Does agricultural diversification build economic resilience to drought and flood? Evidence from poor households in Zambia

Shun Chonabayashi*
World Bank, Washington DC, USA and Cornell University, Ithaca, USA. E-mail: schonabayashi@worldbank.org

Theepakorn Jithitikulchai
World Bank, Washington DC, USA and Harvard T.H. Chan School of Public Health, Boston, USA. E-mail: theepakorn@worldbank.org

Yeqing Qu
World Bank, Washington DC, USA. E-mail: yqu@worldbank.org

* Corresponding author

Abstract

The adverse effects of weather extremes produce widespread damage and cause severe alterations in the normal functioning of household agricultural production in Zambia. Extreme weather events such as floods and drought are expected to increase in intensity and frequency due to climate change. Coupled with high poverty levels and limited institutional capacity, the country is highly vulnerable to the impact of extreme events. We quantify the effects of economic diversification on agricultural productivity of poor farm households with a skew-normal regression approach while accounting for drought and flood shocks. Our analysis finds that economic diversification is a strategy to increase agricultural productivity and mitigate the adverse impact of droughts and floods on agricultural households. The results also support the country's policies to encourage hybrid maize production and to provide crop seeds and fertiliser to poor farmers. This paper provides a framework to plan and inform interventions to enhance household economic resilience to weather shocks through agricultural diversification in Zambia and other countries.

Key words: agricultural productivity; diversification; drought; flood; climate change; resilience

1. Introduction

The impact of climate change, along with the expectation of more severe and frequent extreme weather shocks, has made poverty reduction in Africa difficult because a large share of the continent's population is engaged in agricultural activities. Previous literature shows that climate change and weather shocks cause losses in agricultural household income and assets in the relatively warm areas of the world (Mendelsohn *et al*. 2006, Lobell *et al*. 2011). Poor people are more likely to be dependent on agricultural income, which is directly influenced by changes in agricultural productivity and generally negatively associated with a hotter and drier climate. For instance, Africa is expected to suffer heavy annual welfare losses by 2070 to 2100, ranging between USD 14 billion and USD 70 billion, depending on the climate scenario and cropland measure considered (Kala *et al*. 2012). Low crop yields can drive up food prices and cause poor households to suffer more from higher food expenditure. Poor people lose more because the quality of their assets fails to resist the regressive impacts of climate change (Mano & Nhemachena 2006; Skoufias 2012; Hallegatte *et al*. 2016). Despite these negative effects of climate change and weather shocks, poor agricultural households may select low-risk and low-return strategies to avoid potential income losses, thereby perpetuating poverty (Hallegatte *et al*. 2016). For example, downside risk in consumption due to rainfall shocks lowers fertiliser application rates, since fertiliser is considered a costly input in Ethiopia (Dercon & Christiaensen 2011).

In Zambia, climate change has become a major threat to sustainable development. Extreme events such as droughts, floods and heavy rainfall have already been occurring and having a negative effect on agricultural production. They also are expected to increase in intensity and frequency. For example, the drought in Zambia from 2004 to 2005 affected 1.2 million people and caused an estimated maize production loss of 740 000 metric tons (United Nations Development Programme [UNDP] 2010; Makano 2011; Gannon *et al*. 2014). Southern Africa has experienced increasing long-term temperatures and decreasing long-term precipitation. Many studies have found that these trends can be projected to continue for the next few decades (Nhemachena & Hassan 2007; Hassan & Nhemachena 2008; Gannon *et al*. 2014; IPCC 2014). Droughts and floods are more likely to occur with greater severity and more frequency in the future (IPCC 2014; World Bank 2014).

Vulnerability to the adverse effects of climate change and weather shocks is not evenly distributed across the country in Zambia (UNDP 2010). Several studies acknowledge that the central and southern regions of Zambia, which have less average annual rainfall, are especially prone to such effects. Thurlow *et al*. (2011) estimate that around 85% of the agricultural GDP losses occurred in the southern and central areas of Zambia from 2006 to 2016, while the northern areas remained relatively unaffected by climate variability. Furthermore, it is also estimated that, using historical data, severe drought is responsible for a 3% to 8% increase in poverty across agro-ecological zones in Zambia for the period from 1976 to 2007 (Thurlow *et al*. 2011).

Farmers do perceive the increasing temperature and decreasing precipitation, and they are using various adaptation strategies in response to the changing climate. According to Nhemachena and Hassan (2007), the top three adaptations in Zambia are i) use of different crop varieties, ii) diversification of crops, and iii) switching from farm to non-farm activities. Drought-resistant crop varieties are introduced in many studies as an effective adaptation to climate change (Nhemachena & Hassan 2007; Pauw *et al*. 2010; Nikoloski *et al*. 2015; Damania *et al*. 2017). To reduce vulnerability and increase access to services for the rural poor, rural non-farm activities need to be an important aspect of their livelihood strategies (World Bank 2017). Crop diversification can serve as important insurance to avoid complete crop failure due to rainfall and temperature shocks. Mixed production of crops and livestock is also a common adaptation strategy to build resilience to climate shocks.

Irrigation is believed to be positively associated with crop intensification and an effective adaptation strategy to increase household resilience to extreme events and climate change (Nhemachena *et al*. 2010; Bryan *et al*. 2013; Nikoloski *et al*. 2015; Binswanger-Mkhize & Savastano 2017). However, small-scale agricultural production in Zambia is mostly rain-fed. Only 5% of the cultivated land is irrigated, which makes Zambian farmers highly vulnerable to both short-term disasters and long-term changes in precipitation patterns (Funder *et al*. 2013). One reason for the low irrigation rate is that a pump-based irrigation system generally requires electricity, which the nation has limited capacity to provide.

Multiple studies have confirmed that access to extension services, fertiliser subsidies, credit markets and other social protection programmes is positively associated with higher agricultural diversification, productivity and income (McCarthy 2011; Bryan *et al*. 2013; D'Alessandro *et al*. 2015; Arslan *et al*. 2016; Asfaw *et al*. 2016; Nagler & Naudé 2017; Lipper *et al*. 2018). Better promotion of and more investment in these areas should be considered as an effective way to increase income and build resilience.

Building on previous literature, we quantitatively investigated a hypothesis that agricultural diversification could enhance household resilience to the negative impacts of extreme events on agricultural productivity and welfare in Zambia. Using the nationally representative household surveys of 2010 and 2015, this study evaluates the effects of farm diversification on agricultural value added per worker when droughts or floods occur. To the best of our knowledge, this is the first study of its kind to analyse the association between agricultural productivity, diversification and extreme events in Zambia.

2. Data

We used the nationally representative household-level data from the Living Conditions Monitoring Surveys (LCMS) of 2010 and 2015, conducted by the Central Statistical Office (CSO) of Zambia. The LCMS 2010 and 2015 provide detailed information on the agricultural production, living conditions, economic activity and employment status of household members, among several others, that is representative for both the entire country and provincial areas. Descriptive statistics of key variables are available in the Appendix (Table A1).

In this study, agricultural households are defined as households that have at least one of their members engaged in any of the following agricultural activities: growing of crops, livestock and poultry ownership, fish farming, or a combination of some of the above. This is the formal definition used by the CSO. Agricultural diversification is measured using available proxies such as the number of agricultural activities and household farm types. There are four agricultural activities, namely the production of crops, livestock and poultry, and fish farming. Household farm types are categorised into crops only, livestock only, and both crops and livestock. The incidence of drought and flood is derived from the survey questions on shocks to household welfare. The survey asks whether a household experienced drought and flood in the last 12 months.

We used agricultural value added per worker as a measure of agricultural productivity. The value added in agriculture measures the value of outputs from the agricultural sector (ISIC divisions 1 to 5), less the value of intermediate inputs. The agricultural sector comprises forestry, hunting and fishing, as well as the cultivation of crops and livestock production. To avoid underestimating the total number of farmworkers, as in McCullough (2017), this study estimates the number of hired workers based on total costs of hired laborers in all agricultural activities and the average wage in the agricultural sector. The total number farmworkers in a household thus consist of family members who are self-employed or unpaid family workers and hired agricultural workers. This study calculates the number of family members who participate in farm production by using the adult equivalent scale to take into account the lower productivity per child. We use the same scales as the CSO (De la Fuente *et al*. 2015), which uses per adult equivalent expenditure for poverty analysis rather than per capita expenditure.

All monetary values in this study are temporally and spatially adjusted to the 2015 values using the consumer price index and the Laspeyres spatial price indices, 1F.[1] Also, because the Zambian currency was rebased in 2013 (1 000 old Kwacha = 1 new Kwacha), monetary values reflect this adjustment as well.

We consider only poor households to eliminate the effects of resources and investment capacity that non-poor households might have. The poverty measurement is based on the incidence of per capita

[1] The Laspeyres price index is "the price index defined as a fixed weight, or fixed basket, index that uses the basket of goods and services of the base period. The base period serves as both the weight reference period and the price reference period" (ILO *et al*. 2004). For further details, please refer to the methodology documentation (World Bank 2015).

consumption lower than the official poverty line constructed by the World Bank and the CSO (De la Fuente *et al*. 2015).

3. Methodology

We tested a hypothesis that diversification of agricultural production increases poor farmers' economic resilience to drought and flood based on a repeated cross-sectional dataset that was constructed by pooling data from the LCMS 2010 and 2015. Agricultural value added per worker is used as a measure of agricultural productivity. Agricultural value added is obtained by subtracting the value of agricultural intermediate input from the value of agricultural output. An agricultural worker is defined as an individual engaged in the agricultural sector.

For the identification of the diversification effects on economic resilience, we regressed agricultural value added per worker on drought dummy, flood dummy and other control variables, with year and province fixed effects for the sub-samples with and without agricultural diversification respectively. In this study, we considered a household as being diversified if it had either at least two agricultural activities or was categorised as both crops and livestock. We assumed that households managed their farm to maximise their net revenue from various farming activities, taking the existing climate as given.

This study considers the following equation to analyse the impacts of drought and flood on the productivity of farm households:

$$Y_{i(t),t,p} = \beta_0 + \beta_D D_{i(t),t,p} + \beta_F F_{i(t),t,p} + \delta' \boldsymbol{X}_{i(t),t,p} + \epsilon_t + \vartheta_p + \varepsilon_{i(t),t,p}, \tag{1}$$

where $Y_{i(t),t,p}$ is the log of the value added per worker from agricultural production activities for a household, *i(t)*, in cross-sectional time t, $D_{i(t),t,p}$ and $F_{i(t),t,p}$ are dummy variables that indicate the incidences of droughts and floods respectively, $\boldsymbol{X}_{i(t),t,p}$ are covariates that include both time-varying and time-invariant observable characteristics, such as socioeconomic and geographical characteristics, ϵ_t and ϑ_p are year and province dummy variables to control for the possible year effect and time-invariant unobservable provincial differences respectively, and $\varepsilon_{i(t),t,p}$ is an error term. Our dataset consists of two independent cross-sections at different points in time. As individuals in different periods are not the same people, we index the variables by a double subscript. In this setting, we estimated the equation for farm households with and without economic diversification respectively. Then we tested a hypothesis of equality of impacts of drought and flood on households with and without economic diversification.

The preliminary OLS regression results showed that the distribution of the error term is skewed, which would not allow us to perform statistical hypothesis testing and generate reliable confidence intervals and prediction intervals. To overcome this, we estimated drought and flood effects on observed farm productivity with a skew-normal regression approach that permits the estimation of the effects on mean, variance and skewness (Henze 1986; Azzalini & Dalla Valle 1996; Azzalini & Capitanio 1999; Gupta & Chen 2001).

The skew-normal distribution, denoted by $SN(\xi, \omega^2, \alpha)$, has the following density:

$$f_{SN}(y;\ \xi, \omega^2, \alpha) = 2\ \omega^{-1} \varphi(z) \Phi(\alpha z) \tag{2}$$

for $y \in (-\infty, \infty)$, where $z = \omega^{-1}(y - \xi)$, $\xi \in (-\infty, \infty)$ is a location parameter, $\omega > 0$ is a scale parameter, and $\varphi(.)$ and $\Phi(.)$ are the probability density function and cumulative distribution function of the standard normal distribution. This distribution is skewed to the right when $\alpha > 0$, is skewed to the left when $\alpha < 0$, and reduces to a normal distribution when $\alpha = 0$.

From centred parameterisation for the univariate skew-normal distribution (Azzalini 1985), one can obtain $\gamma = (4 - \pi)\text{sign}(\alpha)\ (\mu_z/\sigma_z^2)^3/2$, which denotes the skewness index, where $\mu_z = \sqrt{2/\pi}\delta$, $\sigma_z^2 = 1 - 2\delta^2/\pi$, and $\delta = \alpha/\sqrt{1+\alpha^2}$. This centre-parameterised skewness index γ, acquired by centering $Y \sim SN(\xi, \omega^2, \alpha)$, can be used to infer the actual magnitude of the departure from normality.

Consequently, this study fits the skew-normal regression model using the following equation:

$$Y_{i(t),t,p} = \beta_0 + \beta_D D_{i(t),t,p} + \beta_F F_{i(t),t,p} + \gamma' \boldsymbol{X}_{i(t),t,p} + \delta_t + \epsilon_p + v_{i(t),t,p}, \tag{3}$$

where $v_{i(t),t,p}$ is the skew-normal error term $v_{i(t),t,p} \sim SN(0, \omega^2, \alpha)$. This model setting is consistent with the empirical evidence that skewness parameters are statistically significant, as shown in Table 1.

The approach used in this study is robust to heteroskedasticity and spatially correlated errors, since the statistical inference for estimated coefficients is based on their cluster-robust standard errors, which allow intragroup correlation at the survey strata level. The sample weight is applied to account for survey stratification.

This study endeavours to evaluate the country's economic impacts of drought and flood with different agricultural diversification scenarios for agricultural households whose per-adult equivalent consumption is below the national poverty line. This study also considers the scenarios in which poor farmers produce hybrid maize[2] or receive crop seeds and fertiliser from the Farmer Input Support Program (FISP). Using the regression results and data on the characteristics of poor agricultural households, we estimated the economic losses from extreme events, gains from climate-resilient practices such as producing hybrid maize, and benefits from seed and fertiliser received from the government through the FISP at the household level. Finally, we aggregated the household-level estimates to the country level.

To obtain the counterfactual predictions, we first estimated Equation (3) using the following five data subsets with different diversification types:

1. All poor agricultural households.
2. Poor agricultural households with only one agricultural activity of crop, livestock, poultry or fish farming.
3. Poor agricultural households with any combination of at least two activities of crop, livestock, poultry and fish farming.
4. Poor agricultural households with either crop or livestock production.
5. Poor agricultural households with both crop and livestock production.

Next, we take the following steps to obtain the baseline predictions for the 2015 total agricultural value added under each of the five diversification scenarios above. First, we compute the fitted agricultural value added per worker evaluated for the year 2015 for all poor households. Second, we multiply the mean fitted value by the product of the average number of agricultural workers in a poor agricultural household for 2015 by the total number of poor agricultural households.

[2] Hybrid maize is non-traditional maize. It is a high-yielding, early-maturing or disease-resistant type of maize, like Pioneer, MM604, MM10, etc. Hybrid maize that has been replanted is no longer hybrid maize and should therefore be recorded as local maize. Local maize is traditional maize, usually planted from own produce.

Table 1: Regression results on agricultural productivity of poor households

Dependent variable: Log of agricultural value added per worker	Agricultural activities			Farm type		
	All poor households	Only one activity	2-4 activities	All poor households	Either crops or livestock	Both crops and livestock
2-4 activities (relative to "Only one activity")	0.165*** (< 0.001)					
Both crops and livestock (relative to "Either crops or livestock")				0.641*** (< 0.001)		
Drought occurrence	-0.243*** (< 0.001)	-0.269*** (0.001)	-0.212*** (< 0.001)	-0.256*** (< 0.001)	-0.295*** (0.002)	-0.194*** (0.005)
Flood occurrence	-0.234*** (0.008)	-0.329*** (< 0.001)	-0.176** (0.035)	-0.222** (0.027)	-0.385 (0.122)	-0.081 (0.234)
Farmland: Quintile 2 (relative to quintile 1)	0.175 (0.158)	0.193** (0.041)	0.179 (0.208)	0.153 (0.248)	0.208 (0.212)	0.003 (0.98)
Farmland: Quintile 3 (relative to quintile 1)	0.425*** (0.001)	0.512*** (< 0.001)	0.400*** (0.007)	0.340*** (0.008)	0.460*** (0.001)	0.104 (0.428)
Farmland: Quintile 4 (relative to quintile 1)	0.846*** (< 0.001)	0.791*** (< 0.001)	0.900*** (< 0.001)	0.726*** (< 0.001)	0.835*** (< 0.001)	0.522*** (< 0.001)
Farmland: Quintile 5 (relative to quintile 1)	1.562*** (< 0.001)	1.300*** (< 0.001)	1.655*** (< 0.001)	1.408*** (< 0.001)	1.434*** (< 0.001)	1.236*** (< 0.001)
Hybrid maize producer	0.532*** (< 0.001)	0.498*** (< 0.001)	0.548*** (< 0.001)	0.499*** (< 0.001)	0.525*** (< 0.001)	0.468*** (< 0.001)
Farmer Input Support Program (FISP)	0.223*** (< 0.001)	0.323*** (0.001)	0.190*** (< 0.001)	0.181*** (< 0.001)	0.431*** (< 0.001)	0.047 (0.318)
Household head: Age	0.031*** (0.004)	0.040** (0.018)	0.024*** (0.001)	0.026** (0.019)	0.026* (0.054)	0.024** (0.023)
Household head: Age^2	-0.000*** (< 0.001)	-0.001*** (0.002)	-0.000*** (< 0.001)	-0.000*** (0.001)	-0.000*** (0.004)	-0.000*** (0.004)
Household head: Male	0.079 (0.113)	0.041 (0.639)	0.077*** (0.007)	0.071 (0.139)	0.052 (0.419)	0.094** (0.04)
Year 2015 (relative to year 2010)	0.345*** (< 0.001)	0.492*** (< 0.001)	0.245*** (< 0.001)	0.441*** (< 0.001)	0.568*** (< 0.001)	0.291*** (< 0.001)
Rural area (relative to urban area)	-0.577*** (< 0.001)	-0.702*** (< 0.001)	-0.450*** (< 0.001)	-0.646*** (< 0.001)	-0.690*** (< 0.001)	-0.566*** (< 0.001)
Province: Copperbelt (relative to Central)	0.117** (0.019)	0.126 (0.456)	0.096 (0.438)	0.136** (0.039)	0.295** (0.023)	0.021 (0.883)
Province: Eastern (relative to Central)	-0.418*** (< 0.001)	-0.466*** (< 0.001)	-0.398*** (< 0.001)	-0.407*** (< 0.001)	-0.269*** (< 0.001)	-0.460*** (< 0.001)
Province: Luapula (relative to Central)	-0.584*** (< 0.001)	-0.720*** (< 0.001)	-0.720*** (< 0.001)	-0.594*** (< 0.001)	-0.664*** (< 0.001)	-0.506*** (< 0.001)

Dependent variable: Log of agricultural value added per worker	**Agricultural activities**			**Farm type**		
	All poor households	**Only one activity**	**2-4 activities**	**All poor households**	**Either crops or livestock**	**Both crops and livestock**
Province: Lusaka (relative to Central)	-0.049 (0.348)	-0.049 (0.402)	-0.049 (0.402)	0.082 (0.146)	0.050 (0.799)	0.201* (0.091)
Province: Northern (relative to Central)	-0.427*** (< 0.001)	-0.427** (0.046)	-0.427** (0.046)	-0.411*** (< 0.001)	-0.370*** (0.001)	-0.434*** (< 0.001)
Province: North Western (relative to Central)	0.023 (0.586)	-0.039 (0.797)	-0.039 (0.797)	0.079* (0.084)	0.166* (0.076)	-0.023 (0.765)
Province: Southern (relative to Central)	-0.429*** (< 0.001)	-0.483** (0.011)	-0.483** (0.011)	-0.409*** (< 0.001)	-0.459*** (0.005)	-0.377*** (< 0.001)
Province: Western (relative to Central)	-0.332*** (< 0.001)	-0.705*** (< 0.001)	-0.705*** (< 0.001)	-0.283*** (< 0.001)	-0.315*** (0.003)	-0.168*** (0.002)
Constant	5.176*** (< 0.001)	5.169*** (< 0.001)	5.169*** (< 0.001)	5.160*** (< 0.001)	5.058*** (< 0.001)	6.005*** (< 0.001)
Gamma (Skewness coefficient)	-0.179*** (0.002)	-0.200*** (0.009)	-0.200*** (0.009)	-0.150*** (0.004)	-0.196*** (< 0.001)	-0.061 (0.335)
Ln(sigma)	0.435*** (< 0.001)	0.473*** (< 0.001)	0.473*** (< 0.001)	0.416*** (< 0.001)	0.533*** (< 0.001)	0.282*** (< 0.001)
Wald χ^2 (*d.f.* = 22 for pool data models, and 21 otherwise)	2 149.414 (< 0.001)	572.212 (< 0.001)	572.212 (< 0.001)	2 478.836 (< 0.001)	841.350 (< 0.001)	1 004.607 (< 0.001)
Number of observations	7 678	2 537	2 537	7 678	3 437	4 241

Notes: Authors' estimates using household-level data from the LCMS 2010 and 2015. This table reports the impacts of drought and flood on the agricultural productivity of poor agricultural households with and without diversification. The four agricultural activities are the production of crops, livestock, poultry and fish farming. Coefficients are the estimates of the skew-normal regression of agricultural value added per worker. Cluster robust *p*-values are in parentheses (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$).

We also computed the counterfactual predictions to explore the potential impacts of the adoption of hybrid maize and agricultural assistance from the FISP on agricultural value added under each diversification scenario. To accomplish this, we took the same steps as in the baseline calculation and first estimated the total agricultural value added of all poor households with the counterfactual data of all households producing hybrid maize and receiving FISP assistance respectively. We then subtracted the baselines from the counterfactual predictions to obtain the effects of the potential policy interventions.

Lastly, we explore how policy interventions could mitigate the adverse impact of droughts and floods. For this, we first multiplied the baseline predictions by the regression coefficients for drought and flood for each diversification scenario respectively to estimate the impact of the extreme event. We then subtracted the intervention effects from the impact of the extreme event under all combinations of policy options. We also computed the percentage effects of extreme events and policy interventions on agricultural productivity to make them comparable across the diversification scenarios.

4. Results

Drought is the most common weather shock at the national level. Based on the LCMS, about 39% of poor agricultural households reported experiencing drought shocks in 2015, while only 7% experienced drought in 2010. Flood experience was reported by 9% and 2% of the poor agricultural households in 2010 and 2015 respectively.

The descriptive statistics show that the diversification of agricultural activities is somewhat limited in Zambia. About 37% of the poor agricultural households in Zambia relied solely on one kind of agricultural production in 2015. On the other hand, there were increasing trends for hybrid maize production and FISP assistance. The fraction of poor farm households producing hybrid maize increased from 27% in 2010 to 46% in 2015. Similarly, the fractions receiving FISP increased from 11% in 2010 to 26% in 2015.

Agricultural value added per worker of farm households with at least two agricultural activities or both crop and livestock production is higher than of those with only one agricultural activity or either crop or livestock production. The two-sample Kolmogorov-Smirnov tests for equality of distribution functions and the graphical illustrations in the Appendix (Figure A1) reveal that a higher degree of agricultural diversification is associated with higher productivity. Moreover, from the regression analysis, we find that agricultural diversification significantly improves poor farmers' productivity, especially if their farm type is both crop and livestock production, as shown in Table 1.

The regression results show that the impact of drought and flood on agricultural productivity are heterogeneous across types of extreme events and different levels of diversification. Drought has significant negative impacts on agricultural value added per worker of poor farm households, but agricultural diversification can mitigate the impacts of drought. For instance, drought occurrence could lead to a reduction of about 29% in agricultural value added per worker for poor farmers who produce either crops or livestock, while the adverse impact decreases to only an 18% reduction for those who produce both crops and livestock. We also find that agricultural diversification could potentially alleviate the negative economic shock of flood on poor farm households, but the relationship is not as robust as drought.

The regression coefficients for the quintile dummies of farmland size indicate an increasing return to scale. In other words, farmers earn more productivity at an increasing rate as they increase their farmland size. We observe significant positive effects of the adoption of hybrid maize on agricultural productivity. This could be because hybrid maize has a higher yield per hectare than traditional maize and thus, coupled with remunerative selling prices, could generate more income. Being a hybrid maize producer could lead to an increase of around 50% in agricultural value added per worker. We also find that the FISP subsidy has positive impacts on agricultural productivity. The age of the household head has a decreasing return to scale, but the gender of the household head does not have a statistically significant association with agricultural value added. Poor farmers in rural areas have significantly lower productivity than those in urban areas, perhaps because of less access to output and input markets and irrigation systems.

The effects of agricultural diversification, policy interventions and extreme weather events on the 2015 total agricultural value added are summarised in Tables 2 and 3. The baseline prediction for the 2015 total agricultural value added of all poor households with the actual diversification practice in Zambia is 1 973 million Zambian kwacha (ZMK) (equivalent to USD 229 million in 2015). Other baselines in the first row of Table 2 are for poor households with only one agricultural activity, at least two activities, either crop or livestock production, and both crop and livestock production respectively. If all poor farm households shift their agricultural diversification to produce both crops and livestock, the 2015 total agricultural value added would increase significantly, to 2 623 million ZMK (equivalent to USD 304 million). Additionally, if all poor agricultural households from the baseline in the actual agricultural diversification scenario produce hybrid maize with all other things held constant, the 2015 total agricultural value added would increase to 3 021 million ZMK, which is equivalent to a 53% increase from the baseline. Furthermore, if all poor agricultural households from the baseline in the actual agricultural diversification scenario produce hybrid maize and receive assistance benefits from the FISP, with all other things held constant, the total agricultural value added of all poor households would increase to 3 460 million ZMK, which is equivalent to a 75% increase from the baseline.

The economic impacts of droughts and floods are substantial according to the estimated coefficients from econometric regressions for different diversification scenarios. Comparing the estimated percentage reductions in total agricultural value added in Table 3, we find that agricultural diversification could considerably mitigate the negative economic shocks. For example, drought and flood could wipe out the agricultural value added by 30% and 39% respectively, in the scenario of all poor agricultural households producing either crops or livestock. On the other hand, the negative impacts of drought and flood reduce to 19% and 8% decreases respectively if all poor agricultural households produce both crops and livestock.

Furthermore, the counterfactual predictions indicate that producing hybrid maize can compensate economic losses from drought and flood. For example, with the actual agricultural diversification, drought reduced the nation's total agricultural value added of all poor households by 480 million ZMK in 2015 (equivalent to USD 56 million) in Table 2, or by 24% in Table 3. However, if all poor agricultural households produce hybrid maize, the negative impacts are compensated for and the total agricultural value added would increase to 569 million ZMK in 2015 (equivalent to USD 66 million), which is equivalent to a 19% increase. While the total agricultural value added decreases due to drought, the reduction is mitigated by hybrid maize production, as well as by seed and fertiliser assistance from the FISP.

Table 2: Predicted effects of diversification, policy interventions and extreme weather events on the 2015 total agricultural value added of poor households in Zambia (2015 million ZMK)

	Actual agricultural diversification	Agricultural activities		Farm type	
		Only one activity	2-4 activities	Either crops or livestock	Both crops and livestock
2015 total agricultural value added of all poor households					
Baseline	1 973	1 860	1 988	1 514	2 623
Baseline + FISP	2 412	2 460	2 367	2 167	2 747
Baseline + hybrid maize	3 021	2 787	3 078	2 309	3 852
Baseline + FISP + hybrid maize	3 460	3 387	3 456	2 962	3 976
Benefits from policy interventions					
FISP	439	600	378	653	124
Hybrid maize	1 049	927	1 090	795	1 229
FISP + hybrid maize	1 488	1 527	1 468	1 448	1 353
Impact of extreme events: Baseline					
Drought	-480	-501	-421	-447	-508
Flood	-462	-612	-349	-583	-212
Impact of extreme events: Baseline + FISP					
Drought	-41	99	-43	206	-383
Flood	-22	-12	29	70	-87
Impact of extreme events: Baseline + hybrid maize					
Drought	569	426	668	349	721
Flood	587	315	740	212	1 017
Impact of extreme events: Baseline + FISP + hybrid maize					
Drought	1 008	1 026	1 047	1 002	845
Flood	1 026	915	1 118	865	1 142

Table 3: Predicted effects of diversification, policy interventions and extreme weather events on the 2015 total agricultural value added of poor households in Zambia (percentage)

	Actual agricultural diversification	Agricultural activities		Farm type	
		Only one activity	2-4 activities	Either crops or livestock	Both crops and livestock
Benefits from policy interventions					
FISP	22%	32%	19%	43%	5%
Hybrid maize	53%	50%	55%	53%	47%
FISP + hybrid maize	75%	82%	74%	96%	52%
Impact of extreme events: Baseline					
Drought	-24%	-27%	-21%	-30%	-19%
Flood	-23%	-33%	-18%	-39%	-8%
Impact of extreme events: Baseline + FISP					
Drought	-2%	4%	-2%	10%	-14%
Flood	-1%	0%	1%	3%	-3%
Impact of extreme events: Baseline + hybrid maize					
Drought	19%	15%	22%	15%	19%
Flood	19%	11%	24%	9%	26%
Impact of extreme events: Baseline + FISP + hybrid maize					
Drought	33%	37%	34%	43%	22%
Flood	34%	33%	36%	37%	30%

5. Discussion and conclusion

Our main findings from the regression analyses are three-fold. First, a higher degree of agricultural diversification of poor farm households leads to higher productivity and economic benefits for the country. Second, agricultural diversification is a strategy for poor farm households to escape from poverty and mitigate the adverse impact of droughts and floods. Third, policy interventions such as hybrid maize promotion and seed and fertiliser assistance also help Zambian farmers cope with the adverse impacts of droughts and floods.

We can draw a few policy implications from these findings. First, increasing agricultural diversification could promote more resilient agricultural development for the country, with positive effects on poor agricultural households. Second, researchers and policymakers need to respond to the country's need to improve farmers' productivity via climate-smart agricultural diversification and extension services in an effective and timely manner, and encourage farmers to apply modern inputs in a more effective and productive way that raises their returns and strengthens their resilience. Third, better access to rural credit markets, especially with respect to modern agricultural input use, would help poor farmers build more resilience to weather shocks and climate change.

There are huge uncertainties about how climate change will influence agricultural and food production, both directly and indirectly, and the related vulnerabilities of farm households in Zambia and other countries. Building resilience now is central to being prepared for future changes and uncertainties. It is thus crucial to increase the adaptive capacity of farmers to be prepared for changes and to recover from shocks. At the same time, there is a need to sustainably increase farm productivity and income to help the poor escape poverty. Therefore, it also becomes vitally important for the resilience policies and strategies to increase agricultural productivity in order to secure enough food for the growing population.

This study is subject to some limitations. A limited set of years is used to study the effects of droughts and floods because the LCMS for previous years does not include data on the incidences of droughts and floods. Better estimates might arise using repeated cross-sectional data for a longer period, or panel household data. Due to limited data availability, our analysis cannot incorporate the distance to main roads or input and output markets to control for heterogeneity in market accessibility. Future research could improve the analysis with better data and alternative models and estimators. For instance, the effects of the actual weather variables, such as temperature, precipitation and counts of extremely hot and wet days, on the mean regressions could be explored. Despite the limitations, this study adds value to the literature by presenting findings on the linkage between agricultural diversification and the economic resilience of poor households, and extreme weather events in Zambia.

Acknowledgements

We thank Christian Lovell, for research assistance; the seminar participants at the American Evaluation Association 2017 conference, the Climate Investment Funds (CIF) Evaluation and Learning (E&L) Initiative TCLP 2018 workshop, the Impacts of Climate Change on Food Security, Environment, and Economy 2019 meeting; as well as the editor and two anonymous referees for helpful discussions and comments on earlier drafts. We thank the CIF E&L and the World Bank Pilot Program for Climate Resilience (PPCR), for financial support. Chonabayashi thanks Cornell University for support and hospitality. Jithitikulchai acknowledges kind support and warm hospitality from the Takemi Program in International Health while visiting the Harvard T.H. Chan School of Public Health. The views expressed here do not necessarily reflect those of the World Bank or their member countries. All errors and opinions are our own.

References

Arslan A, Belotti F, Asfaw S, Karfakis P & Lipper L, 2016. Welfare impacts of climate shocks: Evidence from Tanzania. ESA Working Paper No. 16-04, FAO. Rome, Italy.

Asfaw S, Carraro A, Davis B, Handa S & Seidenfeld D, 2016. Cash transfer programmes for managing climate risk: Evidence from a randomized experiment in Zambia. In 2016 Fifth International Conference of the African Association of Agricultural Economists (AAAE), 23–26 September, Addis Ababa, Ethiopia.

Azzalini A, 1985. A class of distributions which includes the normal ones. Scandinavian Journal of Statistics 12(2): 171–8.

Azzalini A & Capitanio A, 1999. Statistical applications of the multivariate skew normal distribution. Journal of the Royal Statistical Society: Series B (Statistical Methodology) 61(3): 579–602.

Azzalini A & Dalla Valle A, 1996. The multivariate skew-normal distribution. Biometrika 83(4): 715–26.

Binswanger-Mkhize HP & Savastano S, 2017. Agricultural intensification: The status in six African countries. Food Policy 67: 26–40.

Bryan E, Ringler C, Okoba B, Roncoli C, Silvestri S & Herrero M, 2013. Adapting agriculture to climate change in Kenya: Household strategies and determinants. Journal of Environmental Management 114: 26–35.

D'Alessandro S, Caballero J, Lichte J & Simpkin S, 2015. Kenya: Agricultural Sector Risk Assessment. Agricultural Global Practice Technical Assistance Paper, The World Bank, Washington DC.

Damania R, Desbureaux S, Hyland M, Islam A, Moore S, Rodella A, Russ J & Zaveri E, 2017. Uncharted waters: The new economics of water scarcity and variability. Washington DC: The World Bank.

De la Fuente A, Murr A & Rascón E, 2015. Mapping subnational poverty in Zambia. Washington DC: World Bank.

Dercon S & Christiaensen L, 2011. Consumption risk, technology adoption and poverty traps: Evidence from Ethiopia. Journal of Development Economics 96(2): 159–73.

Funder M, Mweemba CE & Nyambe I, 2013. The climate change agenda in Zambia: National interests and the role of development cooperation. DIIS Working Paper No. 2013:13, Copenhagen, Denmark.

Gannon C, Kandy D, Turner J, Kumar I, Pilli-Sihvola K & Chanda FS, 2014. Near-term climate change in Zambia. The Hague: Red Cross/Red Crescent Climate Centre.

Gupta AK & Chen T, 2001. Goodness-of-fit tests for the skew-normal distribution. Communications in Statistics – Simulation and Computation 30(4): 907–30.

Hallegatte S, Bangalore M, Bonzanigo L, Fay M, Kane T, Narloch U, Rozenberg J, Treguer D & Vogt-Schilb A, 2016. Shock waves: Managing the impacts of climate change on poverty. Washington DC: The World Bank.

Hassan R & Nhemachena C, 2008. Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis. African Journal of Agricultural and Resource Economics 2(1): 83–104.

Henze N, 1986. A probabilistic representation of the 'skew-normal' distribution. Scandinavian Journal of Statistics (13(4): 271–5.

ILO, IMF, OECD, Eurostat, UNECE, World Bank, 2004. Producer price index manual: Theory and practice. Washington DC: International Monetary Fund.

IPCC, 2014. Climate change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Geneva, Switzerland.

Lipper L, McCarthy N, Zilberman D, Asfaw S & Branca G, 2018. Climate smart agriculture: Building resilience to climate change. Cham, Switzerland: Springer.

Lobell DB, Schlenker W & Costa-Roberts J, 2011. Climate trends and global crop production since 1980. Science 333(6042): 616–20.
Makano R, 2011. Forests and climate change: Integrating climate change issues into national forest programmes and policy frameworks. Background paper on climate change issues, FAO, Zambia.
Mano R & Nhemachena C, 2006. Assessment of the economic impacts of climate change on agriculture in Zimbabwe: A Ricardian approach. CEEPA Discussion Paper No. 11, Centre for Environmental Economics and Policy in Africa, University of Pretoria, South Africa.
McCarthy N, 2011. Understanding agricultural households' adaptation to climate change and implications for mitigation: Land management and investment options. Washington DC: LEAD Analytics Inc.
McCullough E, 2017. Labour productivity and employment gaps in Sub-Saharan Africa. Food Policy 67: 113–52.
Mendelsohn R, Dinar A & Williams L, 2006. The distributional impact of climate change on rich and poor countries. Environment and Development Economics 11(2): 159–78.
Kala N, Kurukulasuriya P & Mendelsohn R, 2012. The impact of climate change on agro-ecological zones: Evidence from Africa. Environment and Development Economics 17(6): 663–87.
Nagler P & Naudé W, 2017. Non-farm entrepreneurship in rural sub-Saharan Africa: New empirical evidence. Food Policy 67: 175–91.
Nhemachena C & Hassan R, 2007. Micro-level analysis of farmers adaptation to climate change in Southern Africa. International Food Policy Research Institute (IFPRI) Discussion Paper 00714, IFPRI, Washington DC.
Nhemachena C, Hassan R & Kurukulasuriya P, 2010. Measuring the economic impact of climate change on African agricultural production systems. Climate Change Economics 1(01): 33–55.
Nikoloski Z, Christiaensen L & Hill R, 2015. Household shocks and coping mechanism: Evidence from Sub-Saharan Africa. Mimeograph. Washington DC: World Bank.
Pauw K, Thurlow J & Van Seventer D, 2010. Droughts and floods in Malawi: Assessing the economywide effects. Washington DC: International Food Policy Research Institute (IFPRI).
Skoufias E, 2012. The poverty and welfare impacts of climate change: Quantifying the effects, identifying the adaptation strategies. Washington DC: The World Bank.
Thurlow J, Zhu T & Diao X, 2012. Current climate variability and future climate change: Estimated growth and poverty impacts for Zambia. Review of Development Economics 16(3): 394–411.
United Nations Development Programme (UNDP), 2010. Adaptation to the effects of drought and climate change in agro-ecological Zone 1 and 2 in Zambia. Project document, UNDP, New York NY.
World Bank, 2014. Turn down the heat: Confronting the new climate normal. Washington DC: The World Bank.
World Bank, 2015. The methodology for consumption-poverty estimation and poverty trends in Zambia in 2010-2015. Internal draft paper. Washington DC: The World Bank.
World Bank, 2017. Growing the rural non-farm economy to alleviate poverty. Washington DC: The World Bank.

Appendix

Table A1: Mean and standard deviation of key variables

Variables	All households	Households with agricultural activities		Households with farm type	
		Only one activity	2 to 4 activities	Either crops or livestock	Both crops and livestock
Agricultural value added per worker (2015 Zambian kwacha)	2 716 (39 712)	2 045 (30 438)	3 029 (43 359)	2 851 (45 956)	2 606 (33 772)
At least two activities (relative to "only one activity")	0.68 (0.47)	0.00 (n.a.)	1.00 (0.00)	0.50 (0.50)	0.83 (0.38)
Both crops and livestock (relative to "either crops or livestock")	0.55 (0.50)	0.30 (0.46)	0.67 (0.47)	0.00 (n.a.)	1.00 (0.00)
Drought occurrence	0.22 (0.41)	0.20 (0.40)	0.23 (0.42)	0.23 (0.42)	0.22 (0.41)
Flood occurrence	0.06 (0.23)	0.06 (0.24)	0.05 (0.22)	0.06 (0.24)	0.05 (0.23)
Hybrid maize producer	0.36 (0.48)	0.29 (0.46)	0.40 (0.49)	0.30 (0.46)	0.42 (0.49)
Farmer Input Support Program (FISP)	0.18 (0.39)	0.16 (0.36)	0.19 (0.40)	0.14 (0.35)	0.22 (0.41)
Household head: age	43.9 (14.6)	42.9 (15.4)	44.4 (14.2)	43.9 (15.3)	44.0 (14.0)
Household head: male	0.80 (0.40)	0.76 (0.43)	0.81 (0.39)	0.77 (0.42)	0.82 (0.39)
Year 2015 (relative to year 2010)	0.47 (0.50)	0.55 (0.50)	0.44 (0.50)	0.56 (0.50)	0.40 (0.49)
Rural area (relative to urban area)	0.96 (0.19)	0.93 (0.25)	0.98 (0.14)	0.95 (0.22)	0.98 (0.15)
Number of observations	7 678	2 537	5 141	3 437	4 241

Notes: Final household sample from the LCMS 2010 and 2015 for all analyses in this paper. Standard deviations are in parentheses. n.a. = not applicable

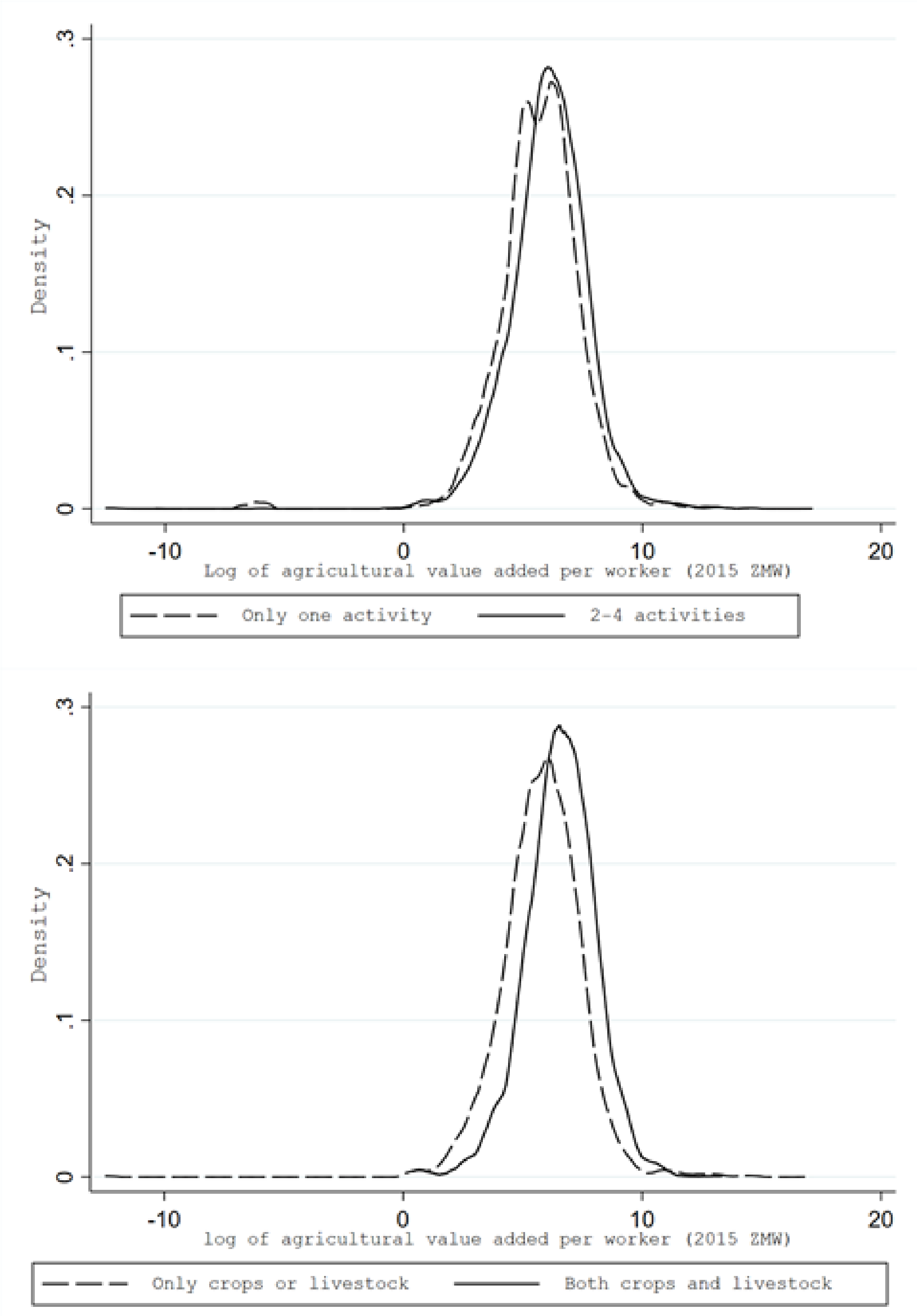

Figure A1: Kernel density estimation of log of agricultural value added per worker (2015 ZMW)