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Abstract

Households living in rural areas of developing countries rely on rain-fed agriculture for their livelihoods and, as such, are highly dependent on climatic conditions. This paper aims at presenting empirical evidence from Zambia to better understand the linkages between climatic shocks, livelihood diversification and welfare outcomes with the goal of highlighting potential policy entry points to incentivize the types of diversification aimed at improving food security and resilience to climate shocks. We also investigate the role of different institutions in shaping diversification decisions to shed some light into potential policy levers at institutional level. We analyze diversification of crops, livestock and income using nationally representative household data from 2012 Rural Agricultural Livelihoods Survey (RALS), merged with data on historical rainfall and temperature as well as with administrative data on relevant institutions. We find that the long-term variation in growing period rainfall pushes households into livestock diversification, whereas the effect of this variable on income diversification is negative. This indicates that households fall back to subsistence maize cultivation in the face of unpredictable rainfall and suggests a lack of other *ex-ante* risk management strategies available to rural households. We also find that smallholders and female-headed households diversify significantly less, providing suggestive evidence for targeting policies that aim to diversify rural livelihood portfolios. Most rural institutions do not have a significant effect on incentives to diversify under high rainfall variability environments, pointing towards a lost opportunity to use these institutions in incentivizing diversification as a way of decreasing vulnerability.

Keywords: Diversification, climate smart agriculture, risk management, Zambia.

JEL codes: O13, Q01, Q12, Q16.

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1 Introduction

Livelihood diversification strategies are implemented by households in rural environments as a response to threats and opportunities to manage risk and increase or stabilize income and consumption. Most households in rural areas of developing countries rely on rain-fed agriculture for their livelihoods and, as such, are highly dependent on climatic conditions. Recent evidence and projections indicate that global climate change is likely to increase the incidence of natural hazards, including the variability of rainfall, temperature and occurrences of climatic shocks (IPCC, 2014). As a consequence, all aspects of food security may be potentially threatened by the effects of changes in climate, including food availability, access, utilization, and stability (e.g., Challinor *et al*., 2010; IPCC, 2014). In this context, diversification strategies play a crucial role in ensuring food security under climate change, as they have the potential to address two of the Climate-Smart Agriculture (CSA) pillars by contributing to food security and adaptation to climate change.[1]

Economic theory, however, suggests that there may be potential tradeoffs between food security and adaptation (i.e. between risk and return) specifically related to diversification behaviour. The potential for tradeoffs and synergies depends on the type of diversification in question and the factors that drive it including climatic and institutional factors. In this paper, we present the results of a comprehensive study on the drivers of diversification as well as its relationship with selected welfare outcomes with a specific attention to climatic variables and institutions.

We first provide an overview of the literature on livelihood diversification, vulnerability and climate change to situate diversification in the CSA agenda. We then present empirical evidence from Zambia to better understand the linkages between climate shocks, diversification and welfare outcomes with a goal to highlight potential policy entry points to incentivize the types of diversification that help households to improve food security and become resilient to climate shocks. We close with a synthesis of results and policy implications.

[1] CSA is an approach to agricultural development policy making that promotes sustainable increases in productivity, while building resilience (adaptation) to climate change and reducing/removing greenhouse gas emissions (mitigation) where possible, in order to achieve national food security and development goals. http://www.fao.org/climate-smart-agriculture/en

2 Concepts in the literature

2.1 Livelihood diversification and vulnerability

Diversification strategies in the presence of imperfect information and risk are acknowledged among the most fundamental theoretical insights in economics. Household models assuming expected utility maximization see diversification as a form of risk aversion, even when credit and insurance markets function (Alderman and Paxson, 1992). Such behavior may apply to many sectors (e.g., finance, industrial production), but the particularities of agricultural production (seasonality in demands for inputs, heterogeneity in land quality or spatial constraints on allocation of resources, dependence on weather patterns) set it apart from other sectors. Specifically, diversification in agricultural production can arise even if we assume no risk or under conditions where specialization would be expected (Just and Pope, 2001; Alderman and Sahn, 1989; Pope and Prescott, 1980). The conditions that lead to diversification are further amplified in rural economies where credit and insurance markets are missing or are imperfect, as diversification takes on a role to fill in the risk-management needs left unmet by these markets (Binswanger, 1983; Reardon, 1997).

Agricultural households in rural economies can adopt diversification leading to better risk-management and smoother income streams ex-ante (Smit and Wandel, 2006), but also as an involuntary ex-post short-term adjustment to smooth consumption in the wake of shocks or crisis, when ex-ante risk mitigation strategies are insufficient (Davies, 1993; Murdoch 1995). The ability of a livelihood system to respond to shocks through coping strategies is thus a key determinant of livelihood resilience and vulnerability, together with ex-ante risk mitigation (Adger, 1999; Bryceson 1996, 1999; Delgado and Siamwalla 1999; Toulmin et al., 2000; Barrett et al., 2001a Adger et al., 2005; Folke, 2006).

These two types of diversification can be on farm (e.g., planting a crop or variety mix, or combining crop and livestock operations) or off farm (e.g., differentiating income sources through wage employment on other farms or in other sectors, starting own business or migration of a household member). The classifications along on-farm vs. off-farm activities are still used in the literature despite Barret's (2001) calls for a unified diversification classification along sectoral and spatial lines. Regardless of the terminology, what matters is that the returns to the chosen bundle of assets, activities and incomes should ideally be perfectly negatively correlated or just not perfectly correlated with each other to be able to act as a smoothing strategy.

The extensive literature on the drivers of diversification tends to classify the drivers into push and pull factors (Reardon, 1997; Barret and Reardon 2000). Push factors include imperfect credit and insurance markets, stagnation in the agricultural sector, high transaction costs, as well as adverse shocks, hence the diversification that is driven by them need not necessarily improve average incomes (Barrett et al., 2001a; Reardon et al., 2007; Lay et al., 2009). Pull factors, on the other hand, include a booming non-farm sector or new/improved technologies in the farm sector, which lead to diversification that is more likely correlated with improved average outcomes, as well as reduced variability of those outcomes (Reardon et al. 2007; Bandyopadhyay and Skoufias, 2013).

When pull factors dominate, livelihood diversification can be a phase in the transition from subsistence to commercial agriculture or non-farm activities, and implicitly a transition out of poverty (Pingali and Rosengrant, 1995). Pull factors, however, tend to dominate for wealthier and more educated households, or in areas where access to markets, infrastructure and urban centers are better (Lanjouw et al., 2001; Fafchamps and Shilpi, 2003, 2005; Deichmann et al., 2008; Babatunde and Qaim, 2009; Davis et al., 2010; Losch et al. 2011). Most empirical evidence on rural households in Sub-Saharan Africa suggests that pull factors dominate for income and labour diversification, so that wealth, education and access to densely populated areas are correlated with higher labour and income diversification, whereas poverty is correlated with higher crop diversification and lower income and labour diversification (Barrett et al., 2001a; Lanjouw et al., 2001; Babatunde and Qaim, 2009; Dimova and Sen, 2010; Asmah, 2011). Though more difficult to establish due to endogeneity issues, the empirical evidence also suggests that more diversified households have higher incomes and greater consumption per capita (Ersado, 2003; Babatunde and Qaim, 2009; Asmah, 2011).

A better understanding of the factors driving diversification by rural households would therefore provide insights into the role of diversification in poverty reduction, food security and development. It would also help design policies that explicitly address diversification as possible determinants of future levels of welfare and foster institutions to support welfare-improving diversification (Barrett et al., 2001b).

The relationship between diversification and vulnerability at the household level seems conceptually clear at first: as the motivation to spread risk over multiple activities is at the heart of diversification, vulnerability should decline as diversification increases. However, while this may be true for deliberate ex-ante diversification that leads to less variable incomes, the opposite may be true for forced or ex-post diversification (Barrett et al., 2001a; Bandyopadhyay and Skoufias, 2013). Here we have just defined vulnerability with variability in incomes; however, there are multitudes of vulnerability definitions and measures that complicate the issue even further (Moret, 2014). Disentangling the cause and effect linkages between diversification and vulnerability is very difficult given the dynamic relationships between them: while the more vulnerable may be more likely to diversify today to prevent negative effects of shocks in the future, the fact that they diversify may allow them to build-up assets/human capital that leads them to be less vulnerable in the future. This difficulty is amplified in the absence of longitudinal data covering an identifiable shock (idiosyncratic or systemic) to track the patterns of household diversification and welfare outcomes over time. Empirical analyses of these complex relationships based on cross-sectional data, therefore, need to be very careful in attributing causality, as in the case studies presented in this paper.

2.2 How does climate change enter the picture?

Agriculture is exposed to various forms of risk ranging from weather variability and pests and diseases to price volatility in output, input and factor markets. For agricultural households that rely on rainfall and face imperfect market conditions, these risks take greater prominence as they lack the means to manage risk effectively (e.g. by investing in irrigation, buying insurance or using credit to smooth income and consumption). Climate change compounds these risks by increasing the probability and severity of unfavourable weather conditions that affect the livelihoods of households in various ways. Direct effects may include drops in agricultural productivity (crops, livestock, fisheries and forestry), while indirect effects may include decreasing demand for labour, increased local prices, and decreased access to markets due to negative impacts on infrastructure. Climate change not only decreases today's incomes, but also makes tomorrow's incomes less predictable by changing the probability distributions in ways that are difficult for households to incorporate into their decision-making (Lipper & Thornton 2014).

Climate change is expected to have generally negative effects on developing-country agriculture, and hence on food security. Climate shocks such as drought, flooding, and extreme temperatures are expected to increase in frequency and intensity, and these impacts are projected to increase over time (Nelson and van der Mensbrugghe 2013, IPCC 2012). In the absence of measures to reduce the vulnerability to, and impacts of, such extreme events, they can be expected to generate significant negative impacts on food security (FAO 2010; Foresight 2011).

The impacts of climate change can be generally classified as push factors for diversification as risk-averse farmers implement ex-ante risk management strategies (by diversifying crops, other agricultural activities or incomes) and trade a part of their expected earnings with a lower variability in income (Alderman and Paxson, 1992; Reardon et al., 1998; 2007; Barrett et al., 2001a). While climate variability associated with farm-income variability is already recognized as one of the main drivers of diversification in developing countries, the above-mentioned impacts of climate change give further incentives for diversification into activities that are less susceptible to disruption from climatic shocks (Newsham and Thomas, 2009).

Empirical evidence on the role of diversification as an adaptation strategy is growing. Crop diversification is shown to help farmers deal with droughts in Nigeria (Mortimore and Adams 2001) and other shocks leading to crop failure in Ethiopia (Di Falco and Chavas 2009, Cavatassi et al. 2011), income and livelihood diversification are shown to help households deal with weather shocks in Zimbabwe and Nicaragua (Ersado 2003, Macours et al. 2012).

2.3 Diversification as CSA

The above discussion on diversification, vulnerability and climate change naturally leads to the realm of CSA, as these concepts are directly concerned with the food security and adaptation pillars of CSA. Adaptation is defined by the IPCC fourth assessment report as "the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects" (IPCC 2007). This implies a permanent change in the livelihood system leading to better risk-management or coping capacity in the long run (Smit and Wandel 2006). Diversification is one of the ways of adapting to the changes in climatic patterns and thus of building resilience to climate change at multiple levels (e.g., household, village, landscape and national), hence it is frequently mentioned in the international CSA policy discourse (FAO, 2010; FAO 2013; Campbell et al., 2014). At the national level, thirteen countries that have submitted National Adaptation Programmes of Action (out of 48) to the UNFCCC have projects explicitly on diversification (of crops, livestock, fisheries, livelihoods) as an adaptation strategy.2 Eleven out of these, are in Sub-Saharan Africa (SSA), where about 30-50 *percent* of rural households rely on non-farm income for their total income (Ellis, 1998; Reardon, 1997; Reardon et al., 1998).3 Many countries in SSA, including Zambia, have also made diversification part of their national agricultural investment strategies/plans and aim to build the necessary enabling environment to support the types of diversification that build resilience.

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[2] United Nations Framework Convention on Climate Change (UNFCCC) established a work programme for least developed countries (LDC) in 2001 that include national adaptation programmes of action (NAPA), to support LDCs to address the challenge of climate change given their particular vulnerability. NAPAs provide a process for LDCs to identify priority activities that respond to their urgent and immediate needs to adapt to climate change – those for which further delay would increase vulnerability and/or: http://unfccc.int/adaptation/workstreams/national_adaptation_programmes_of_action/items/7572.php

[3] http://unfccc.int/adaptation/workstreams/national_adaptation_programmes_of_action/items/4583.php

The ideal enabling environment for diversification choices would consist of institutions and markets that turn push factors into pull factors by facilitating higher income levels with lower levels of variability under expected climatic shocks. For example, while households may diversify their crops by incorporating legumes into maize plots to buffer maize from rainfall and temperature shocks (especially when inorganic fertilizer use is negligible), this strategy may yield to lower incomes if there is no established market for legumes. Improving access to markets and value chains for legumes would be a CSA strategy in this context as it would both improve incomes and make them more resilient to weather shocks. Such a strategy has also the potential to contribute to the mitigation pillar, as legume intercropping (by fixing nitrogen in the soil) would decrease the need for inorganic fertilizers, the production and inefficient use of which contribute to the emissions from agriculture. These types of mitigation potentials, however, should be considered a co-benefit only in rural environments based on small-scale agriculture, where food security and adaptation are the development priorities.

In this paper, we also investigate the role of various institutions in diversification decisions; hence, resilience and other welfare outcomes in order to shed light into potential policy levers at institutional level.

3 Empirical Evidence

In what follows, we present the results of an empirical analysis investigating the factors driving diversification and its relationship with selected vulnerability indicators in Zambia.4 Zambia already faces the negative impacts of climate change manifested in increasing frequency of droughts and floods, as well as increased temperatures (Thurlow et al., 2012; Kanyanga et al. 2013). The analysis in this paper provides an insight into the role of climatic shocks in driving diversification, vulnerability outcomes and the types of institutions that may help support diversification in rural Zambia. Given the prominence of livelihood diversification in the country's climate change and agricultural policy discourse, it provides timely information to support policies aimed at decreasing vulnerability through diversification.

3.1 Background

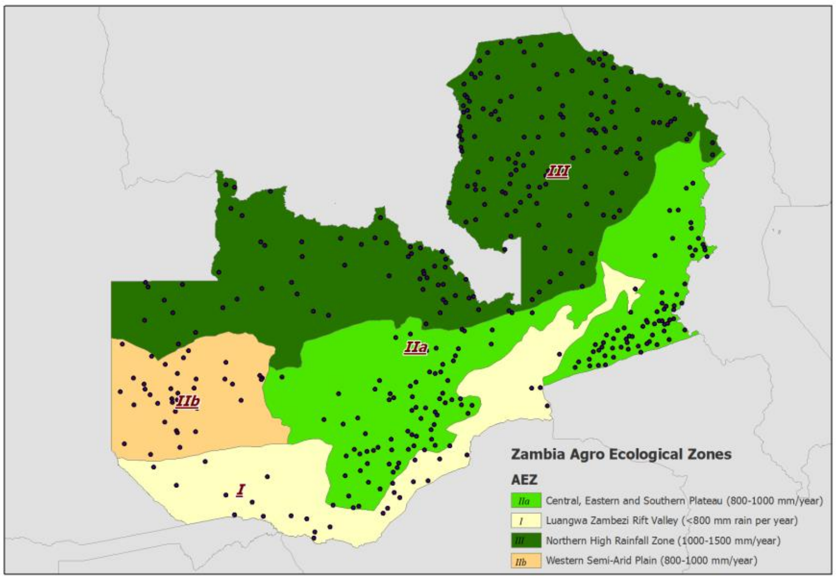
Zambia ranks 15th in the list of countries that are most vulnerable to climate change (Wheeler, 2011). The agricultural sector accounts for approximately 20 *percent* of the GDP and around 80 *percent* of the rural population lives below the poverty line (World Bank 2013; Chapoto et al. 2011). Furthermore, the fact that 64 *percent* of the total population lives in rural areas that primarily depend on rain-fed subsistence agriculture provides a glance into the rural vulnerability to various shocks, be it weather shocks or other shocks typical of the agricultural sector (input/output price shocks).

Temperatures in Southern Africa are projected to increase by 0.6-1.4°C by 2030 and by 1.5-3.5°C during 2040-2069 (Lobell et al. 2008; Kihara et al. 2015). Rainfall predictions are more ambiguous, with models suggesting either reduced or increased precipitation (Lobell et al. 2008). Regional models, however, agree more on the prediction of decreased rainfall for Southern Africa (Kihara et al. 2015).

Zambia has four distinct Agro-Ecological Regions (AER) and the predicted impacts of climate change differ across AERs (Figure 1). The western and southern parts of the country (AER I) are exposed to low, unpredictable and poorly distributed rainfall in general, whereas the central part of the country (AER IIa & b) has the highest agricultural potential, with well-distributed rainfall (Jain 2007). Zambia-specific climate models predict that rainfall will decrease and temperatures will increase in AER I and II, while rainfall will increase in the northern parts of the country (AER III) (Kanyanga et al. 2013). Combined with projections of prolonged drought and dry spells, maize production is expected to be severely affected in these regions that cover the majority of Zambia's maize growing area. Increased rainfall on the already leached soils of AER that are also acidic is expected to have a negative impact on crop production. Some of the most vulnerable parts of the country lie in the transition zones identified by Jones and Thornton (2009), where maize agriculture is expected to cease to be a "normal agricultural activity" and a transition to herding and income diversification will be necessary for adaptation.

[4] This case study forms part of the evidence base for a three-year project on CSA that was funded by the European Commission (EC) and implemented by the Economic and Policy Innovations for CSA (EPIC) programme in FAO during 2012-2015. This project was the first of its kind focused on evidence base development for policy support to CSA to improve the efficiency of policy making and targeting for sustainable improvements in food security under climate change.

Figure 1 Zambia's AER overlaid with the SEAs of the RALS data



Source: Authors' own elaborations.

It is also predicted that the climate variability will increase, which has reduced the country's economic growth by four *percent*age points over the last ten years pulling an additional two *percent* of the population into poverty (Thurlow et al., 2012). Empirical analyses show that agricultural technologies promoted in rural Zambia, including sustainable agricultural practices as well as the use of modern inputs, are not suited to deal with various shocks expected to get worse under climate change and a more tailored approach is needed to support agricultural growth and food security (Arslan et al. 2015).

The recent Zambia Vulnerability and Needs Assessment Report (VNAR) prepared as a response to prolonged droughts in the 2015 season shows that agriculture is the main income source for 60 *percent* of the population and that droughts increased food insecurity in 31 of 48 districts assessed, as around 800,000 people were in need of food relief (VAC, 2015). It was also observed that costly risk-coping mechanisms were commonly adopted in response, leading to the recommendation that "livelihood diversification programmes be scaled up to reduce dependency on agriculture based activities in view of climate shocks" (VAC, 2015). By providing detailed insight into the drivers of diversification under climate change and how institutions may help foster diversification to decrease vulnerability, this paper provides timely evidence to support policy in Zambia.

3.2 Empirical Model and Data

a. Empirical model: We model diversification outcomes at the household level as the result of household optimisation decisions subject to multiple constraints (e.g. imperfect labour, land, credit or insurance markets, and transaction costs) based on standard theoretical models of agricultural household decision making (Singh et al., 1986; de Janvry et al., 1991). Given the imperfect market conditions pervasive in rural areas of developing countries and the multiple push and pull factors explained above that drive households to diversify their income generating activities (both within the farm and off-farm sectors), the observed diversity outcomes can be modelled as functions of endowments and indicators of push and pull factors to test various hypotheses on the drivers of diversification (van Dusen and Taylor, 2005). We use the following estimating equation to understand the drivers of diversification including climatic variables as well as relevant institutions in each country:

$$D_{ij} = \beta_0 + \beta_1 C_k + \beta_2 X_i + \beta_3 G_k + \beta_4 I_d + \varepsilon_i$$

where D_{ij} is the diversification index for household i for the dimension j analysed, C_k are climatic variables at ward level, X_i are household level variables including socio-demographic characteristics and wealth and social capital indicators, G_k are variables that capture community characteristics at the ward level, and I_d are institutional variables at the district level.

Diversification can be measured along many dimensions using a variety of different indices. Given the high share of agriculture in total incomes of households in our sample (73 *percent* on average), the importance placed on diversification into livestock activities as well as diversification of livelihoods in general in the national policy (e.g., NAIP, VNAR, INDC), we measure diversification along three dimension: crops, livestock and income.5 Diversification indices in the literature range from simple count measures (Jones et al., 2014) or income shares from different sources (Lay et al. 2008; Davis et al., 2010), to more complex indices usually borrowed from biology literature (Smale, 2006), which account for evenness, abundance or both. We use the Gini-Simpson index defined as $D_{ij} = (1 - \sum_j w_{ij}^2)$, where w_{ij} is the number of distinct diversity units in the corresponding index j for household i.6 These are: (a) the area allocated to different crop species for crop diversification, (b) the contributions of different livestock species to the total livestock holdings measured by Tropical Livestock Units (TLU) for livestock diversification, and (c) the monetary shares of income sources disaggregated into six categories for income diversification (see footnote 8 on income categories).

The diversification indices described above capture the diversification within each category. Diversification into livestock is one of the main agricultural policy targets to address vulnerability in Zambia, hence understanding the variables that enable or prevent diversification is essential to guide policy. We therefore complement the analysis above by looking into the determinants of households' decisions to engage in livestock activities. This decision can be analyzed using a similar empirical specification to the one above, where the dependent variable takes the form of a binary variable capturing weather the household has any livestock or not. We separate the livestock species into ruminants and non-ruminants given the structural differences in managing these categories as well as their potential impacts on livelihoods.

b. Data sources: To estimate the models described above, we use three main data sources: i) a nationally representative household survey, ii) historical rainfall and temperature data at high resolution from publicly available data sources, and iii) administrative data on relevant institutions.

The household data come from the 2012 Rural Agricultural livelihoods Survey (RALS) collected by the Central Statistics Office (CSO) in collaboration with Michigan State University (MSU) and the Indaba Agricultural Policy Research Institute (IAPRI). The data set is nationally

[5] The income categories used are based on the IAPRI methodology of defining income sources and consist of income from crops, livestock, businesses, remittances, agricultural wages and non-agricultural wages.
[6]Count, Simpson and Berger-Parker indices were also constructed and used in analyses for robustness checks. We present results based on the Gini-Simpson index, which performed the best.

representative and includes detailed information on agriculture (crop and livestock) practices, other sources of off-farm rural activities along with household demographic characteristics as well as social capital indicators. The sample consists of more than 8,000 farmers, which are representative at the province level (and at the district level in the Eastern province) (RALS, 2012).

The RALS data were merged with a set of rainfall and temperature variables to characterise the historical trends as well as current period shocks in these variables that are closely linked with agricultural production. Rainfall variables are based on data from the Africa Rainfall Climatology version 2 (ARC2) of the National Oceanic and Atmospheric Administration's Climate Prediction Center (NOAA-CPC) for the period of 1983-2012. ARC2 data are based on the latest estimation techniques on a daily basis and have a spatial resolution of 0.1 degrees (~10km).7 Temperature variables are based on surface temperature measurements at 10 day intervals (i.e. dekad) with a resolution of 0.25 degrees (~28km) for the period of 1989-2012 generated by the European Centre for Medium-Range Weather Forecasts (ECMWF).8 We also use data from the Harmonized World Soil Database (HWSD) with a resolution of 30 arc-seconds to control for soil quality on incentives for diversification.9

Lastly, administrative data on rural institutions including extension and other sources of agricultural information, credit sources, local community groups, were collected at district level to better understand the rural institutions that play a role in household livelihood strategies. These data on the availability of rural institutions provide an opportunity to deal with the endogeneity issue in self-reported information on access to institutions from household surveys.

3.3 Descriptive analysis

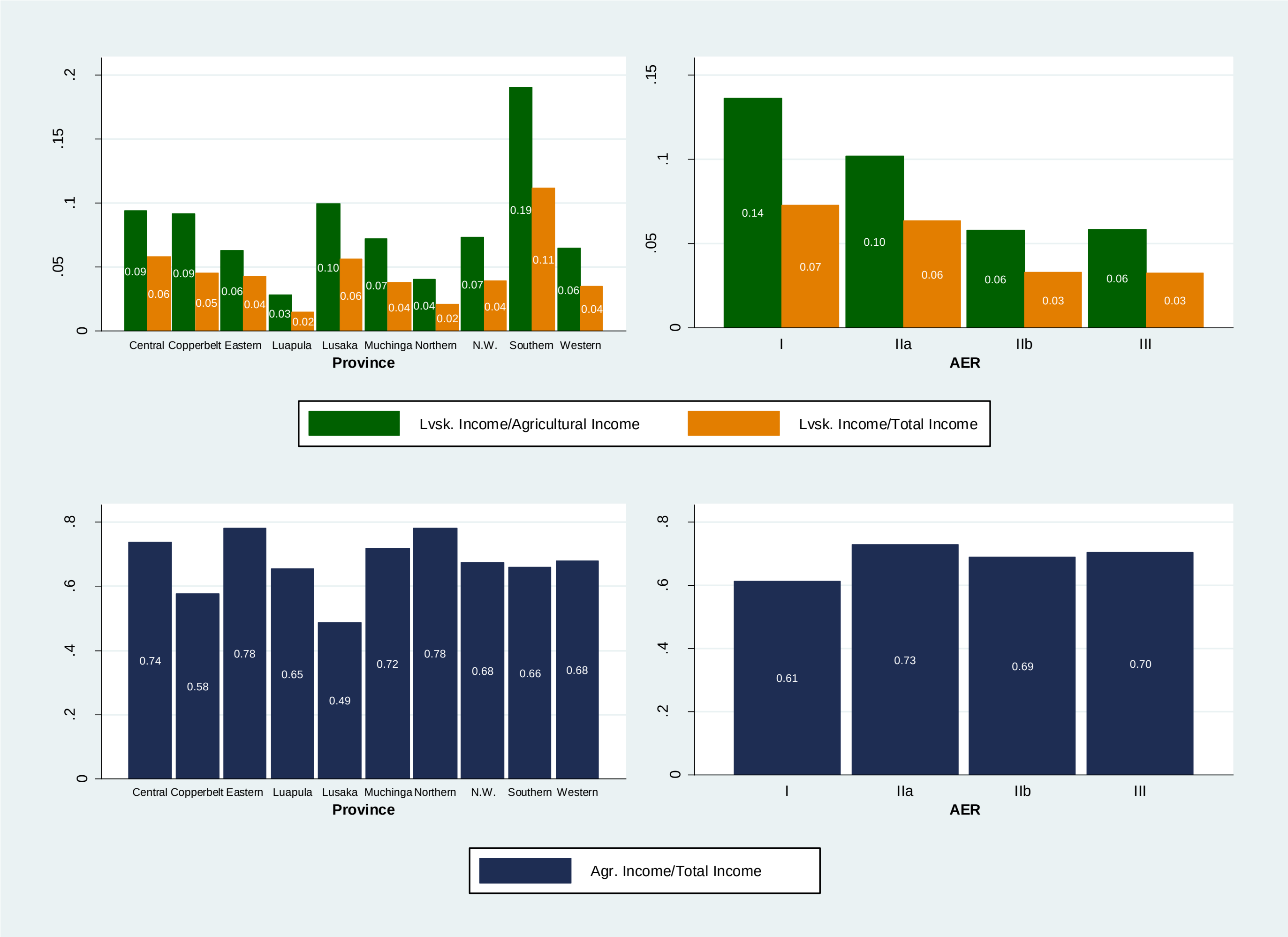
Given the AER-specific nature of rainfall regimes, predicted climate change impacts, as well as soil structures, one might expect distinct incentives for crop, livestock and income diversification in each AER. We first present descriptive statistics on diversification by AER to provide an understanding of the livelihood structures across the country. Just as push factors related to distinct rainfall regimes of each AER may affect incentives for diversification differently, so do pull factors including the status of the local economy (income generating opportunities, roads and infrastructure, political environment) that can be differentiated along administrative regions. We therefore provide a documentation of income sources and diversification patterns at the province level as well.

Figure 2 summarizes the shares of total agricultural (from crops and livestock) and livestock income in total income (only for those that have livestock income) by province and AER. The share of agricultural income in total income is the highest in the easternmost provinces (Muchinga, Eastern, and Northern provinces) and the Central province, where it exceeds 70 *percent*. Lusaka province has the lowest share of agricultural income in total income as expected (49 *percent*), given its status as the biggest urban and administrative center of the country. Southern Province stands out significantly in terms of the share of livestock income in livelihoods, contributing 19 *percent* of agricultural income and 11 *percent* of total income. In

[7] See http://www.cpc.ncep.noaa.gov/products/fews/AFR_CLIM/AMS_ARC2a.pdf for more information on ARC2.
[8] ECMWF data were accessed from the Institute for Environment and Sustainability (IES) of the European Commission http://spirits.jrc.ec.europa.eu/?page_id=2869.
[9] See http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML for more information.

fact, in all provinces households seem to use livestock as a form of on-farm diversification contributing 3-10 *percent* of agricultural income.

Figure 2 Share of agricultural and livestock incomes by Province and AER

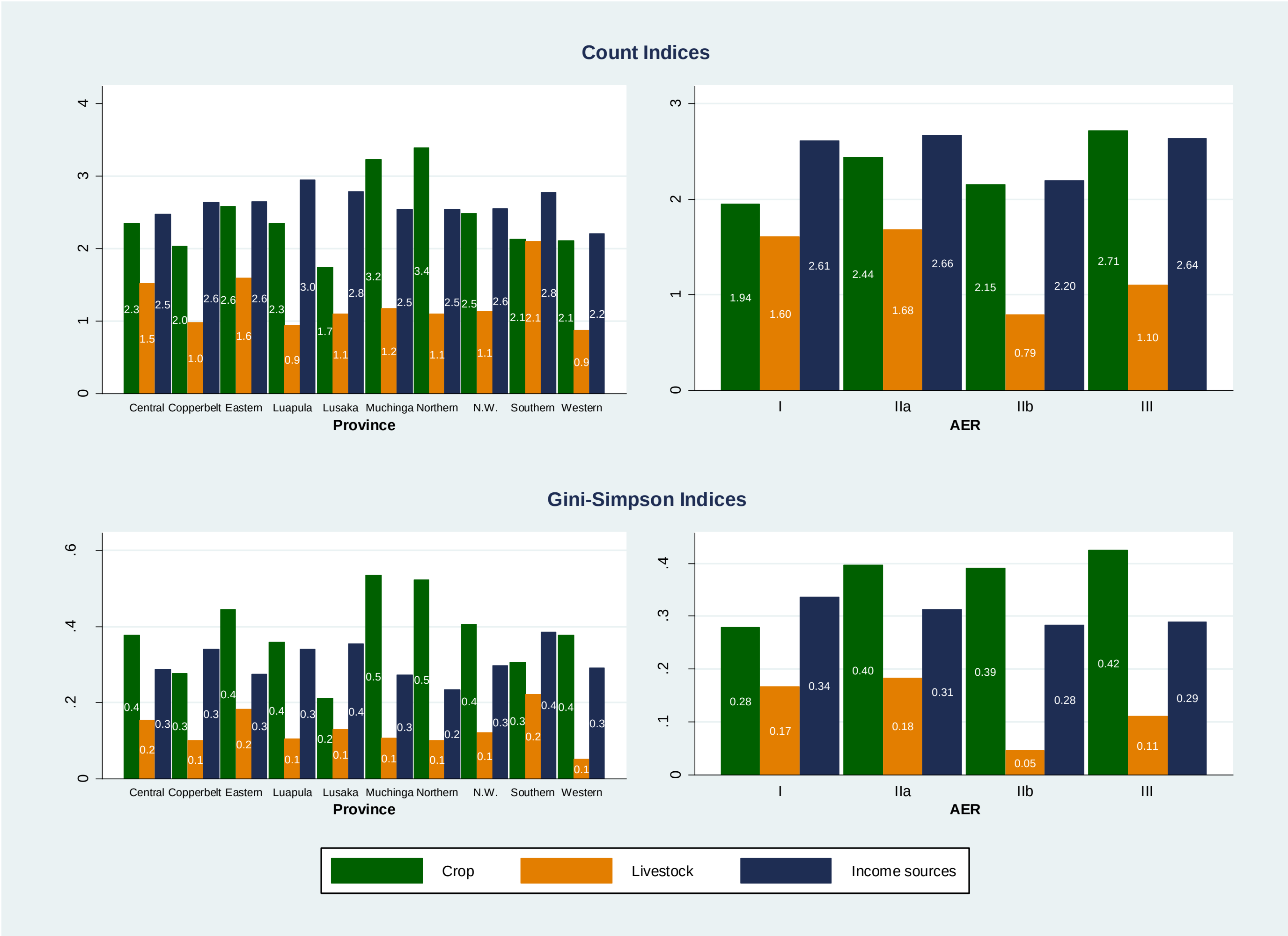


Source: Authors' own elaborations.

Looking at the panels on the right in Figure 2, we can see a clear correlation of agricultural and livestock income shares with rainfall regimes along which the AER are defined. Just as average rainfall decreases as we move from south-east (AER I) to north-west (AER III), so do the role of agricultural income in total income and that of livestock in agricultural income. While livestock income contributes almost 15 *percent* of agricultural income in AER I as expected given the fact that it covers the provinces where majority of traditional livestock herders live, this share is lowest (6 *percent*) in AER IIb and AER III. AER I also covers most of the "transition zones" identified in Jones and Thornton (2009), underlining the importance of understanding the drivers of diversification into livestock and other income sources for effective climate change adaptation.

Figure 3 shows both the count and Gini-Simpson indices by province and AER. The provinces characterized by the lowest crop diversification are Lusaka and Copperbelt, with less than 1.7 and 2 crop species on average, respectively. On the other hand, the most diversified in terms of number of crops are Muchinga and Northern provinces with 3.2 and 3.4 species, respectively. Livestock diversification is more limited throughout the country, especially in Copperbelt, Luapula and Western provinces, where households have only one type of livestock on average. Southern province is the most diversified in terms of livestock with more than 2 types.

Figure 3 Average count and Gini-Simpson indices of diversification by Province and AER

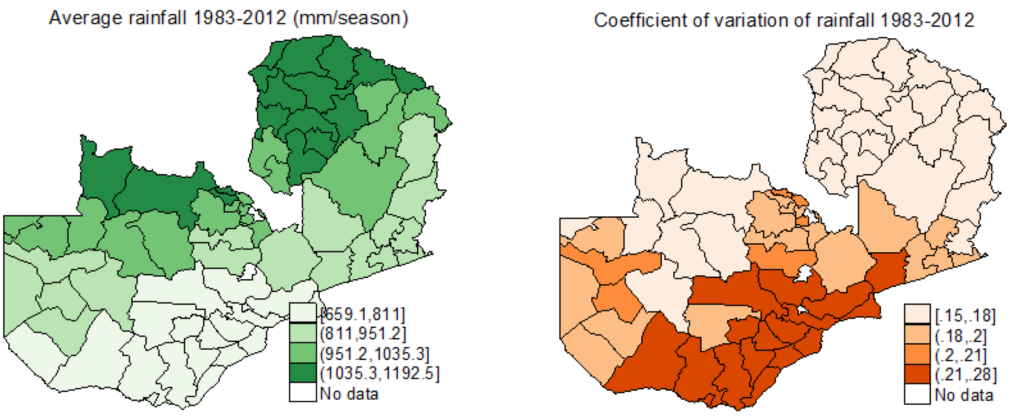


Source: Authors' own elaborations.

The main criteria used to distinguish the AER in Zambia is the average rainfall, which combined with different trends in both rainfall and temperature leads to distinct projections in climate models. Given that climatic shocks are one of the important push factors into livelihood diversification, we discuss the status of diversification by AER. In particular, AER III is the most diversified in terms of crops with more than 2.8 crop species per household, followed by AER IIa and IIb (2.4 and 2.2 species, respectively). AER IIa is the most diversified region in terms of livestock as expected with an average of 1.7 types of livestock per household, followed by AER I and AER III. Households in all AERs have on average at least two income sources. AER IIa has the highest count index of income diversification, followed by AER III. The income diversification is the only dimension that switches the rankings going from count index to Gini-Simpson index, as AER I has the highest Gini-Simpson index for income diversification, indicating that the income shares are more equally distributed in this region contributing more to diversity (measured by proportional abundance) even though it is the third most diverse by the count index.

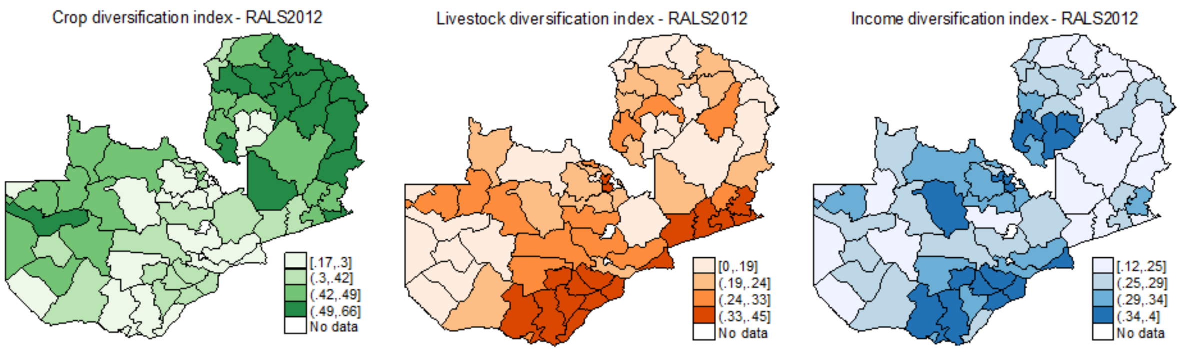
The observed diversification patterns are the results of both push and pull factors, and the AER classification provides only a broad insight into the climatic push factors into diversification. For example, given the projections of higher temperatures and even lower rainfall in AER II, if the push factors dominate we might expect increased income diversification with lower welfare in this region. AER IIa, however, also includes the urban centers of Lusaka and Eastern provinces, which provide opportunities for pull factors that might be associated with higher diversification at higher welfare levels. Similarly, AER III is projected to have increased rainfall on soils that are already highly leached, but it also includes Copperbelt province with significant mining activity providing potential pull factors. Understanding which factors dominate in driving diversification and what types of welfare outcomes might be expected requires analyses at higher resolution that control for all potential factors as we do below.

Figure 4 Average growing season rainfall and coefficient of variation over 1983-2012 by district



Source: Authors' own elaborations.

Figure 5 Diversification indices in RALS 2012 data by district



Source: Authors' own elaborations.

We first look at district level climatic variables and diversification outcomes before moving to household level analysis. Figure 4, shows the distribution of long term average of seasonal rainfall and its coefficient of variation (CoV), and figure 5 shows the diversification indices by district. Whereas the long run average rainfall in our data conforms to the classification of AER, there is more heterogeneity across districts within AERs in terms of CoV of rainfall indicating climate risk management strategies need to be based on site-specific analyses. It is interesting to note that households seem to diversify their crops more in areas with higher long term average seasonal rainfall, and similarly livestock diversification seems higher in areas where the long term variation in rainfall is higher. Income diversification on the other hand shows no clear pattern correlated with the weather variables plotted in figure 4. The heterogeneity within AERs in climatic variables (especially for the variation in rainfall over time) and diversification, provides further evidence that agricultural development planning at the AER level may not be able to capture all factors at play in shaping livelihood decisions. The unconditional averages plotted in these figures provide suggestive evidence only, as it remains to be seen whether and how weather shock variables drive diversification outcomes controlling for other variables that affect livelihood decisions and risk attitudes.

Table 1 presents descriptive statistics of all control variables used in the analyses on the determinants of diversification. Our climate variables include the long-term (1983-2012) CoV of rainfall during the cropping season and the current period rainfall anomaly constructed as the deviation of the rainfall in the season covered by the survey from the long-term average. While the coefficient of variation captures the effect of long term variation in rainfall on *ex-ante* incentives, the current period anomaly captures the immediate effect of shocks on diversification (e.g., household being *pushed* into petty jobs to substitute for agricultural income lost due to a shock).

Around 24 *percent* of household heads are female, and this variable may be expected to have a negative effect on diversification a priori, as female-headed households may find it more difficult to access resources that enable them to take advantage of pull opportunities for diversification (Ellis 1998; Davies and Hossain, 1997). However, based on evidence in the literature to suggest that women are more risk averse (Hartog *et al.*, 2002; Borghans *et al.*, 2009), which should "push" them into diversification, the combined effect of gender on diversification is ambiguous and may differ by types of diversification analysed here. Number of household members is a proxy for labour availability and the average household in our sample has 5.4 members. Household wealth is expected to affect diversification outcomes as discussed above. We use operated land size in hectares (2.8) and a household wealth index constructed by principal component analysis based on data on dwelling characteristics as well as the ownership of a large set of assets. We also include squared terms for these variables to test whether the relationship between wealth and diversification is nonlinear.[10]

Social capital and market access can act as pull factors for diversification as households share information and knowledge in groups or in market places that act as information hubs (Cavatassi *et al.* 2012). We use the share of households in a Standard Enumeration Area (SEA) that participate in farmer cooperatives, women's groups or savings & loan societies, as well as household's kinship ties to the chief and the headman of the community as a proxy for social capital. In an average SEA in our sample 50 *percent* of the households participate in any of the groups mentioned above. Almost half of the households have a member with kinship ties to the headman, whereas only 11 *percent* have kinship ties to the chief. Village chiefs in Zambia are representatives of their tribe, whereas headmen are elected by the community and deal with day-to-day activities in the village. We, therefore, expect the kinship ties to the headmen to be stronger drivers of diversification outcomes. Access to urban centers and

[10] Although the gains from specialization that lead to the nonlinear wealth-diversification relationship were not observed in most African agricultural settings as discussed in Barret et al. (2001), the agricultural development trends since the turn of the century may have changed this relationship in some countries. We use the squared terms of wealth indicators to provide a quick peak into this relationship in rural Zambia.

markets is one of the frequently cited pull factors for diversification as summarized above. We use the distance to a tarmac road and an established marketplace with many buyers and sellers to test this hypothesis. Average distance to a tarmac road is around 35 km, and average distance to a marketplace is about 29 km (both with large variations across the sample).

Table 1 Descriptive statistics of control variables

Variable	Mean	Std.Dev	Min	Max
Climate variables				
CoV of Oct-Apr rainfall 1983-2012	19.54	3.00	13.52	29.61
Rainfall anomaly during 2010-11 season	0.08	0.09	0.00	0.38
Household socio-demographic				
Head is female	0.24	0.43	0.00	1.00
Age of household head	44.55	15.56	17.00	111.00
Number of household members	5.42	2.53	1.00	29.00
Avg adult yrs of education	5.61	2.83	0.00	18.00
Household wealth				
Land size in hectares	2.79	3.83	0.00	71.56
Wealth index (PCA excluding livestock)	-0.54	1.86	-2.46	26.42
Social capital & market access				
Group membership share in SEA	0.49	0.25	0.00	1.00
Head/spouse is kin of chief	0.11	0.32	0.00	1.00
Head/spouse is kin of headman	0.49	0.50	0.00	1.00
Distance to road (km)	34.76	39.01	0.00	247.00
Distance to established market place (km)	28.83	24.11	0.00	153.30
Ward/district characteristics				
Moderate soil constraint	0.37	0.48	0.00	1.00
Severe/very severe soil constraint	0.36	0.48	0.00	1.00
District poverty rate	0.56	0.13	0.16	0.86
District population density (person/km2)	0.02	0.03	0.00	0.67
Institutions				
FISP access (share in SEA)	0.30	0.46	0.00	1.00
FRA depots in district (nr.)	10.64	11.19	0.00	48.00
Extension agents from all sources (nr.)	0.58	0.49	0.00	1.00
Banks in district (nr/100 km2)	0.03	0.07	0.00	1.44
Tobacco & cotton buyers in district (nr.)	0.82	1.02	0.00	3.00

Note: Nr. of observations=8,152.
Source: Authors' own elaborations.

Given the role that institutions can play in driving diversification outcomes, we use a set of variables to capture the access to relevant institutions. The Farmer Input Support Subsidy Programme (FISP) is one of the most important programmes in Zambia, accounting for around 60 *percent* of the poverty reduction programme budget of the ministry of agriculture. It provides fertilizers and seeds to "vulnerable but viable" farmers (i.e. those that have the ability to produce at least 0.5 ha of maize) that are members of cooperatives/farmer groups (Mason *et al.* 2013). Depending on the specific interventions, such programmes can increase or decrease incentives for diversification. Crop diversification may increase if a diverse set of seeds are distributed, or it may decrease if only a couple of crops are the focus of these programmes. In Zambia, only hybrid maize seed was distributed along with fertilizers until 2009, after which rice, sorghum, cotton and groundnuts were included (Mason *et al.* 2013). In any case, crop/agricultural diversification can be expected to come at the expense of livelihood diversification, increasing the vulnerability of livelihoods in general. We use the share of households in a given SEA who received FISP support to control for the effect of FISP on diversification.

The Food Reserve Agency (FRA) is another important government programme that takes up the rest of the ministry of agriculture's poverty reduction programme budget (Mason *et al.* 2013). FRA buys maize from farmers at above market prices, aiming to take some of the price risk away from farmers. By making maize incomes less risky, it increases incentives to grow maize, and hence may be expected to decrease crop diversification. However, it may also increase crop diversification if farmers experiment with other crops given the improved security about their maize income, making the a-priori expectations ambiguous. FRA's effect on other indices of diversification is ambiguous as well as it depends on other factors at play. We use the number of FRA depots in the district to understand these interactions.

Access to credit is very limited in rural Zambia. Only 15 *percent* of households in our sample have received a loan from any source during the 2010/11 season. Around 11 *percent* of these were from out-grower schemes (65 *percent* of all loans in our sample), while only 0.25 *percent* were from commercial banks. Rather than using the household reported access to loans that is likely to be endogenous, we use the number of banks per 100 km^2 and the number of tobacco and cotton buyers, who are the main suppliers of agricultural credit, to control for the role of credit. Whereas each district has almost one (0.82) cotton or tobacco buyer on average, the average number of banks per 100km2 is only 0.03. We also control for the number of extension agents in each district to understand the impacts of the availability of the information and technical assistance provided by all available extension sources in driving diversification choices.

Finally, yet importantly, we include a number of district and ward level variables, primarily to mitigate potential "placement effects" bias on the coefficients for the institutional variables. Thus, we include measures of soil quality at the ward level, and population density and poverty rate data at the district level. Around 37 *percent* of the wards in our sample face moderate soil nutrient constraints, with another 36 *percent* facing severe/very severe soil nutrient availability constraints as defined by the HWSD. The average district poverty rate is 56 *percent*, with an average population density of 2 people per 100 km^2 according to the latest census data (CSO, 2010).

4 Results

We first present the results of the models explaining the determinants of crop, livestock and income source diversification measured by the Gini-Simpson indices explained above and then present the results explaining the determinants of diversification into livestock (separately for ruminants and non-ruminants).

4.1 Diversification within crops, livestock and income sources

Table 2 shows the determinants of diversification for both simple and interaction models, all estimated using a tobit model specification given the bounded nature of the Gini-Simpson index.[11] The long-term variation in season rainfall measured by the CoV is positively and significantly correlated with livestock diversification, whereas it is negatively and significantly correlated with income diversification. This suggests that households in areas with highly variable seasonal rainfall perceive livestock diversification as an *ex-ante* risk management strategy.[12]

Contrary to the expectations, income diversification decreases as rainfall variation increases, suggesting that under highly variable rainfall conditions households revert back to subsistence activities and therefore that pull factor drivers fade away. Current season rainfall deviation from the long-term average is not significantly correlated with diversification, suggesting that households are not able respond to immediate shocks to rainfall using the types of diversification analysed here.[13]

In terms of socio-demographic characteristics, female-headed households are less likely to be diversified in terms of crops and livestock but more likely to be diversified in terms of income. These results suggest that female-headed households are not able to take advantage of on-farm diversification opportunities, perhaps due to a gender imbalance in agricultural extension service staff in Zambia (McCarthy *et al.* 2006). Greater income diversification in female-headed households may be driven by their higher risk aversion, which leads them to manage risk by engaging in off-farm income opportunities. Education seems to facilitate pull factors into income source diversification by opening up non-farm income opportunities as expected.

[11] An alternative empirical approach would be to use a two-step Heckman selection model (aka Tobit type II), which would allow the control variables to affect the decision to diversify *into* an activity and *within* an activity differently. Identification of this type of model requires identification restrictions, which are difficult to find in our data. Furthermore, the current study is part of a series including FAO (2015) on diversification under climate change, hence we try to keep the conceptual models as similar as possible. In this paper we additionally analyze the binary decision to diversify only for livestock, which is practically the first step in a selection model, given its importance for the national policy on vulnerability.

[12]Our livestock diversification index captures diversification within livestock types. A separate analysis of diversification into livestock activities (especially for ruminants) reported in table 3 confirms this finding that higher rainfall variation is significantly and positively correlated with diversification *into* livestock as well as *within* livestock activities.

[13] It should be noted here that rainfall anomalies were, for the most part, not very pronounced during the 2010-2011 growing season. Diversification in response to shocks, primarily of income sources, might still occur with greater anomalies.

Table 2 Determinants of crop, livestock and income diversification (tobit model results)

	Simple Models			Interaction Models		
	Crop	Livestock	Income	Crop	Livestock	Income
Climate variables						
CoV of rainfall 1983-2012	-0.004	0.026***	-0.007***	0.002	0.031***	0.001
Rainfall anomaly 2010-11	0.127	-0.121	0.053	0.112	-0.131	0.062
Household socio-demographic variables						
Head is female	-0.015*	-0.044***	0.025***	-0.016*	-0.044***	0.025***
Age of household head	0.001***	0.001***	-0.000	0.001***	0.001***	-0.000
HH members	0.006***	0.014***	0.002	0.006***	0.014***	0.002
Education (avg)	0.001	-0.004**	0.006***	0.001	-0.004*	0.005***
Household wealth						
Land size in hectares	0.017***	0.011***	-0.003	0.017***	0.011***	-0.002
Land size in hectares squared	-0.000***	-0.000***	0.000*	-0.000***	-0.000***	0.000*
Wealth index (normalized)	-0.335***	1.292***	0.424***	-0.328***	1.282***	0.438***
Wealth index squared	-0.158	-1.748***	0.839***	-0.150	-1.734***	0.821***
Social capital & market access						
Group membership	0.082	0.146**	0.005	0.080	0.146**	0.018
Kin of chief	-0.000	0.003	0.026***	-0.002	0.004	0.025***
Kin of headman	0.025***	0.009	0.013**	0.024***	0.009	0.013**
Distance to road (km)	-0.018	0.035	0.028***	-0.019	0.035	0.031***
Distance to market place (km)	0.114***	0.086**	-0.056***	0.120***	0.084**	-0.055***
Ward/district characteristics						
Moderate soil constraint	0.025	-0.013	0.010	0.020	-0.012	0.007
Severe/v.severe soil constraint	0.026	0.004	0.018*	0.020	0.004	0.013
District poverty rate	-0.221***	0.095	0.028	-0.230***	0.090	0.038
District population density (person/km2)	0.583***	0.484**	0.367**	0.955**	1.030*	-0.155
Institutions & their interactions						
FISP access (share in SEA)	0.039	-0.040	-0.053*	0.279	0.194	-0.189
FRA depots in district	0.001	0.000	0.000	0.001	0.000	0.001
Extension agents in district	0.016***	0.006	0.002	-0.028	0.032	0.025
Banks in district	-0.147*	-0.042	-0.078	-0.947	-1.377	1.267*
Tobacco & cotton buyers in district	-0.031***	-0.006	0.001	0.099	-0.021	0.118***
FISP * CoV Rain				-0.013	-0.012	0.007
Extension * CoV Rain				0.002	-0.001	-0.001
Banks * CoV Rain				0.030	0.052	-0.054*
Tobacco/cotton buyers * CoV Rain				-0.007*	0.001	-0.006***
N	8,005	6,713	8,152	8,005	6,713	8,152
Pseudo R2	0.287	0.199	0.244	0.292	0.200	0.251

Note: Standard errors are clustered at the SEA level. *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' own elaborations.

Regarding wealth indicators, land size is significantly positively correlated with crop and livestock diversification, but not with income diversification. On the other hand, a higher wealth index, which excludes land, leads to lower crop diversity, but higher livestock and income diversity. The inclusion of squared terms for the wealth variables suggests a non-linear relationship of land size with diversification outcomes – although the coefficients of the squared terms are very small. Crop and livestock diversification increase with farm size at first but the effect turns negative after achieving a certain size (i.e., an inverted U-shaped relationship). An opposite relationship is observed with income diversification, though to a lesser extent, as the land size has a positive but not significant coefficient but its square is significantly negatively correlated with income diversification. Wealth index[14] exhibits the inverse-U shaped relationship with livestock diversification only, which reinforces the non-linear relationship between land size and livestock diversification. The square of the wealth index is strongly positive and significant, suggesting that wealth levels in our sample have not yet reached a point, where the incentives to specialize set in.

Membership in cooperatives, farmers', women's or savings and loan groups seems to be effective in facilitating livestock diversification only, while it is not significantly correlated with crop and income diversification. The connections of these groups with other sectors to facilitate different income generating opportunities as well as their access to diversified seed sources would need to be supported if they were to be used as policy entry points to increase income and crop diversification as a risk management strategy. On the other hand, having a kinship tie to the village chief or the headman facilitates income diversification.

The coefficients of the distance to market variable suggest that market constraints/transaction costs act as push factors into crop and livestock diversification as households are significantly more likely to be diversified along these dimensions the farther they are from markets. At the same time, income diversification decreases as the distance to market increases as expected. Distance to road, on the other hand, is positively correlated with income diversification, suggesting that while local markets give incentives to diversify income sources, having access to urban centers via all-weather roads gives incentives for specialization.

The institutional variables we use cover the most important institutions that shape households' incentives in rural Zambia, ranging from the most important government programmes to support (particularly maize) farmers, to those that address information and credit constraints. Controlling for all other variables, the higher the proportion of households in the SEA that accessed FISP the less diversified are incomes. This provides suggestive evidence that by giving incentives to cultivate maize (and lately legumes as well) FISP decreases incentives to diversify incomes. FISP and FRA do not have a significant impact with any other diversification outcomes, contrary to the expectations.

The availability of extension agents is positively correlated with crop diversification only, suggesting they mostly assist farmers on crop production in spite of efforts to improve livestock activities in rural Zambia. Credit constraints seem to act as a push factor into crop diversification as households diversify their crops significantly less in districts with more banks and tobacco and cotton buyers that provide credit. The corollary however is not true, as the number of banks and other credit providers are not positively correlated with livestock and income diversification, suggesting that the credit available is only enough to specialize on farm

[14] Wealth index has been normalized before being squared given that its range goes from negative to positive.

rather than acting as a pull factor into other activities. These results should be interpreted with a caveat in mind as the number of credit institutions in our sample is extremely low as discussed above.

Table 2 also presents the results of the models where we included interaction variables between institutional variables and the coefficient of variation in rainfall to investigate whether and how these institutions perform under highly variable rainfall conditions. This is important if these institutions are to act as policy entry points to decrease vulnerability to climate shocks by facilitating diversification. The coefficient of the FISP variable in income diversification model remains significantly negative and is bigger in magnitude, however its interaction with rainfall variation is not significant (although positive) indicating that FISP does not play a different role under highly variable rainfall conditions.

The role of extension also does not differ by rainfall variation, nor does the role of the availability of banks in the district – except for income diversification. The interaction term between banks and rainfall variation is negative and significant in the income diversification model, indicating that they do not currently act as catalysts for income diversification where agricultural income is highly vulnerable to rainfall shocks. This is similarly true for tobacco and cotton buyers, as the interaction variable with rainfall variation is also negative and significant. The interaction term models point towards a missed opportunity in terms of using these institutions as channels through which household incentives for diversification can be improved especially under highly unpredictable rainfall conditions to decrease vulnerability.

4.2 Diversification into livestock

Table 3 presents the results of the model of farmer's decision to adopt ruminant and non-ruminant livestock species as a function of the control variables used in the previous table.[15] The coefficient of variation of rainfall measuring the long-term variability in season rainfall is positively and significantly correlated with ruminant ownership only, providing suggestive evidence for the importance of these types of livestock (i.e. cattle, goats, and sheep) in providing insurance against risk faced by vulnerable households.

Additional household members increase the probability to own and invest in both types of livestock because both children and older members may contribute to on-farm activities. As was observed for *within*-livestock diversification in table 2, female headed households are significantly less likely to own ruminants, suggesting a gender difference in the potential role of livestock as a risk-management strategy. Dealing with ruminants is perceived as a primarily male-activity, which combined with other potential barriers, seems to prevent female-headed households from investing in this type of livestock.

Among household wealth variables, both farm size and the wealth index have a positive and significant role in increasing incentives to invest in both types of livestock. In particular, consistently with results on *within*-livestock diversification presented in table 2, an additional hectare of land is correlated with a 7 per cent increase the probability of owning both ruminants and non-ruminants. Both of these variables have the same inverse-U shaped relationship with diversification *into* livestock as they had with diversification *within* livestock found in the previous section. Majority of the social capital and market access variables are positively and

[15] The ruminant category includes sheep, goats, and cattle, whereas within non-ruminants donkeys, chicken, pigs, fowls ducks and rabbits are comprised.

significantly correlated with non-ruminant ownership, whereas only distance to market significantly increases ruminant ownership.

Unlike in the *within*-livestock diversification above, the number of FRA depots in the district is positively and significantly correlated with non-ruminant ownership, while it is not significantly correlated with ruminant ownership.[16] This finding suggests that by making income from maize cultivation more secure, FRA enables households to invest in smaller livestock (but not ruminants). Access to credit, both from banks and tobacco and cotton buyers, is negatively correlated with ruminant ownership, suggesting that ruminants may play an *ex-ante* risk management tool role, which is dampened if households have access to credit.

Table 3 also shows the results of models including interaction terms between the rainfall variability and institutional variables as in Table 2. Similar to the results above, most interaction variables are insignificant, indicating that these institutions do not have a differentiated effect on incentives to own livestock under different rainfall variability regimes. The only significant coefficient is that of the interaction term between rainfall variability and the number of tobacco and cotton buyers in the district in the model explaining the probability to own ruminants.

Combined with the strongly negative and significant coefficient on the number of tobacco and cotton buyers in the district, this interaction indicates that the negative effect of this variable on the incentives to own ruminants is less negative in highly variable rainfall environments – again underlining the strong effect of rainfall variability on pushing households into diversification into livestock (ruminant) activities.

We have also included a variable to control for the potential effects of too hot temperatures (greater than 28°C) on livestock and hence the incentives to invest in this activity. As documented by the literature, increases in ambient temperature may affect growth, reproduction performance, production, as well as, animal health and welfare (Walter *et al.*, 2010; Reilly 1996). In the interaction model results, the coefficient of the variable indicating too hot growing seasons is positive and significant in the model explaining the probability of owning non-ruminants. Thus, as growing season temperatures rise farmers seem to prefer investing in small animals like donkeys, pigs, rabbit and poultry, instead of ruminants that suffer more from heat stress with negative consequences on milk and meat production (Robertshaw and Finch, 1976).

[16] It is interesting to note that almost all variables (except the FRA for non-ruminants) have the same sign when significant (and there are no sign reversals) in the models for diversification *within* and *into* livestock, providing a confirmation for a tobit approach above, which assumes that the control variables affect both decisions in the same way.

Table 3 Determinants of livestock diversification (probit model results)

	Simple Models		Interaction models	
	Ruminant	Non-Ruminant	Ruminant	Non-Ruminant
Climate variables				
CoV of rainfall 1983-2012	0.115***	0.014	0.083**	0.029
Rainfall anomaly 2010-11	-0.066	-0.334	-0.009	-0.361
Max temperature >28°C	-0.036	0.117	-0.035	0.176**
Household socio-demographic variables				
Head is female	-0.169***	-0.049	-0.172***	-0.044
Age of household head	0.007***	0.002	0.007***	0.002
HH members	0.061***	0.065***	0.061***	0.066***
Education (avg)	-0.041***	0.003	-0.040***	0.004
Household wealth				
Land size in hectares	0.067***	0.062***	0.066***	0.062***
Land size in hectares squared	-0.001***	-0.001***	-0.001***	-0.001***
Wealth index (normalized)	7.940***	2.705***	7.962***	2.681***
Wealth index squared	-7.675***	-3.387***	-7.746***	-3.400***
Social capital & market access				
Group membership	0.405	0.746***	0.354	0.786***
Kin of chief	0.016	0.056	0.024	0.057
Kin of headman	0.061	0.097**	0.066*	0.099**
Distance to road (km)	0.069	0.218***	0.062	0.224***
Distance to market place (km)	0.485***	0.371***	0.473***	0.344***
Ward/district characteristics				
Moderate soil constraint	0.003	-0.117*	0.029	-0.111*
Severe/v.severe soil constraint	0.104	-0.051	0.133*	-0.044
District poverty rate	0.615**	0.216	0.680**	0.159
District population density (person/km2)	2.044***	-1.132	1.679	0.933
Institutions				
FISP access (share in SEA)	0.007	0.038	0.631	-0.626
FRA depots in district	-0.003	0.017***	-0.006	0.018***
Extension agents in district	0.054**	0.002	0.022	0.270
Banks in district	-0.665**	-0.033	-0.271	-4.740
Tobacco & cotton buyers in district	0.035	-0.056	-0.776**	0.020
FISP * CoV Rain			-0.029	0.031
Extension * CoV Rain			0.001	-0.014
Banks * CoV Rain			-0.010	0.181
Tobacco/cotton buyers * CoV Rain			0.040***	-0.004
N	0.215	0.108	0.217	0.109
Pseudo R2	0.215	0.108	0.217	0.109

Note: Standard errors are clustered at the SEA level. *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' own elaborations.

4.3 Diversification and vulnerability

Linking the diversification model results with household vulnerability outcomes empirically is inherently fraught with endogeneity problems (due to both reverse causality and selection/omitted variables bias) as household diversification outcomes are the results of actions taken in response to vulnerability of income/consumption under imperfect market conditions and risk aversion. Therefore, an analysis of the dynamic concept of vulnerability – however defined – as a function of diversification indices using cross-sectional data would very likely produce biased results. Here we present only a descriptive analysis of the correlations between vulnerability indicators in our data and diversification measures.

We use three variables as indicators of vulnerability: the logarithm of income per capita and its variance, and the number of months the household did not have enough food during the survey year. The levels of a welfare outcome (consumption or assets) and its variance are used as the components of vulnerability in the vulnerability to poverty literature (Christiaensen and Subbarao, 2005; Chaudhuri *et al.*, 2002). RALS data does not have a detailed consumption module, therefore we use total income and its variance estimated from a regression of income determinants as components of vulnerability to income poverty. We also use the income poverty line from the Zambian Living Conditions Monitoring Report (CSO, 2010) to calculate the Foster-Greer-Thorbecke (FGT) poverty measures.

Table 4 reports the simple correlations between diversification measures and vulnerability indicators. Income per capita is positively, and its variance is negatively, correlated with all diversification measures as expected. Number of food deficit months on the other hand is positively correlated with income diversification, suggesting that income diversification may act as a coping strategy to deal with transient shocks.

Table 4 Correlation coefficients between diversification and vulnerability indicators

	Diversification			**Income per capita (ln.)**	**Variance of Income**	**Food deficit months**
	Crop	**Livestock**	**Income**			
Crop Div.	1					
Livestock Div.	0.07	1				
Income Div.	-0.11	0.05	1			
Income per capita (ln.)	0.05	0.09	0.12	1		
Variance of Income	-0.14	-0.03	-0.01	0.00	1	
Food deficit months	-0.04	-0.12	0.05	-0.22	0.03	1

Source: Authors' own elaborations.

In order to unpack the relationship between vulnerability to food shortages and diversification, table 5 reports the average diversification indices by different categories of food deficit months. Households that had less than 3 months of food deficit have the highest crop and livestock diversification and the lowest income diversification. On the other hand, those who had more than 6 months of food deficit have the lowest crop and livestock diversification and the highest income diversification, providing suggestive evidence that income diversification results from push factors in rural Zambia, at least in terms of food availability. Higher incomes per capita, then, do not necessarily translate into the ability to purchase the same amount of food as is available to households with larger landholdings and thus own production. Given the subjective nature of this result, however, more research is needed to establish the channels through which this correlation may be explained.

Table 5 Food deficit categories and diversification

Food deficit	Diversification		
	Crop	Livestock	Income
Less than 3 months	0.41	0.15	0.29
3-6 months	0.36	0.09	0.33
More than 6 months	0.35	0.09	0.33
Total	0.40	0.14	0.30

Source: Authors' own elaborations.

Finally, in table 6 we present the distribution of diversification and vulnerability measures across AERs, which shape the thinking about climate change and its impacts on agriculture and livelihoods in Zambia.

Table 6 Diversification, vulnerability and poverty by AER

AER	Diversification			Income per capita	Var. of Income	Food deficit months	Poverty Rate	Depth of Poverty
	Crop.	Livestock	Income					
I	0.28	0.17	0.34	137,262.83	0.76	1.75	0.79	0.62
IIa	0.40	0.18	0.31	170,601.86	0.62	1.23	0.70	0.57
IIb	0.39	0.05	0.28	135,814.12	0.69	3.35	0.79	0.59
III	0.43	0.11	0.29	170,386.51	0.60	1.53	0.67	0.52
Total	**0.40**	**0.14**	**0.30**	**165,010.43**	**0.63**	**1.57**	**0.70**	**0.55**

Source: Authors' own elaborations.

AER I, which is the region with the lowest rainfall that also has the highest variability across years, has the lowest crop diversification and highest income diversification. It also has the second lowest income per capita with the highest variance as well as highest rate and depth of poverty. Given the importance of livestock in the incomes of households in AER I, and the fact that rainfall is projected to decrease with increased unpredictability, combined with our finding that increased rainfall variation increases livestock diversification indicates that policies that can facilitate diversification under the predicted impacts of climate change are needed to address the compounded issues of poverty and vulnerability in the region. This finding becomes more important taking into account that income diversification is negatively correlated with income and is a coping strategy for the poorest and most food insecure in this region.

AER IIb also stands out with its low incomes with high variance, high average food deficit months and poverty rate, and lowest livestock and income diversification. Projected impacts of climate change in this region (including decreased rainfall and increased temperatures and unpredictability) underline the importance of actions to improve the capacity to diversify income sources and, where possible, livestock.

5 Conclusions and policy implications

The analysis presented in this paper demonstrates that diversification is clearly an adaptation response as long term trends in climatic shocks have a significant effect on livelihood diversification in rural Zambia. The long-term variation in growing period rainfall acts as a push factor into livestock diversification, whereas the effect of this variable on income diversification shows the opposite sign indicating that households revert back to subsistence crop production activities instead of diversifying incomes. The fact that this effect of rainfall variation disappears when we control for its interactions with institutional variables suggests that a focus on on-farm income generation is facilitated by FISP and credit access from various sources that incentivize agricultural production – potentially at the expense of long-term livelihood resilience. Diversification into and within livestock activities has long been promoted as a way to address vulnerability, and our results show that rainfall stress increases the incentives to do so. Further research on the implications of these activities for vulnerability based on panel data is needed to devise targeted policies to support livelihoods under climate stress.

Female-headed households as well as those with higher education are found to be more likely to have diversified income sources, which seems to be driven by women's higher risk aversion. Furthermore, households with female heads seem not to be able to benefit from pull factors into crop diversification. Households with larger land are significantly more likely to diversify their crops indicating that smallholders may need to be targeted by specific policies in cases where climate variability is expected to negatively affect the subsistence crop production they heavily depend on. Another indicator of wealth measured by the wealth index has the same negative correlation with crop diversification, whereas it correlates positively with livestock and income diversification.

With regard to institutions, we find that access to extension agents positively and significantly correlates with crop diversification as well as diversification into livestock, underlining the role of extension in promoting more resilient farming technologies in rural Zambia. Fertilizer subsidies are among the most important agricultural policies in the country and we find that they significantly and negatively affect incentives for income diversification. (more so under average rainfall variability. If income diversification is a policy goal to decrease vulnerability to climate change as stated in recent national policies and programmes, research to better understand how these subsidy programmes can be reformed to achieve this goal is necessary. Lastly, access to credit is found to decrease crop diversification, especially under highly variable rainfall conditions, which requires special attention in the context of climate change as rural development policies strive to improve the functioning of credit markets.

This paper documents distinct ways in which incentives for livelihood diversification (measured along different dimensions) are shaped by increased variability in rainfall and rural institutions. The results also demonstrate that diversification can be an effective adaptation response and the risk-return tradeoffs are not as pronounced as might be expected. The differences across types of diversification and drivers in shaping the tradeoffs and synergies underline the importance of identifying and promoting the desirable diversification options for specific country circumstances. Given the predicted impacts of climate change on rainfall patterns, the implied changes in livelihood diversification merit special attention as part of a climate smart approach to agricultural development. Diversification has the potential to improve food security as well as contribute to adaptation efforts by decreasing vulnerability, however disentangling these multi-dimensional and dynamic relationships requires panel data analyses planned for future research. Establishing causality among the multiple diversification strategies, institutions and climatic shocks using cross-sectional data is not feasible, hence the results presented here should be interpreted with this caveat in mind.

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