hypothesis)
Bold = positive and statistically significant result—contrary to *a priori* expectations

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 90th percentile of HIV prevalence. This finding is contrary to what we would expect under the NVF hypothesis. For output/ha/capita and cultivated area, however, while female headship shocks do not 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 we 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, we 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/capita), the results are opposite of what NVF would predict: the negative impact of female headship shocks is less negative at high HIV prevalence relative to mean HIV prevalence. For AIDS-related mortality models, NVF is only supported for the effect of female headship shocks on cultivated area and cultivated area/capita.

In agrozone 3, the findings are similarly weak. Although we do not find direct contradictory evidence against NVF, in only two of the 12 models (six models each for HIV prevalence and AIDS-related mortality) do we find evidence to support the NVF hypothesis. In the case of HIV prevalence, NVF is supported for the negative effect of female headship shocks on output, and in the case of AIDS-related mortality, NVF is supported for output/ha/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 we find evidence to unequivocally reject the NVF hypothesis in this agrozone.

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

Tables 5A and 5B present the results of the simulations for the partial effect (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/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 5A. 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	Dependent Variable					
		Output	Output Per Capita	Output/ha	Output/ha Per Capita	Cultivated Area	Cultivated Area Per Capita
1	Mean (17.33%)	0.4% (1.38)	0.3% (0.14)	0.1% (2.93)**	1.2% (0.65)	0.0% (0.20)	233.1% (1.62)
	High (25.00%)	1.5% (2.74)**	6.6% (2.02)*	0.1% (1.41)	0.6% (0.18)	0.4% (1.18)	357.0% (1.80)+
2	Mean (11.77%)	0.7% (2.43)*	-1.0% (0.48)	0.0% (1.21)	**-6.0% (2.87)****	0.7% (3.78)**	-0.1% (0.04)
	High (18.78%)	0.6% (1.27)	-3.1% (0.68)	0.0% (0.19)	-5.5% (1.35)	1.0% (2.91)**	0.0% (0.02)
3	Mean (8.56%)	1.3% (1.29)	23.0% (3.56)**	0.2% (2.01)*	18.9% (2.70)**	-0.2% (0.06)	17.7% (2.13)*
	High (12.00%)	-0.5% (0.32)	-3.0% (0.29)	-0.1% (0.83)	**-21.4% (1.76)+**	1.9% (0.87)	0.8% (0.06)
4	Mean (10.43%)	3.5% (4.00)**	14.8% (3.23)**	0.0% (0.42)	-0.1% (0.02)	3.2% (4.15)**	13.6% (3.96)**
	High (21.03%)	2.2% (1.19)	3.5% (0.41)	-0.2% (1.30)	-7.9% (0.90)	4.1% (2.30)*	9.3% (1.37)

Table 5B. 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	Dependent Variable					
		Output	Output Per Capita	Output/ha	Output/ha Per Capita	Cultivated Area	Cultivated Area Per Capita
1	Mean (6.87%)	2.0% (1.46)	-0.7% (0.37)	0.1% (3.72)**	0.8% (0.36)	-0.3% (1.15)	-2.0% (1.14)
	High (12.34%)	1.6% (2.07)*	4.2% (0.85)	0.1% (3.20)**	0.5% (0.19)	0.2% (0.43)	3.9% (0.86)
2	Mean (3.66%)	0.7% (2.61)**	-0.4% (0.18)	0.0% (0.83)	**-3.0% (1.75)+**	0.7% (4.36)**	0.8% (0.70)
	High (7.23%)	0.6% (1.22)	-4.7% (1.48)	0.0% (0.97)	-3.1% (0.88)	1.2% (2.86)**	2.8% (0.87)
3	Mean (2.66%)	9.3% (2.38)*	-30.3% (2.20)*	0.0% (0.10)	13.7% (1.62)	2.7% (0.39)	11.8% (1.96)*
	High (5.07%)	-2.5% (1.43)	-5.4% (0.46)	0.0% (0.07)	14.0% (0.58)	6.3% (0.62)	**-29.1% (2.37)***
4	Mean (4.63%)	2.6% (2.83)**	14.3% (2.98)**	**-0.1% (1.97)***	6.3% (1.44)	3.8% (5.66)**	14.9% (4.60)**
	High (13.73%)	-3.6% (1.26)	8.0% (0.72)	**-1.1% (4.81)****	2.6% (0.22)	6.9% (3.62)**	27.9% (2.99)**

Source: Authors' 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
Shaded = positive effect of productive asset base increases less positive when evaluated at high relative to mean HIV/AIDS (consistent with predictions of NVF hypothesis)
Bold = negative and statistically significant result–contrary to *a priori* expectations

In agrozone 1, we find little evidence for the NVF prediction that the positive effect of increases in the mean household productive asset base is reduced by HIV/AIDS. In HIV prevalence models, this NVF scenario is only observed for output/ha and we find evidence contrary to NVF for output and output/capita. We 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 we find that the positive effect of productive asset base increases is 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 effect on cultivated area is more positive when HIV/AIDS is high relative.

Findings from agrozone 3 are most consistent with the predictions of the NVF hypotheses. In HIV prevalence models, for four of the six indicators (output/capita, output/ha, output/ha/capita, and cultivated area/capita), the statistically significant positive effect of productive asset base increases is 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 we do find that high AIDS-related mortality reduces the positive partial effect of productive asset base increases on output and cultivated area/ha.

In agrozone 4, results from the HIV prevalence models support the NVF hypothesis for output, output/capita, and cultivated area/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 we consistently find weak evidence that HIV/AIDS reduces the positive impact 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 community.

5. CONCLUSIONS AND POLICY IMPLICATIONS

The NVF hypothesis has become an important framework for understanding the impact of HIV/AIDS on agrarian livelihoods. This paper is the first to set out to empirically test its predictions. Using nationally-representative panel data from 1991/92 to 2002/03, we use econometric analysis 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 agrarian livelihoods? and (2) Is HIV/AIDS indirectly affecting agricultural production by exacerbating the impact of drought and other shocks? The analysis generates a number of findings that may help evaluate the validity of the NVF hypothesis as an analytical framework in the context of agrarian livelihoods and food security in Zambia.

First, only in agrozone 1 do we consistently find evidence of a significant negative independent effect of HIV/AIDS on agrarian livelihoods 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. The estimated partial effect of HIV/AIDS is negative in many of the other agrozones for several of the agricultural production indicators, but these effects are imprecisely measured. 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; Drinkwater, McEwan, and Samuels 2006).

Second, for the key NVF prediction that HIV/AIDS exacerbates the impact of drought on agrarian livelihoods, the results of this paper lend some support to this prediction for agrozones 1, 2, and 3, particularly when the outcome variable is crop output or output/ha (both in levels and 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. However, NVF-like phenomena are far from universal even within these agrozones, and the results are sensitive to the HIV/AIDS variable used.

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 impact of female headship shocks will be exacerbated by HIV/AIDS. Of the 48 simulations done, the results of only six are consistent with the predictions of the NVF hypothesis as it relates to female headship shocks. While we find some evidence of negative impact 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, Jayne, and Mason 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.

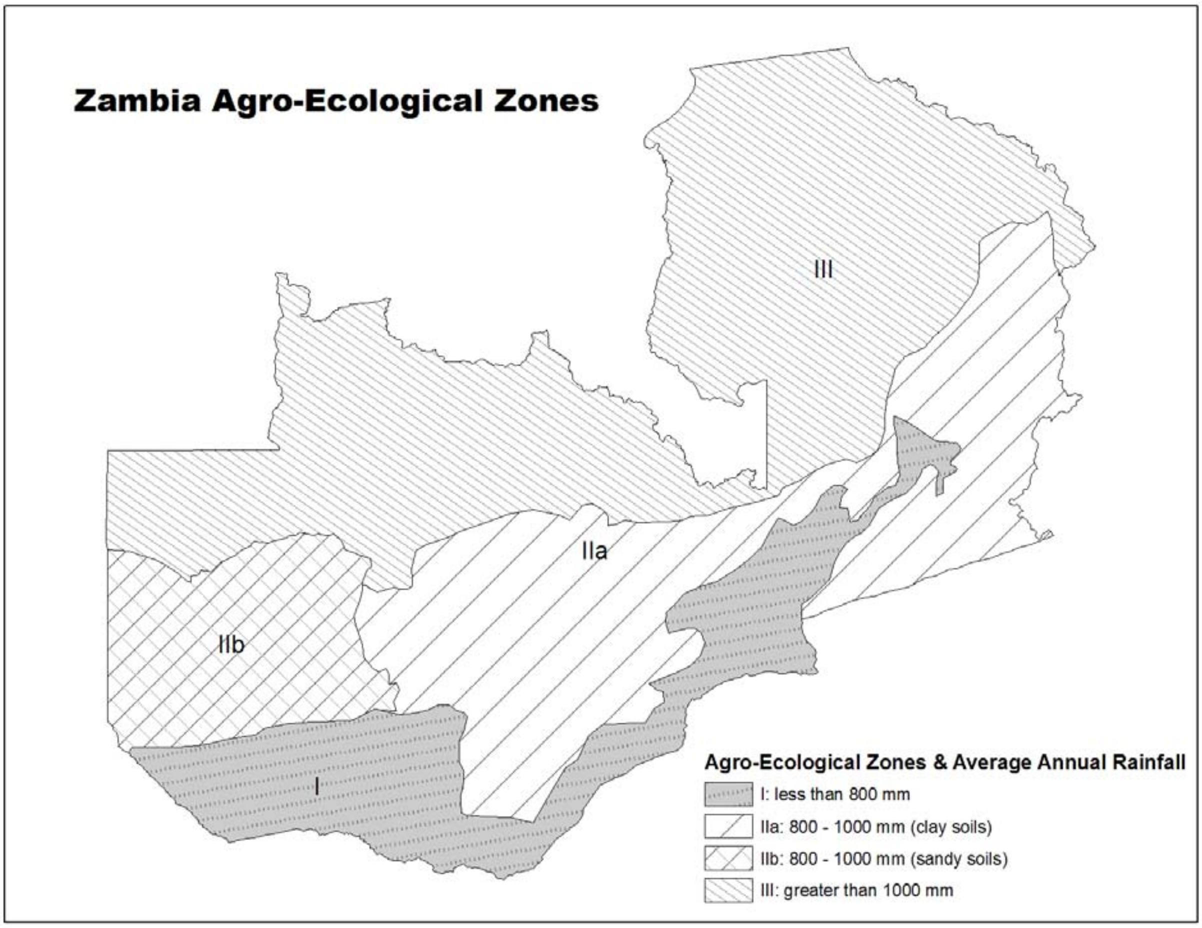
And fifth, only in agrozone 3 do we consistently find weak evidence that HIV/AIDS reduces the positive impact of productive asset base increases as would be expected under the NVF hypothesis. In mean household terms, the productive asset base in agrozone 3 is lower than the other three agrozones (although 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 community.

None of these findings lend unequivocal support to the NVF hypothesis in Zambia, but there is more evidence that HIV/AIDS exacerbates the effect of drought (particularly in low rainfall areas) than there is evidence that HIV/AIDS exacerbates other disturbances, such as fertilizer subsidy, female household headship, and productive asset base shocks. Furthermore, these 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 affected districts (or agrozones) into one category and overgeneralize as to the effect of HIV/AIDS (and its interaction with other shocks) on rural 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-affected 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 impact 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 affected agrarian communities.

APPENDIX

Figure A.1. Agroecological Regions of Zambia



Source: FSRP, Lusaka, Zambia

Table A.1. 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: Authors' 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 A.2. 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, 1991/92-2002/03, CSO, Lusaka

Where:

Variable	Description	Units	Level	Years
OUTPUT	Mean household crop output	'000 ZMK	District	Agric
OUTPUTPC	Mean household crop output/capita	'000 ZMK	District	Agric
YIELD	Mean household crop output/ha	'000 ZMK/ha	District	Agric
YIELDPC	Mean household crop output/ha/capita	'000 ZMK/ha	District	Agric
AREA	Mean household cultivated area	0.1 ha	District	Agric
AREAPC	Mean household cultivated area/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 PPI 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/capita	'00,000 ZMK	District	Agric

Notes: Agric=Agricultural years (October through September) 1991/92-2002/03; Calen=Calendar years 1991-2002

Table A.3. 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, 1991/92-2002/03, CSO, Lusaka

Table A.4. 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, 1991/92-2002/03, CSO, Lusaka

Table A.5. 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, 1991/92-2002/03, CSO, Lusaka

Table A.6. 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*:* Authors' calculations

Table A.7. 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 A.8. Mean and 90th Percentile of HIV Prevalence by Agrozone and Lag

Lag	Zone 1	Zone 1	Zone 2	Zone 2	Zone 3	Zone 3	Zone 4	Zone 4
	Mean	90th	Mean	90th	Mean	90th	Mean	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

Table A.9. Mean and 90th Percentile of AIDS-related Mortality by Agrozone and Lag

Lag	Zone 1	Zone 1	Zone 2	Zone 2	Zone 3	Zone 3	Zone 4	Zone 4
	Mean	90th	Mean	90th	Mean	90th	Mean	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

Table A.10. Regression Results from Agrozone 1 Models Using HIV Prevalence and Including Interaction Terms Between HIV Prevalence and Other Exogenous Factors

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 PPI (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)
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)

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Table A10. 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)
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)	
Negative rainfall shock*HIV prevalence						-0.325
						(1.61)
Negative rainfall shock squared*HIV prevalence						0.004
						(0.93)

contd……

Table A10. continued

Explanatory Variables	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)
	Dependent Variable [units] (lag structure for HIV/AIDS variable)					
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)		
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)	

contd……

Table A10. 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)
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*:* Authors' 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 3.2.2 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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