Preferences and crop choice during Zimbabwe's macroeconomic crisis

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Abstract

Smallholder farmers face considerable risk and uncertainty, particularly when markets are incomplete or missing. We consider household crop diversity and crop choice in Zimbabwe, where output markets are largely absent and price signals are inaccurate. In this setting, considering preferences and tastes provides a deeper understanding of how households ensure food security in environments without robust markets. We use data that straddles the period of hyperinflation in Zimbabwe and the collapse of the country's currency to study household cropping behaviour in a time of extreme stress. This allows us to better understand the relationship between market failure and crop choice in Sub-Saharan Africa.

Key words: missing markets; crop choice; Zimbabwe; hyperinflation; taste

1. Introduction

Smallholder farmers form the core of many developing countries; millions of farm households around the world produce food and other goods, both for their own consumption and for sale. Smallholder farm households face considerable risk and uncertainty and often operate in markets that are incomplete or missing. Decision-making in these contexts diverges from circumstances with complete markets (De Janvry *et al*. 1991; LaFave & Thomas 2016). Under these conditions, crop choices may shift when production decisions are closely tied to ultimate consumption outcomes.

We explore the impact of missing and incomplete markets on agricultural household decision-making in Zimbabwe by examining household staple crop choice during the period of macroeconomic crisis and hyperinflation between 2000 and 2015.[1] In 2009, Zimbabwe stopped using the Zimbabwe dollar.[2] The effect on the country and its markets was stark: Zimbabwe had previously stood out from other nations in Sub-Saharan Africa, at first positively – as the continent's bread basket in the 1990s; but later the nation was distinguished as an outlier, marked by falling GDP per capita, declining agricultural output, and rising poverty and hunger throughout the country.

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[1] Zimbabwe is currently suffering a period of macroeconomic instability and inflation, following the reinstatement of an independent currency in the summer of 2019. For the sake of clarity, in this paper we refer to only the first period of hyperinflation and the ultimate collapse of the Zimbabwe dollar, unless explicitly noted otherwise.
[2] Although the government had stopped publishing official inflation figures in 2007, estimates put inflation rising from 100 000% in January of 2008 to 231 151 000% in July and 79 600 000 000% by November of that same year.

During the period of hyperinflation, complete output markets in Zimbabwe became the exception, not the rule (see, for example, Omamo & Farrington 2004; LaFave & Thomas 2016). Domestic markets collapsed, and the previously traditional surpluses in agricultural products and industrial raw materials either declined or disappeared completely. This ultimately made Zimbabwe a net importer of agricultural products when it had historically been an exporter of maize and other staples (Kaminski & Ng 2011). These changes had consequences for smallholder farmers across the country, as households became more responsible for their own food security (FAO nd; Kuhudzay & Mattos 2018).

We investigate household decision-making by smallholder farmers, guided by De Janvry *et al*. (1991). Specifically, we investigate the relationship between crop choice and household preferences and labour availability. The objective of this work was to better understand the role of these factors in determining staple crop choice in a period of unprecedented inflation and of incomplete markets. We pay particular attention to the role played by smallholder farm households' preferences for different crops in their cultivation decisions. A large literature has studied the factors affecting the decisions to cultivate particular crops (Feder *et al*. 1985; Foster & Rosenzweig 1995). Yield has traditionally been considered the dominant factor among these choices. A number of additional explanations have been explored, including liquidity and credit constraints (Croppenstedt *et al*. 2003; Moser & Barrett 2006), learning externalities (Foster & Rosenzweig 1995; Conley & Udry 2010), heterogeneity in farmers (Suri 2011), and risk and safety-first strategies (Smale *et al*. 1994), along with poverty itself (Dercon & Christiaensen 2011). Extending this work beyond yield, a recent strand of the literature has criticised breeding programmes for their continued focus, almost exclusively, on yields (Haugerud & Collinson 1990; Adesina & Zinnah 1993; Smale *et al*. 2001, 2003; Edmeades *et al*. 2008; Verkaat *et al*. 2017). We seek to contribute to the literature that highlights non-yield traits and related factors as essential in farmers' crop-choice decisions. Specifically, we investigated the relationship between preferences and crop choice. We are particularly interested in crop choice, as it allows us to directly measure the preferences of farmers as reported by the household.

To advance the literature on crop choice, we used panel data from Zimbabwe collected in the 2004/2005 and the 2012/2013 growing seasons. We estimated crop choice, both as household crop diversity and area allocated to staple crops, including sorghum, maize and millet. To this end, we used a double hurdle (DH) model to estimate the decision-making process in two steps and to address non-cultivation of various crops, following Burke (2009). We estimated the DH with the Mundlak-Chamberlain (MC) device that includes the time averages of all time-varying covariates, to deal with endogeneity causes by non-random crop choice (Mundlak 1978; Chamberlain 1984). We were particularly interested in the role of preferences that smallholder households have for consuming different crops. However, we also paid attention to the effects of labour availability and allocation, rainfall, as well as household wealth and asset ownership.

We found that preferences for staple crops significantly affect the diversity of a household's overall crop cultivation choice, as well as the decision to cultivate and the area allocated to sorghum, maize and millet. However, the ranking of these preferences also proves to be important: a strong preference for consuming millet and/or sorghum increases the probability of growing that crop and allocating area to it, while it is negatively associated with the decision to grow and the area allocated to maize. In contrast, a consumption preference for maize increases the probability of growing maize, as well as the area allocated to it, but does not significantly affect the decision to grow sorghum or millet, nor the area allocated to either of these crops. We interpreted these findings for farms in the Zimbabwean context: effectively, all households grow and consume maize, but sorghum and millet may diversify a farm's crop portfolio.

We also found that labour availability and allocation significantly influence household crop diversity and area allocated to various staple crops. In particular, participation in off-farm labour, part-time farm labour and migration all significantly affect household crop diversity. These findings suggest that labour availability and allocation have a role in crop choice decision-making in a household.

With this paper, we contribute to the literature on incomplete markets and crop choice, as well as the policy conversation on food security and subsistence food production in Sub-Saharan Africa (SSA). In times of stress on smallholder farmers and in circumstances of incomplete or absent markets, we shed light on household crop choice behaviour. Further, this paper contributes to the ongoing discussion of Omamo and Farrington (2004), Timmer (2012) and others, who suggests that a better understanding of market participant responses to policy is necessary in addressing the behavioural dimensions of food security. Although the collapse of the Zimbabwean currency is not a policy per se, it is an outcome of a series of policies (Chuku & Onye 2019) that ultimately affected millions of people across the nation, including smallholder farmers.

The case of Zimbabwe and the outcomes of hyperinflation represent an extreme case of missing and incomplete markets, but market failure remains common around the globe (Omamo & Farrington 2004; LaFave & Thomas 2016). Understanding how these circumstances affect household behaviour, food production and food security has important implications for producers and consumers around the world.

2. Background

2.1 Macroeconomic conditions in Zimbabwe

Zimbabwe began facing macroeconomic difficulties in the 1990s, during which period the government undertook a structural adjustment programme, which included land reform. This programme, along with other contemporaneous policies, resulted in declining food production, a collapsing banking sector, rising unemployment, and declining life expectancy (Coltart 2008). The World Bank (2014) referred to the early 2000s as a “de-industrializing” of the Zimbabwean economy.

The period of hyperinflation generally refers to the time between 2004 and dollarization in 2009, during which the inflation rate rose tremendously. In July of 2007, the Zimbabwean government ceased to publish official inflation figures. As a result, it is difficult to ascertain actual hyperinflation, and correspondingly prices, during this period. By most accounts, the inflation rate accelerated dramatically in 2008, from a rate in January of over 100 000% to an estimated rate of over 1 000 000% by May, and nearly 250 000 000% by July. The worst of period of inflation was experienced in 2008, which led the nation to stop using the Zimbabwe dollar by 2009 (Hanke 2009; Hanke & Kwok 2009). The peak month of hyperinflation occurred in mid-November 2008, with a rate estimated at 79 600 000 000% per month. At this time, US$1 was approximately equivalent to Z$2 621 984 228 (BBC 2008). As hyperinflation resulted in the daily fluctuation of inflation rates, it became difficult to determine what things actually cost. Even dollarization in 2009 did not entirely eliminate these issues. In addition to the anecdata from the time and qualitative discussions, our conclusions are informed by both statistics from the Food and Agriculture Organization (FAO) and ZimSTAT, the Zimbabwean statistical agency, and from field group discussions conducted contemporaneously to the household survey we use in our empirical analysis.

It was not possible to obtain price data on any crop from ZimSTAT through formal and informal requests. FAO reports price data on maize meal from 2009 through 2019 in their Global Information and Early Warning System Food Price Monitoring and Analysis tool. Figure 1 reports these prices in current Zimbabwean dollars. Unfortunately, prices are not available prior to the 2009 dollarization.

The lack of credible prices obtained through signals in functioning input and output markets is also evident in the field group discussions and our survey data. These field group discussions provide important details about the status of prices and of markets. Respondents indicated that seed was accessible through agro-dealers in most communities, similar to the findings in Lunduka *et al*. (2017), but there were almost no output markets for crops. It was possible to purchase ground maize as a final product in grocery stores in some areas, but there were very few opportunities for farmers themselves to participate as sellers in output crop markets; only one community was able to provide prices for maize and ground maize from local markets.[3] The household micro-level data reveals more prices and transactions, but demonstrates dramatic market losses between 2005 and 2013. The relevant statistics are reported in Table 1. In 2005, many households reported regularly transacting in crop markets: for sorghum and maize, there are more than 1 000 transactions, while millet, groundnut and cowpea all had several hundred each, out of a total of about 3 000 transactions. This stands in dramatic contrast to the findings from 2013: only 50 transactions are reported for maize, 20 for sorghum, 36 for millet, 10 for groundnut, and seven for cowpea, out of just over 100 transactions in total. Due to these thin markets, price transmission was likely not robust (McLaren 2015).

Table 1: Price statistics

	2005			2013		
	Mean	**Median**	**No. of transactions**	**Mean**	**Median**	**No. of transactions**
Maize	0.498	0.40	1 039	0.5	0.47	50
Sorghum	0.712	0.50	1 150	0.874	0.38	20
Millet	0.787	0.60	203	0.434	0.40	36
Groundnut	0.549	0.50	434	1.38	1.00	10
Cowpea	0.778	0.80	248	1.74	1.10	7

Note: prices are reported in USD ($) per kilogram

Following these findings, we do not explicitly include prices in our empirical estimation. Because of the output market collapse observed in our survey data, as well as the broader context of inaccurate or missing prices, we instead consider crop output markets to be incomplete in our empirical estimation

2.2 Crop portfolios and choice

Maize is the dominant crop produced in Zimbabwe. The country is one of the largest producers, by area, of maize in Eastern and Southern Africa, with maize occupying more than 75% of cereal area in the country (Smale & Jayne 2010).[4] Maize has been grown widely in Zimbabwe for many years, as the preferred staple food is derived from maize meal. Maize grows well in the country, in part due to ongoing breeding programmes to improve the crop. But, as a function of the climatic conditions of the country, both millet and sorghum also naturally grow well. Sorghum varieties have been distributed widely in the southern part of the nation due to its amenable traits for the environment, in particular drought tolerance. The cultivation of non-maize staple crops, however, remains low. For example, consider the case of sorghum: less than 30% of total staple area is allocated to any variety of sorghum (Orr *et al*. 2016).

[3] In neither household- nor community-level data do farmers refer to the Zimbabwe Grain Marketing Board, which also is a possible purchaser of crops, in particularly maize, from farmers.
[4] According to Smale and Jayne (2010), only Kenya, Malawi, Zambia and Zimbabwe have more than 75% of cereal area dedicated to maize.

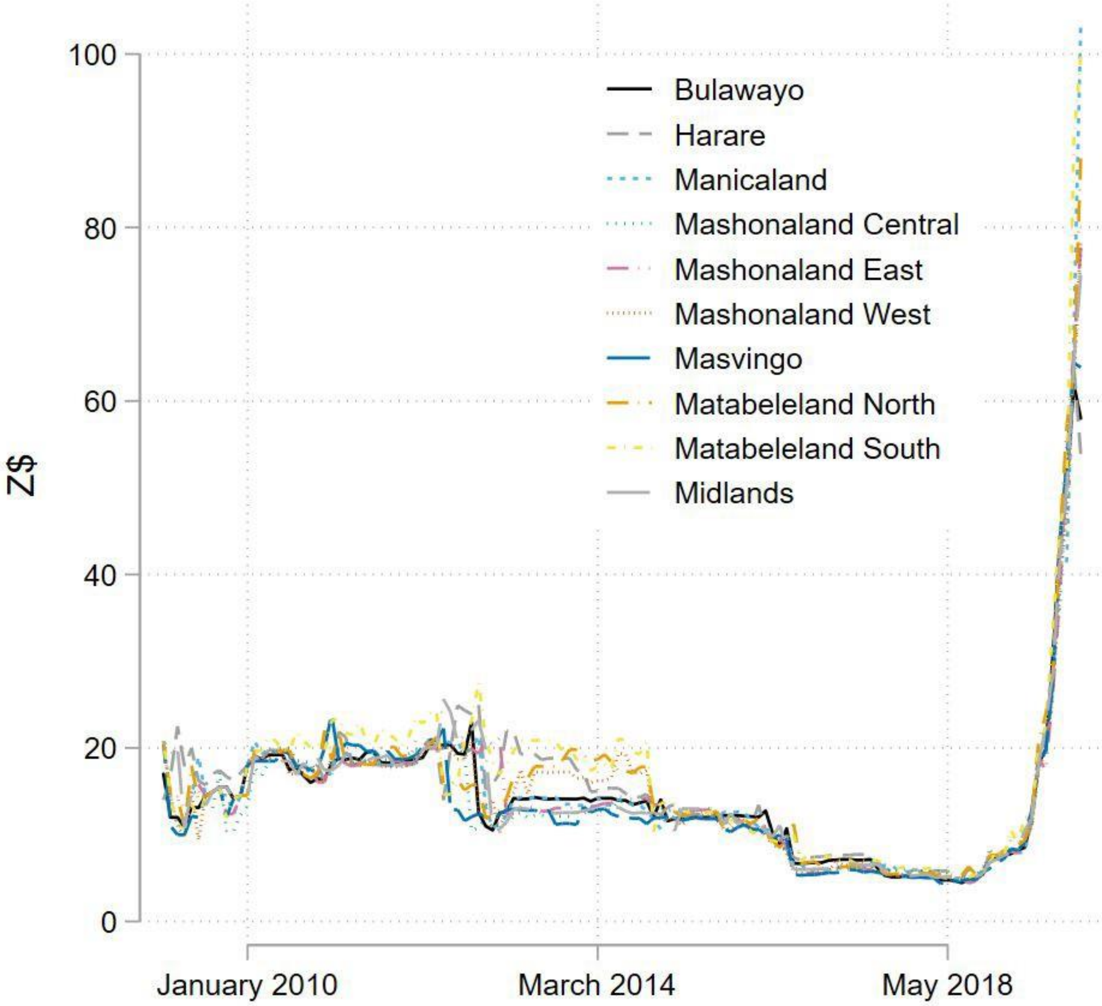

Figure 1: Price of maize meal, 2009 to 2019

Despite all being staple crops, it is not necessarily the case that sorghum, maize and millet are perfect substitutes for one another. Tradeoffs may exist between crops. For example, due to the widespread cultivation of maize, there may be gains from growing a familiar crop. Further, it may be the case that few people cultivate millet or sorghum due to a lack of familiarity with the crops, or due to intensive requirements associated with labour, both with respect to cultivation as well as in consumption (due to a lack of mechanisation for processing). Conversely, there may be gains from the other crops: sorghum and millet are generally more drought resistant than maize, resulting in greater output during years of low rainfall. Thus, these crops provide a potential advantage as households cope with the changing and drying climate in the country. We explored the possibility of different production processes influencing crop choice decisions, with the results presented in Table A.1 and discussed in section A in the Appendix.

2.3 Tastes and preferences

In environments with incomplete or missing markets, people primarily produce food for their own consumption. In these circumstances, taste preferences are crucial to farmers' crop choice decisions (Singh *et al*. 1986; De Janvry *et al*. 1991; Fafchamps 1992). Decisions are made when households consider what they want to eat, and then make cultivation choices from the set of crops that are feasible to produce in their area based on their consumption preferences. Only a few studies have accounted for explicit preferences in crop-allocation decisions and, although some work considers the preferences of farmers for crop traits, taste has not often been explored as a driver of crop-choice decisions (e.g. Adesina & Zinnah 1993; Smale *et al*. 1995; Venkatesh *et al*. 2000; Sunding & Zilberman 2001; Konana & Balasubramanian 2005; Edmeades & Smale 2006; Greig 2009; Useche *et al*. 2009; Mzoughi 2011).

Outside of the economics literature, researchers have studied taste extensively. Taste preferences are created in early childhood and are considered to be set by adulthood. Preferences are determined by flavour, which is perceived by one's taste buds. Other factors may also be influential, in particular, food availability: people can only form a preference for what is actually available to them. Sticky preferences, formed in childhood, may have consequences for long-term health and food security (Drewnowski 1997; Atkin 2013). In the absence of markets that may expose households to new tastes or foods, the consumption preferences of a household are likely to be fixed over long periods of time. This also has the effect of setting the preferences of younger household members, so that taste preferences are perpetuated across families and over generations. Beyond taste and availability, colour also plays a role in determining taste preferences. Foods that produce pleasing colours are preferred to those that are less attractive (Cardello 1996). Colour is particularly relevant in the case of sorghum and millet in Zimbabwe. When processed, both crops have a brown and muddy colour, which is often perceived to be of a lower quality and less desirable than the pure white colour produced by maize. Colour preference is influential in driving consumption preferences, to the detriment of health outcomes (e.g. Groote and Kimenju (2008), who find that there is a higher willingness to accept/lower willingness to pay for non-white maize in Kenya, even when nutritional benefits are present).

Preferences are implicitly evaluated and traits are weighed by consumers when purchasing products, as well as by producers when making production decisions. In a missing or incomplete market context, where producers are consumers, preferences become particularly crucial. Ultimately, individual and household behaviour will be driven by taste preferences. In this paper, we consider each household to have a local taste preference that is operationalised as their ranking of their top three crops.

3. Empirical estimation

To evaluate the relationship between preferences and crop choice, we follow Singh *et al*. (1986) and De Janvry *et al*. (1991). Due to hyperinflation, standard assumptions of separability are unlikely to hold in the context of Zimbabwe during the period of study. Thus, the setting of this paper is one of the non-separability of production and consumption decisions. We account for this constraint in the empirical estimation and assume that household sociodemographic factors, including preferences, affect production choices. Consider the following reduced-form equation:

$$y_{ijt} = x_t\beta + \Upsilon_i\gamma + E_i\ , \tag{1}$$

where y_{ijt} represents the crop portfolio of some household i, which is comprised of various crops j in time t. Υ_i represents household traits, including staple crop preferences, age and education of the household head, measures of wealth and asset ownership, and labour availability, with corresponding parameter vector γ. x_t represents local agronomic conditions, including rainfall, with corresponding parameter vector β. Finally, E is a compound error term, which is composed of unobserved time-invariant factors and unobserved time-variant shocks.

We used equation (1) to explore both crop choice with respect to crop diversification on the farm, as well as decisions related to the cultivation of staple crops. In the latter case, the estimation is complicated by issues such as problems of unobserved heterogeneity and of potential corner solutions in the dependent variable. We address these challenges in the following sections.

3.1 Crop diversity

To investigate the household crop portfolio, we use an index of crop diversity. The crop diversity index is more complicated: we follow Michler and Josephson (2017) to specify this diversity index. The index measures the total number of different crops a household grows in a year (n_{it}), relative to the total number of different crops grown within the village in that year (N_{vt}). We then square this ratio:

$$div_{it} = \frac{{n_{it}}^2}{N_{yt}} \tag{2}$$

Michler and Josephson (2017) identify a number of advantages to using this index relative to alternative index measures.[5] The primary advantage is that, by using the total number of crops presently grown in the village as the denominator, we control for village-specific agroclimatic conditions, so any household's crop diversity (or lack thereof) is not measured against the agricultural practices of households in other villages, but against the practices common to its own village.

As our index is a ratio, lower values indicate a more agriculturally specialised household relative to the cropping practices in the area. and higher values indicate a more diversified household relative to the village. We include in our diversity count 20 different crops, including staple crops such as maize, millet and sorghum, as well as higher-value crops such as vegetables, including various dark leafy greens and tomatoes. Table 2 presents summary statistics of crop count and the diversity index in Panel A.

The estimation of this specification is straightforward, using panel methods and controlling for unobserved heterogeneity, as described in more detail below.

3.2 Staple crop choice

To investigate household staple crop choice, we considered the decision to grow sorghum, millet and maize, as well as the area allocated to each crop. Estimation in these cases is complicated by issues that include problems of unobserved heterogeneity and of potential corner solutions in the dependent variable.

As a large number of households in our sample do not grow some of the staple crops, specifically sorghum and millet, the data take on properties of a non-linear corner solution. In our sample, nearly 50% of households grow no sorghum or any millet. The prevalence of households that choose to exclude sorghum and/or millet from their crop portfolio means that our model must accommodate non-linear corner solutions, following:

$$Y_{ij} = \max \{0, B_i\alpha + x_{ij}\beta + \Upsilon\gamma + E_{it}\}. \tag{3}$$

[5] Alternative indices include the Shannon index and the Herfindahl (or Simpson) index. These indices measure diversity in terms of share or proportionality instead of count. In the case of crop production, an obvious alternative to our index would be to use either the Herfindahl or Shannon index and the area planted to each crop. However, constructing the index in this way would result in severe measurement error coming from self-reported land measures (Carletto *et al.* 2013, 2015). As a result, an index which uses area planted as the input would systemically overestimate diversity since households would overestimate the area planted in minor crops and underestimate the area planted in major crops.

Table 2: Summary statistics

	2005			2013			Total		
	Mean	**St. dev.**	**Median**	**Mean**	**St. dev.**	**Median**	**Mean**	**St. dev.**	**Median**
Panel A: Crop and farm area									
Sorghum grown*	0.523	0.500	1.000	0.534	0.500	1.000	0.527	0.500	1.000
Area allocated to sorghum (hectares)	0.241	0.544	0.040	0.264	0.603	0.101	0.250	0.568	0.080
Maize grown*	0.906	0.292	1.000	0.884	0.321	1.000	0.897	0.304	1.000
Area allocated to maize (hectares)	0.909	0.801	0.667	0.599	0.631	0.405	0.786	0.753	0.667
Millet grown*	0.349	0.477	0.000	0.456	0.499	0.000	0.391	0.488	0.000
Area allocated to millet (hectares)	0.511	1.281	0.000	0.336	0.635	0.000	0.442	1.075	0.000
Total land area (hectares)	1.876	1.617	1.500	1.567	1.440	1.295	1.754	1.556	1.433
Crop count	4.766	2.334	5.000	4.372	2.068	4.000	4.610	2.240	4.000
Diversity index	0.203	0.196	0.144	0.184	0.171	0.132	0.195	0.187	0.141
Panel B: Household traits									
Age of head of household (years)	53.300	15.785	53.000	57.217	14.873	57.000	54.924	15.531	55.000
Education of head of household (years)	5.351	3.711	6.000	6.040	3.530	7.000	5.637	3.653	7.000
Female-headed household*	0.275	0.447	0.000	0.383	0.487	0.000	0.318	0.467	0.000
Number of cattle owned	2.832	4.470	1.000	4.276	6.026	3.000	3.400	5.182	2.000
Own plough*	0.594	0.491	1.000	0.783	0.412	1.000	0.665	0.472	1.000
Received extension*	0.211	0.408	0.000	0.493	0.500	0.000	0.323	0.468	0.000
Number of workers	3.407	2.002	3.000	2.844	1.466	3.000	3.183	1.829	3.000
Number of off-farm labour participants	0.877	1.079	1.000	1.059	0.943	1.000	0.950	1.031	1.000
Number of on-farm full-time labour participants	2.973	1.877	3.000	2.365	1.278	2.000	2.732	1.692	2.000
Number of on-farm part-time labour participants	1.723	1.773	1.000	1.692	1.444	1.000	1.711	1.650	1.000
Number of migrants	0.328	0.495	0.000	0.472	0.593	0.000	0.385	0.541	0.000
Panel C: Staple preferences									
Sorghum No. 1*	0.062	0.241	0.000	0.059	0.236	0.000	0.060	0.238	0.000
Sorghum No. 2*	0.361	0.481	0.000	0.356	0.479	0.000	0.359	0.480	0.000
Sorghum No. 3*	0.188	0.391	0.000	0.191	0.394	0.000	0.190	0.392	0.000
Maize No. 1*	0.703	0.457	1.000	0.706	0.456	1.000	0.705	0.456	1.000
Maize No. 2*	0.160	0.366	0.000	0.162	0.368	0.000	0.161	0.367	0.000
Maize No. 3*	0.086	0.282	0.000	0.084	0.277	0.000	0.085	0.279	0.000
Millet No. 1*	0.235	0.424	0.000	0.235	0.424	0.000	0.235	0.424	0.000
Millet No. 2*	0.165	0.372	0.000	0.170	0.376	0.000	0.168	0.374	0.000
Millet No. 3*	0.078	0.269	0.000	0.075	0.264	0.000	0.077	0.267	0.000
Panel D: Rainfall									
Total rainfall	1 017	694	717	1 080	603	830	1 042	660	772
Rainfall shock	0.882	0.688	0.648	0.770	0.471	0.708	0.837	0.613	0.676
St. dev. of rainfall	264	144	200	263	128	256	264	138	216

Note: * indicates binary variable; St. dev. = standard deviation

This specification allows for the decision not to grow some staple crop to be optimal for some households. The observations of zero sorghum or millet growth represent a choice not to grow the crop, and not a missing value resulting from truncation. Because of this, the Tobit estimator could be used.[6] However, the Tobit estimator implies that the decision to cultivate a crop and the degree of cultivation are determined by the same process. As this need not be the case, we use a double-hurdle (DH) model. The DH model relaxes the restrictions of the Tobit estimator (Cragg 1971). In the first stage of the DH model we consider the choice to grow a crop, while in the second stage of the DH model we consider the area allocated to that crop. The decision to grow sorghum, millet or maize is estimated with separate probit regressions (does the household grow a crop (0/1)?).[7] The degree or intensity of cultivation of that crop is estimated with a truncated normal regression (how much area is allocated to the crop (hectares)?). In each hurdle, we include our variables of interest – a set of controls, year indicators, and our MC device (discussed in more detail below in section 3.3). Regressions for each crop are estimated separately and average partial effects are calculated, following Burke (2009).

This specification also allows us to control for decision-making with respect to reference points. Instead of simply asking for the allocation of area, we account for the multiple decision elements that constitute the complete crop-choice decision, including both the initial decision to plant and final area allocation.

3.3 Unobserved heterogeneity

We are potentially concerned that some of the factors affecting crop choice may suffer from endogeneity caused by omitted variable bias. Specifically, some households are simply more likely to grow more crops or grow particular crops than other households, for reasons unknown to the researcher. We deal with this by employing a specification using a Mundlak Chamberlain (Mundlak 1978; Chamberlain 1984) device (MC device). To implement the MC device, we include a vector of variables containing the means for household i of all time-varying covariates from Y_i. These variables have the same value for each household in every year, but they vary across households. We use the device in both stages of the DH, and it entails adding the time averages of all time-varying household-level variables to the model. Doing so controls for unobserved household-level heterogeneity, similar to a fixed-effects estimator, but the MC device is unlike a fixed-effects specification as it does not remove time-constant covariates from the model. As some of our variables of interest (such as taste preference) do not vary over time, or very only slightly, the MC device estimator allows us to include these variables in the empirical estimation (Wooldridge 2010).

4. Data

We used household panel data collected by the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT). Originally designed to measure the adoption of a sorghum variety developed by ICRISAT, the survey also contains information on agricultural practices and household composition and behaviour, including preferences. These data were collected in the 2004/2005 and

[6] We tested this specification and include the results in Table B.2 in Appendix B. We also performed an LR test to verify that our chosen specification, the double-hurdle (DH), is more appropriate for the sorghum and for the millet specifications. For the sorghum specification, we find a χ^2 value of 192.15 and a p-value of 0.000. For the millet specification, we find a χ^2 value of 33.37 and a p-value of 0.000. These results verify that the DH estimation provides an improvement over the Tobit estimation. Conversely, for the maize specification we find a χ^2 value of -453.77 and a p-value of 1.000. This suggests that the DH does not necessarily provide an improvement over the Tobit specification. This is not surprising, as nearly all households cultivate maize, and therefore the decision-making process is different than that for cultivating sorghum or millet. We therefore proceeded with the DH specification for both crops to provide a more intuitive comparison.

[7] We tested an alternative specification of area shares, presented in Table B.3 in Appendix B. Similar to the index construction, we do not prefer this specification due to possible mismeasurement (Carletto *et al*. 2013, 2015).

the 2012/2013 growing seasons. The survey spans three regions in Zimbabwe: Matabeleland North, Matabeleland South and Masvingo. The areas are considered to be the sorghum-growing regions in the country due to the favourable climatic conditions. However, maize remains the dominant crop in most households' crop portfolios. In the sample, a total of 605 households were surveyed in the first year and 407 households were surveyed in the second year. We used this unbalanced panel in our analysis.[8]

We rely on the survey data from the ICRISAT for our analysis. We present summary statistics for our dependent variables, related to sorghum and maize, in Panel A of Table 2. We also control for total farm size when considering the area allocated to each crop, as crop choice often relies on risk preferences, human capital, credit constraints and labour requirements, among other factors. We also use a rich set of control variables, including household and farm characteristics, presented in Panel B of Table 2. These variables can be categorised as related to household traits, preferences, or local agronomic traits. The household characteristics include the age and education of the head of the household, the number of cattle owned, whether the household owns a plough, whether the household received extension services,[9] and the labour available to the household.

Preferences are measured via taste. Households were asked to rank their top three crops, with no requirements for type or breed of crop. These preferences are akin to stated preferences for their preferred crop, which give us the variable that we used to assess preference-related behaviour (Dohmen *et al*. 2011; Frey *et al*. 2017). The three most popular crops were maize, sorghum, and millet, followed by groundnut and cowpea. In order to capture taste preferences, we included a binary measure of the household's staple grain consumption preference for a particular staple crop, either sorghum, maize or millet. Household staple grain preference was designated by a zero in this measure if they responded with a preference for any crop but the one of interest, and was designated with a one if they responded with a preference for the crop of interest. We created three variables following this binary measure. This allowed for a broad analysis of preferences considering a household's preference for multiple crops. The relevant summary statistics for these variables are reported in Panel C of Table 2. We used these three measures for all three crops in all specifications in the empirical analysis.

To account for climate and agronomic conditions that may lead a household to cultivate a particular set of staple crops or otherwise shift their crop cultivation behaviours, we included a few measures of rainfall. We used the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) data. CHIRPS is a thirty-year quasi-global rainfall dataset. It spans 50 degrees S to 50 degrees N, with all longitudes, and incorporates 0.05-degree resolution satellite imagery with in situ station data to create a gridded rainfall time series (Funk *et al*. 2015). Rainfall statistics are calculated at the community level. We used three measures of rainfall: the previous season's total rainfall (measured in millimetres), the standard deviation of the previous season's rainfall,[10] and a rainfall shock, measured following Josephson and Shively (2017). The rainfall shock was calculated as a Z-score ($\lambda = \left|\frac{x-\mu}{\sigma}\right|$) following Michler *et al*. (2019) and Azzarri and Signorelli (2020).[11] Relevant summary statistics for these variables are reported in Panel D of Table 2.

[8] Using a balanced panel does not significantly influence the results. We provide additional details on attrition, including a series of tests for differences between attriting and non-attriting households, in Section C in the Appendix.
[9] There is some possibility that extension services may include the distribution of seed. We consider this possibility and find that only 3% of respondents in our sample received seed from ICRISAT extension, government extension, or other NGO networks.
[10] Standard deviation is calculated as $\sigma = \sqrt{\sum(x-\mu)^2}$, where x is total rainfall in the previous season and μ is the trailing twenty-year average of total seasonal rainfall.
[11] Alternative lags with tested, including five, ten and fifteen years, with no significant differences.

5. Results and discussion

In the following subsections, we consider four aspects and explanations for crop choice in Zimbabwe. First, we examine households' crop portfolios, measured as a diversity index. Next, we consider staple crop choice, explicitly evaluating the influence of preferences, followed by a discussion of the impact of labour availability and allocation. Finally, we examine an alternative perspective on crop choice with respect to varietal adoption.

5.1 Crop portfolios

The results relating to households' crop choice, as measured using the diversity index, are presented in Table 3. We find that preferences are significantly associated with household crop diversity: sorghum preferences are associated with having less diversity, while preferences for maize and millet are associated with more diversity. Interestingly, the significant effects of the preference variables are observed on lower-level preferences (e.g. ranking a particular crop as second or third most preferred), while higher-order preferences are generally not significant. An exception to this (which is unsurprising) is the case of maize: a first preferred staple of maize is associated with a greater crop diversity index. These findings suggest that preferences are significantly associated with the diversity of a household's cultivation portfolio.

Next, we considered the rainfall variables, which are calculated as a lagged variable for the previous year's cropping season. We find that greater total seasonal rainfall is associated with a greater crop diversity index. In the case of the latter finding, the coefficient, while significant, is extremely small in magnitude, such that the effect is likely not important in a practical sense. Furthermore, the standard deviation is not significant in either regression. Considering the effect of a shock on household diversity, the interpretation is more complicated, although it does suggest that experience of a previous shock may be associated with cultivating a larger number of crops, perhaps associated with building resilience to such events through crop diversification (Michler & Josephson 2017).

Finally, considering household variables, we find that greater total farm area and age of the household head are positively and significantly with a higher crop diversity index. It makes sense that larger farms are more likely to be diverse, as those households have more space on which to grow a larger set of crops. Farms in Zimbabwe are smaller than two hectares (see Table 2 for more) on average, and so smaller farms are likely to be specialised more specifically in subsistence crops so as to ensure sufficient food production for their household. Farms with more space, on the other hand, are able to diversify more easily. The association of the age of the household head suggests that older heads are more likely to be diverse. This follows from the traditional cropping behaviours in the country. As explained by Orr *et al*. (2016): area planted to non-maize staples, in particular sorghum, was traditionally based on building reserves of the grain. If maize failed in a particular year, households would consume an existing stock of the non-maize crop over the lean season and, in the following season, the household would plant more of that crop to rebuild reserves. In recent years, this custom has fallen out of both favour and practice. But it may be the case that only older household heads practise this cultivation strategy and, as a result, have more diverse crop portfolios on average.

As is evident from the results presented in Table 3, several of the labour variables, including number of workers and participants in off-farm labour and part-time labour, along with the number of migrants, are significant. We explore these variables in more detail in section 5.3, which discusses labour variables specifically.

These findings indicate that, in the context of missing and incomplete markets as well as under the macroeconomic challenges of hyperinflation, the role of preferences is important. Furthermore, in addition to the influences of these preferences, other household factors, as well as local agronomic conditions, also affect households' crop diversity.

Table 3: Crop diversity regressions

	Crop diversity index
1^{st} preferred staple: sorghum	0.031 (0.051)
2^{nd} preferred staple: sorghum	-0.046*** (0.011)
3^{rd} preferred staple: sorghum	0.009 (0.023)
1^{st} preferred staple: maize	0.084** (0.030)
2^{nd} preferred staple: maize	-0.0001 (0.007)
3^{rd} preferred staple: maize	0.065*** (0.010)
1^{st} preferred staple: millet	0.077 (0.090)
2^{nd} preferred staple: millet	0.055* (0.029)
3^{rd} preferred staple: millet	0.057 (0.073)
total rainfall	0.0001*** (0.00002)
rainfall shock	0.018 (0.013)
standard deviation of rainfall	0.00003 (0.0003)
total farm area	0.017*** (0.004)
age of head of household	0.002** (0.001)
education of head of household	0.004 (0.003)
female head of household	0.019 (0.015)
number of cattle owned	0.0003 (0.002)
own plough	-0.011 (0.040)
received extension services	-0.009 (0.034)
number of workers	0.027*** (0.0004)
number of off-farm labour participants	0.025*** (0.007)
number of on-farm full-time labour participants	-0.010 (0.010)
number of on-farm part-time labour participants	0.005*** (0.001)
number of migrants	0.016 (0.047)

Note: Fully robust standard errors clustered at the household are in parentheses. (* p < 0.10, ** p < 0.05, *** p < 0.01). Village indicators and MC device variables are included, though are not reported for parsimony.

5.2 Crop choice and allocation

Presented in Table 4 are the results of the double hurdle estimation, including the decision to grow specific crops, and the corresponding area allocated to that crop. These crops include sorghum (columns (1) and (2)), maize (columns (3) and (4)) and millet (columns (5) and (6)). Column (1), column (3) and column (5) of Table 4 report the coefficient estimates of the first stage of the double hurdle (DH) model, presented as average partial effects. Column (2), column (4) and column (6) report estimates of the second stage of the DH, presented as average partial effects, in which the dependent variable is the log of area allocated to each crop.[12]

In this specification, we are most interested in the results with respect to preferences. Considering these findings, the results generally follow expectations, although they still provide interesting insights. For example, any preference ranking for sorghum significantly increases the likelihood of growing that crop and significantly increases the area allocated to the crop. For millet, all preference rankings increase the likelihood of growing that crop, but there are no significant relationships in the preferences for millet associated with increasing the area allocated to that crop. For both sorghum and millet, very few cross-preferences are significant in either stage of the double hurdle. For maize, although the results are quite interesting in that, as expected, a preference for maize is significantly associated with growing more of the crop and allocating more area to it, preferences for sorghum and for millet are associated with growing less maize. This finding is likely related to the preference rankings with respect to household crop diversity: if maize is ranked as a household's first crop preference, they are likely to allocate some area to sorghum and millet due to their lower preferences. These results suggest that preferences are significant, regardless of ranking, in influencing crop choice decisions in both the choice of whether to grow a crop and how much area to allocate to it.

We also find that several household factors are consistently significant across dependent-variable specifications. We find that total farm area increases the probability of growing sorghum and millet, as well as the area allocated to maize and millet. This is supported by our findings on household crop diversity: we find that a greater diversity index is significantly associated with a higher probability of growing millet and sorghum, as well as more area allocated to sorghum. This again directly supports the findings on household crop diversity discussed above.

We also see that there is some heterogeneity in cropping behaviour, based on different characteristics of decision makers within the household. In fact, the finding regarding female headship is in line with findings from focus group discussions that show that women dislike the cultivation of sorghum due to their perception that it is time intensive to grow and to process. Women raised concerns about the cultivation time required with respect to the time that has to be dedicated to protecting the crop from birds and other pests.[13] Women also raised issues about the processing time required to pound sorghum for processing into flour before consumption. Unlike maize, the processing of sorghum and millet is still largely unmechanised in Zimbabwe.

These results suggest that, when output markets are missing, particularly given the context of hyperinflation, the role of preferences is essential in determining households' staple crop allocation choices, both with respect to the decision to grow a crop and the choice of area to allocate to that crop. In addition, beyond the importance of these preferences, other household factors also become important in influencing households' crop diversity, particularly with respect to landholding and overall crop diversity of the household.

[12] Appendix B includes alternative specifications.
[13] As sorghum has no exterior husk, it can be quite labour intensive for cultivators of the crop, as they must be vigilant to protect it from birds in the fields.

Table 4: DH regressions

	(1) Hurdle 1 Grow sorghum	(2) Hurdle 2 Sorghum area	(3) Hurdle 1 Grow maize	(4) Hurdle 2 Maize area	(5) Hurdle 1 Grow millet	(6) Hurdle 2 Maize area
1st preferred staple: sorghum	0.601*** (0.203)	1.222 (1.383)	-0.031 (0.073)	-0.083 (0.103)	-0.110 (0.074)	
2nd preferred staple: sorghum	0.346*** (0.044)	0.704*** (0.129)	0.111*** (0.042)	-0.029 (0.024)	-0.003 (0.032)	-0.148 (0.114)
3rd preferred staple: sorghum	0.244*** (0.069)	0.496*** (0.191)	-0.024 (0.033)	0.048 (0.038)	-0.068 (0.043)	-0.034 (0.044)
1st preferred staple: maize	-0.044 (0.209)	-0.089 (1.406)	0.056 (0.071)	0.189* (0.101)	-0.005 (0.070)	-0.191 (0.122)
2nd preferred staple: maize	-0.057 (0.113)	-0.116 (0.294)	0.099*** (0.045)	0.204*** (0.070)	0.121* (0.068)	-0.291** (0.118)
3rd preferred staple: maize	-0.093 (0.131)	0.189 (0.344)	-0.018 (0.051)	0.207*** (0.078)	0.082 (0.066)	-0.172 (0.109)
1st preferred staple: millet	0.069 (0.217)	0.141 (1.386)	-0.064 (0.084)	-0.294** (0.118)	0.276*** (0.074)	0.110 (0.116)
2nd preferred staple: millet	0.047 (0.096)	0.095 (0.238)	0.024 (0.055)	-0.189*** (0.059)	0.272 (0.054)	-0.106 (0.135)
3rd preferred staple: millet	0.034 (0.075)	0.069 (0.119)	-0.125*** (0.054)	-0.102** (0.045)	0.141*** (0.031)	0.037 (0.104)
total rainfall	0.0001 (0.0001)	0.0001 (0.0002)	0.0001 (0.0001)	0.00002 (0.00004)	-0.00002 (0.0001)	0.00001 (0.0001)
rainfall shock	-0.008 (0.056)	-0.017 (0.134)	-0.008 (0.032)	-0.025 (0.023)	0.040 (0.030)	-0.043 (0.038)
standard deviation of rainfall	-0.002 (0.001)	00.003 (0.003)	-0.001* (0.001)	0.002*** (0.001)	-0.0004 (0.001)	0.0001 (0.001)
total farm area	0.037* (0.019)	0.076 (0.054)	0.004 (0.011)	0.055*** (0.020)	0.038*** (0.010)	0.10** (0.043)
diversity index	0.662*** (0.119)	1.347*** (0.340)	0.102 (0.127)	0.141 (0.063)	0.267*** (0.065)	-0.096 (0.105)
age of head of household	0.004 (0.003)	0.007 (0.008)	0.001 (0.002)	-0.003** (0.001)	-0.003 (0.002)	-0.002 (0.002)
education of head of household	0.014 (0.014)	0.029 (0.034)	-0.011 (0.007)	-0.010 (0.007)	-0.026*** (0.008)	0.004 (0.011)
female head of household	0.033 (0.077)	0.068 (0.170)	-0.115*** (0.045)	-0.083 (0.034)	0.055 (0.040)	0.053 (0.069)
number of cattle owned	-0.003 (0.007)	-0.005 (0.017)	-0.002 (0.004)	0.004 (0.003)	-0.002 (0.003)	0.007 (0.008)
own plough	-0.066 (0.078)	-0.134 (0.200)	-0.049 (0.048)	-0.008 (0.036)	0.055 (0.048)	0.041 (0.067)
received extension services	0.026 (0.055)	0.052 (0.146)	-0.074** (0.032)	-0.052** (0.026)	0.010 (0.033)	-0.110 (0.071)
number of workers	0.036 (0.024)	0.073 (0.060)	0.021 (0.016)	0.020* (0.012)	-0.022* (0.012)	0.022 (0.027)
number of off-farm labour participants	-0.021 (0.026)	-0.041 (0.068)	0.020 (0.014)	0.013 (0.013)	0.016 (0.014)	-0.070** (0.034)
number of on-farm full-time labour participants	-0.039 (0.025)	-0.080 (0.061)	-0.013 (0.013)	-0.006 (0.011)	0.012 (0.014)	-0.015 (0.022)
number of on-farm part-time labour participants	0.012 (0.020)	0.025 (0.052)	0.025* (0.014)	-0.008 (0.009)	0.008 (0.012)	-0.027 (0.025)
number of migrants	-0.050 (0.052)	-0.103 (0.130)	0.043 (0.035)	0.015 (0.022)	0.003 (0.025)	0.075 (0.048)

Note: Robust standard errors clustered at the household level are in parentheses. Average partial effects are reported at * p < 0.10, ** p < 0.05, *** p < 0.01.
A year indicator, natural region indicators, and MC device variables are included, though these are not reported for parsimony.

5.3 Labour

In this section, we consider the results related to the availability and allocation of household labour as it affects crop diversity and count, as well as the specific cultivation decisions for staple crops. The results are reported in Tables 3 and 4. For both crop diversity decisions about crop cultivation and area allocation, we find that the availability of labour is a small but significant factor in determining these outcomes. We consider a broad measure (number of workers) and four more specific allocations of labour, including off-farm labour, full-time on-farm labour, part-time on-farm labour, and migration. These results suggest that the labour behaviour observed in this context validates our standard conceptions of labour availability and allocation.

First, simply considering the number of workers in a household, we find that households with more workers have a higher crop diversity index, although the coefficient is relatively small. We find that the number of workers in a household is significantly associated with cultivating a greater maize area. On this somewhat more aggregated level, this suggests that the availability of labour is important in determining crop portfolios and area allocation.

To explore these findings further, we considered the allocation of these workers to different, specific activities. We find that, while having more off-farm labour participants in a household is associated with greater crop diversity, it is also associated with cultivating less area in millet. This makes sense, as if households are growing more types of crops, there is likely less area allocated to any individual crop. More generally, this finding is interesting because it suggests that diversity in cultivation may also be associated with diversity in labour behaviour. Considering on-farm labour availability: both part-time and full-time farm labour significantly influence cultivation behaviour. The number of part-time on-farm labourers is associated with a greater crop diversity index, and is also associated with a higher probability of growing maize. This is interesting, although perhaps unsurprising, as sorghum is perceived by many in Zimbabwe to be labour intensive and so they would tend towards the less-intensive maize if there was more part-time, rather than full-time, labour available in the household (for more, see Table B.1 in the Appendix).

We investigated these results further to better understand in what way labour may influence a household's crop choice decisions. Figure 2 presents the results for why a household selected to cultivate *less* of a particular crop. The survey respondents were asked why they removed area from a particular crop and into a different crop in the past year (generally, households were moving out of millet and sorghum cultivation and into maize, although not exclusively). Answers were classified by the authors into five categories: (1) rain/weather factors, (2) inputs, including fertiliser, manure, mechanisation, etc., (3) seed, (4) labour, and (5) yield. For the most part, the reasons are distributed approximately equally across crops. The notable exception to this is for sorghum: many households were unable to obtain satisfactory sorghum seeds at various points. In this figure, however, labour does not emerge as a significant factor.

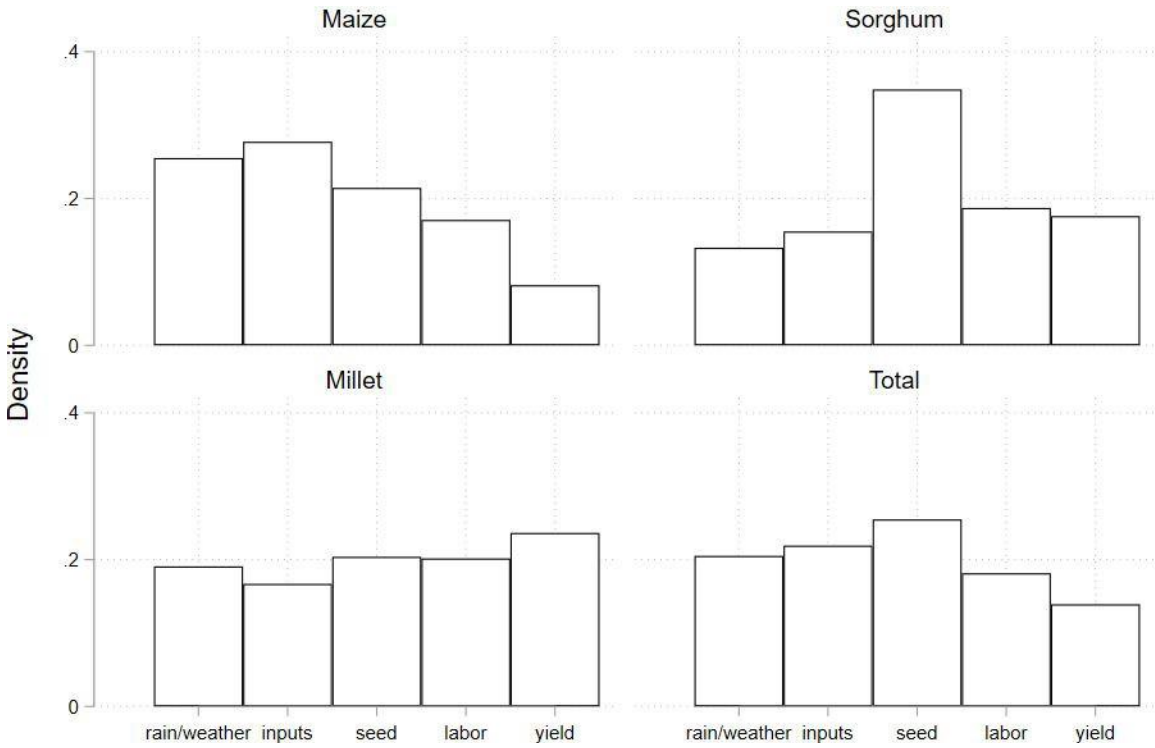

Figure 2: Motivations for crop choices

5.4 Preferences for hybrid crops

We finally considered the possibility that preferences exist for different varieties of a single crop, rather than for different crops. Specifically, we considered the possibility that households are cultivating alternative varieties of maize, rather than cultivating sorghum or millet. These crops would have some of the traits of sorghum and millet, but would have the taste of maize and thus would be preferred by households that rank maize highly in their preferences.

We did this by examining the varieties reported to be cultivated by the survey respondents. We find that most of the households in our sample were not growing drought-tolerant maize varieties. The three most common varieties of maize grown by farmers in our sample were Seedco Zebra (13% of maize cultivated), Pannar maize (13% of maize cultivated), and Seedco Monkey (12% of maize cultivated). None of these varieties are bred specifically for drought tolerance. Instead, these particular maize varieties are bred for early maturation and high yield.

Another possibility was that late season maize was being cultivated. This would account for a case in which some staple crop failed early in the season and was replaced by a late season maize crop. However, we again find this not to be the case. Of the 150 varieties of maize reported to be under cultivation, only two would be appropriate for a short, late season crop. Of these two varieties, only 16 households grew them in 2005, and only 12 households grew them in 2013. Based on these findings, we also failed to find support for the explanation that households are not cultivating sorghum or millet but are instead cultivating varieties of maize bred for drought tolerance or rapid maturation.

6. Conclusion

In this paper, we considered household decision-making in the context of incomplete or missing markets. This allowed us to explore how various factors affect household crop diversity and choices on cultivation and allocation in Zimbabwe. This context is informative for other situations with thin or absent markets, in relation to which the development economics literature increasingly acknowledges that market failure is more the norm than the exception (Omamo 2004; Omamo & Farrington 2004; LaFave & Thomas 2016). A deeper understanding of the relationships and factors affecting crop choice in these contexts has considerable validity far beyond the specific Zimbabwe case, but also in other cases of missing markets – whether as a result of macroeconomic instability, infrastructure challenges, conflict, or any of a myriad other reasons.

We find that preferring a particular staple crop significantly influences a household's crop diversity, as well as specific decisions on growing staple crops. This is due to the importance of a household's preferences in the context of missing markets. We find that the specific ranking of these crops, relative to one another, is important in influencing these crop choice decisions. Further, we find that labour affects household crop diversity, as well as decisions related to the growth of staple crops.

With this paper, we contribute to the ongoing discussion in the literature about incomplete markets and crop choice. Although much effort has been made to improve supply and value chains across Sub-Saharan Africa in recent decades, in times of stress, crises or other challenging circumstances, markets may not exist, may be incomplete, or otherwise be inaccessible for many in rural environments. We add evidence on the strategies undertaken by these households, given the experience of hyperinflation and the related macroeconomic instability in Zimbabwe in the 2000s. It is imperative to understand these sorts of challenges and the related circumstances in order to cope with them better in the future. As many countries continues to face macroeconomic, political and social variability, incomplete and missing markets are a persistent challenge faced by many people living in those nations as they seek to ensure their own food security.

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Appendix

Section A: Crop production processes

We considered the possibility that sorghum, maize and millet may have different production processes. These production processes might influence a household's decision to cultivate one crop over another if one crop has more intensive requirements. We specified a production function and interacted each production input variable with a dummy variable for sorghum, for maize, and for millet. We considered the coefficients of the interaction terms for each crop, evaluating if inputs were different, which would signify different production processes between the crops.

These results are presented in Table A.1. Although we include rainfall characteristics in the regression, we focus only on the household and farm traits, which are significantly different in this discussion. We see some differences between crops: significant differences exist between maize and sorghum with respect to use of manure, use of topcoat and basal fertiliser, and total area; between maize and millet with respect to use of basal fertiliser, number of workers, and total area; between sorghum and millet with respect to use of basal fertiliser, number of weedings, cattle and workers, and receiving an extension visit.

For those variables that are different across crops, we used a Wald test to establish which is larger in order to determine which crop requires more intensive cultivation. First, comparing sorghum and maize, maize has considerable requirements for the use of both fertilisers and manure, but sorghum is associated with greater household landholding. Next, comparing millet and maize, maize has greater requirements in the case of all of the differences between the two crops. Finally, comparing millet and sorghum, sorghum requires more intensive cultivation through a greater number of weedings, workers, extension and area, while millet is associated with a greater number of cattle.

For the most part, the differences that exist are relatively small and suggest only minor discrepancies between the crops. One exception to this, suggesting a significant and large disparity, is sorghum and the number of weedings, which results in greater yields. Greater sorghum yield is significantly associated with a larger number of weedings compared with millet or maize. However, reviewing the summary statistics in the data suggests that maize is actually weeded more than either millet or sorghum. On average, maize is weeded nearly three times as much as millet and sorghum, which are both weeded less than once (see Table B.1 for more). Weeding is a labour-intensive activity and it may be the case that households allocate labour to their preferred crop. To further investigate this potential influence of labour availability and allocation on crop choice, we explicitly considered these labour measurements in our empirical analysis. This allowed us to consider the importance of the required labour availability for crops, which may be differentially intensive.

These findings suggest differences in the production processes of these crops, indicating that maize is the most intensive crop with respect to cultivation requirements, followed by sorghum and then millet. As maize is more widely cultivated, these findings suggest that it is likely that households are not deterred by the higher requirements in the production process of crops, at least not in the case of maize. This result is generally supported by studies of staple crops in Southern Africa, which find that maize is more input intensive, but also more widely grown (Du Plessis nd).

Table A.1: Production systems of staple crops

	Maize (Ln) yield	Sorghum (Ln) yield	Millet (Ln) yield
Use manure	0.603 (0.690)	0.144 (0.480)	0.337*** (0.082)
(Ln) Quantity of basal fertiliser	0.027 (0.034)	-0.120 (0.096)	0.267** (0.122)
(Ln) Quantity of topcoat fertiliser	0.192*** (0.013)	0.083 (0.072)	0.151 (0.264)
Number of weedings	0.788*** (0.228)	1.602*** (0.451)	0.620** (0.262)
Received extension	0.461*** (0.052)	0.300 (0.409)	0.193** (0.084)
Received free seed	-0.303 (0.197)	-0.366*** (0.074)	-0.237 (0.547)
(Ln) Number of workers	0.325* (0.168)	0.373*** (0.064)	0.119 (0.154)
(Ln) Household farm area	-0.448** (0.184)	-0.253*** (0.062)	-0.654*** (0.115)
(Ln) Number of cattle	0.154*** (0.011)	0.094 (0.134)	0.360** (0.144)
(Ln) Average rainfall	7.518*** (2.132)	6.056*** (1.068)	1.402 (2.546)
(Ln) Standard deviation of rainfall	-8.468*** (2.449)	-6.347*** (1.050)	-1.792 (2.028)

Note: Left-hand side variable is log of yield, run in a single regression. Indicator variables for staple crop (sorghum, maize, millet – millet excluded variable) and region (Chivi, Zaka, Gwanda, Bulilima, Binga, Nkayi, Tsholotsho – Tsholotsho excluded variable) are included, but omitted from the table for brevity. Fully robust standard errors clustered at the household level are in parentheses (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$).

Section B: Specification of alternatives

This section presents additional tables and figures to our main results.

Table B.1: Crop comparison: Reported activities

	Mean	Standard deviation	Median
Maize			
Basal fertiliser	10.489	124.235	0.000
Topcoat fertiliser	3.371	12.695	0.000
Use manure	0.389	0.488	0.000
Weedings	2.914	2.534	2.000
Sorghum			
Basal fertiliser	0.353	3.182	0.000
Topcoat fertiliser	0.340	5.214	0.000
Use manure	0.059	0.236	0.000
Weedings	0.984	1.286	1.000
Millet			
Basal fertiliser	0.137	1.797	0.000
Topcoat fertiliser	0.124	1.399	0.000
Use manure	0.124	0.330	0.000
Weedings	0.806	1.345	0.000
All staple crops			
Basal fertiliser	3.660	71.895	0.000
Topcoat fertiliser	1.278	8.098	0.000
Use manure	0.244	0.429	0.000
Weedings	1.568	2.050	1.000

Table B.2: Tobit

	Grow sorghum	Grow maize	Grow millet
1st preferred staple: sorghum	0.593*** (0.193)	-0.133 (0.115)	-0.108 (0.085)
2nd preferred staple: sorghum	0.380*** (0.050)	0.056*** (0.021)	-0.005 (0.027)
3rd preferred staple: sorghum	0.289*** (0.078)	0.006 (0.048)	-0.082 (0.052)
1st preferred staple: maize	-0.030 (0.209)	0.086 (0.118)	-0.017 (0.086)
2nd preferred staple: maize	-0.081 (0.111)	0.218** (0.108)	0.112 (0.073)
3rd preferred staple: maize	-0.097 (0.125)	0.146 (0.114)	0.063 (0.072)
1st preferred staple: millet	0.073 (0.212)	-0.255** (0.127)	0.637*** (0.109)
2nd preferred staple: millet	-0.005 (0.098)	-0.052 (0.056)	0.578*** (0.082)
3rd preferred staple: millet	0.016 (0.073)	-0.062 (0.039)	0.299*** (0.068)
total rainfall	6.04e-05 (8.82e-05)	1.25e-05 (3.24e-05)	1.59e-05 (5.73e-05)
rainfall shock	0.001 (0.057)	-0.004 (0.022)	0.018 (0.036)
standard deviation of rainfall	-0.002 (0.001)	-0.001 (0.001)	-0.0003 (0.001)
total farm area	0.027* (0.016)	0.0002 (0.010)	0.032*** (0.010)
farm diversity index	0.655*** (0.107)	0.095* (0.055)	0.299*** (0.081)
age of head of household	0.003 (0.003)	0.001 (0.002)	-0.002 (0.002)
education of head of household	0.014 (0.014)	-0.002 (0.008)	-0.030*** (0.010)
female head of household	0.011 (0.081)	-0.065 (0.040)	0.073 (0.050)
number of cattle owned	-0.001 (0.007)	0.001 (0.004)	-0.002 (0.004)
own plough	-0.073 (0.082)	-0.030 (0.041)	0.057 (0.050)
received extension services	0.033 (0.057)	-0.054** (0.024)	-0.017 (0.035)
number of workers	0.038 (0.024)	0.026* (0.015)	-0.022 (0.015)
number of off-farm labour participants	-0.120 (0.027)	-0.001 (0.012)	0.014 (0.017)
number of on-farm full-time labour participants	-0.044* (0.025)	-0.015 (0.015)	0.012 (0.017)
number of on-farm part-time labour participants	0.010 (0.020)	0.006 (0.012)	0.007 (0.014)
number of migrants	-0.050 (0.056)	0.029 (0.025)	-0.006 (0.031)

Note: Fully robust standard errors clustered at the household level are in parentheses (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$). A year indicator is also included, as well as natural region indicators, although these are not reported.

Table B.3: Shares of staple crops in total area

	Share of sorghum	Share of maize	Share of millet
1st preferred staple: sorghum	0.029 (0.076)	-0.264** (0.125)	0.079 (0.092)
2nd preferred staple: sorghum	-0.023 (0.039)	-0.072*** (0.020)	-0.090 (0.073)
3rd preferred staple: sorghum	0.125* (0.071)	0.094** (0.112)	-0.071* (0.039)
1st preferred staple: maize	-0.147* (0.076)	0.136 (0.142)	
2nd preferred staple: maize	-0.116 (0.079)	0.255** (0.108)	-0.098 (0.060)
3rd preferred staple: maize	0.137 (0.091)	0.317*** (0.109)	-0.104 (0.085)
1st preferred staple: millet	-0.235** (0.106)	-0.514*** (0.130)	0.201** (0.082)
2nd preferred staple: millet	-0.103 (0.080)	-0.243*** (0.051)	6.5e-05 (0.081)
3rd preferred staple: millet	0.055 (0.048)	-0.085** (0.036)	0.003 (0.077)
total rainfall	3.95e-05 (5.97e-05)	-1.67e-05 (3.64e-05)	2.87e-05 (6.01e-05)
rainfall shock	0.013 (0.031)	-0.037 (0.023)	-0.048 (0.039)
standard deviation of rainfall	0.001 (0.001)	0.002*** (0.001)	-0.001 (0.001)
farm diversity index	-0.514*** (0.106)	-0.108** (0.047)	-0.163** (0.074)
age of head of household	0.004** (0.002)	-0.0003 (0.001)	-0.002 (0.002)
education of head of household	0.013 (0.018)	-0.0002 (0.006)	-0.001 (0.009)
female head of household	-0.063 (0.046)	-5.34e-05 (0.033)	0.049 (0.053)
number of cattle owned	-0.001 (0.006)	0.001 (0.003)	0.003 (0.004)
own plough	0.058 (0.052)	-0.011 (0.036)	0.042 (0.059)
received extension services	-0.014 (0.036)	-0.009 (0.025)	0.008 (0.045)
number of workers	-0.032* (0.017)	0.019* (0.011)	-0.020 (0.016)
number of off-farm labour participants	-0.036** (0.018)	0.020* (0.011)	-0.033 (0.024)
number of on-farm full-time labour participants	0.025 (0.017)	-0.011 (0.011)	0.013 (0.015)
number of on-farm part-time labour participants	0.003 (0.013)	-0.022** (0.009)	0.002 (0.015)
number of migrants	0.005	0.018	0.030
	(0.034)	(0.021)	(0.039)

Note: Fully robust standard errors clustered at the household level are in parentheses (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$). A year indicator is also included, as well as natural region indicators, although these are not reported.

Section C: Attrition

We used an unbalanced panel in our empirical analysis and did not see significant differences in the results. In this section, we consider additional details on attrition in our sample. All efforts were made to interview the same households in both rounds of the survey; however, as with any panel, there was some attrition. Approximately 80% of the original households were re-surveyed. We tested to ensure that attrition was non-random and unbiased.

We considered attrition in our data using two tests. First, we compared the summary statistics for attriting and non-attriting households. Table C.1 shows the summary statistics for the main set of variables used in our analysis. We tested for differences between the two groups within these variables, using a t-test. We find that there are some significant differences and thus, to investigate if these differences drove attrition from the sample, we undertook the second test: a Probit regression on whether a household is a panel household (0 = attriting households, 1 = panel, non-attriting households) with these same variables. These results are presented in Table C.2. In this regression, we find that several variables are significant, including some of the preference rankings for sorghum, maize and millet, some rainfall traits, and some household characteristics, including household headship by women, age of household head, receiving extension, and number of cattle owned.

Ultimately, we conclude that there may be non-randomness in attrition, which may result in bias if using a balanced panel and thus, in our analysis, we prefer the unbalanced panel specification.

Table C.1: Summary statistics

	Non-panel households			Panel households			Total		
	Mean	Standard deviation	Median	Mean	Standard deviation	Median	Mean	Standard deviation	Median
Panel A: Crop and farm area									
Sorghum grown*	0.502	0.501	1.000	0.535	0.499	1.000	0.527	0.500	1.000
Area allocated to sorghum (hectares)	0.195	0.356	0.020	0.267	0.619	0.100	0.250	0.568	0.080
Maize grown*	0.862	0.345	1.000	0.908	0.289	1.000	0.897	0.304	1.000
Area allocated to maize (hectares)	0.842	0.830	0.667	0.768	0.727	0.608	0.786	0.753	0.667
Millet grown*	0.329	0.471	0.000	0.411	0.492	0.000	0.391	0.488	0.000
Area allocated to millet (hectares)	0.469	1.261	0.000	0.433	1.010	0.000	0.442	1.075	0.000
Total land area (hectares)	1.684	1.446	1.333	1.776	1.589	1.446	1.754	1.556	1.433
Crop count	4.293	2.402	4.000	4.710	2.177	5.000	4.610	2.240	4.000
Diversity index	0.160	0.167	0.111	0.207	0.192	0.160	0.195	0.187	0.141
Panel B: Household traits									
Age of head of household (years)	54.38	16.104	54.000	55.084	15.358	55.000	54.924	15.531	55.000
Education of head of household (years)	5.291	3.929	6.000	5.740	3.561	7.000	5.637	3.653	7.000
Female-headed household*	0.307	0.461	0.000	0.321	0.467	0.000	0.318	0.467	0.000
Number of cattle owned	2.204	3.887	0.000	3.777	5.477	2.000	3.400	5.182	2.000
Own plough*	0.547	0.498	1.000	0.704	0.457	1.000	0.665	0.472	1.000
Received extension*	0.138	0.345	0.000	0.382	0.486	0.000	0.323	0.468	0.000
Number of workers	3.153	1.845	3.000	3.193	1.821	3.000	3.183	1.829	3.000
Number of off-farm labour participants	0.835	1.033	1.000	0.986	1.027	1.000	0.950	1.031	1.000
Number of on-farm full-time labour participants	2.696	1.833	2.000	2.743	1.645	2.000	2.732	1.692	2.000
Number of on-farm part-time labour participants	1.652	1.778	1.000	1.729	1.608	1.000	1.711	1.650	1.000
Number of migrants	0.320	0.486	0.000	0.406	0.556	0.000	0.385	0.541	0.000
Panel C: Staple preferences									
Sorghum No. 1*	0.111	0.317	0.000	0.059	0.236	0.000	0.060	0.238	0.000
Sorghum No. 2*	0.167	0.376	0.000	0.363	0.481	0.000	0.359	0.480	0.000
Sorghum No. 3*	0.222	0.420	0.000	0.189	0.391	0.000	0.190	0.392	0.000
Maize No. 1*	0.611	0.492	1.000	0.707	0.455	1.000	0.705	0.456	1.000
Maize No. 2*	0.278	0.452	0.000	0.158	0.365	0.000	0.161	0.367	0.000
Maize No. 3*	0.000	0.000	0.000	0.087	0.282	0.000	0.085	0.279	0.000
Millet No. 1*	0.278	0.452	0.000	0.234	0.423	0.000	0.235	0.424	0.000
Millet No. 2*	0.222	0.420	0.000	0.166	0.372	0.000	0.168	0.374	0.000
Millet No. 3*	0.000	0.000	0.000	0.079	0.269	0.000	0.077	0.267	0.000

Note: * indicates binary variables

Table C.2: Attriting household tests

Grow sorghum	-0.004 (0.016)
Grow maize	-0.001 (0.014)
Grow millet	-0.002 (0.020)
1st preferred staple: sorghum	0.003 (0.021)
2nd preferred staple: sorghum	0.004 (0.016)
3rd preferred staple: sorghum	0.046** (0.016)
1st preferred staple: maize	0.067** (0.027)
2nd preferred staple: maize	0.009 (0.027)
3rd preferred staple: maize	
1st preferred staple: millet	0.147*** (0.035)
2nd preferred staple: millet	0.079 (0.027)
3rd preferred staple: millet	
Plot area	-0.002 (0.005)
Staple plot area	-0.001 (0.007)
Diversity index	0.267** (0.124)
Crop count	-0.005 (0.009)
Total rainfall	–7.87e-05*** (2.06e-05)
Rainfall shock	-0.033*** (0.011)
Standard deviation of rainfall	0.0004*** (9.27e-05)
Age of head of household	-0.002*** (0.0004)
Education of head of household	-0.0002 (0.002)
Female head of household	0.061*** (0.014)
Own plough	0.022 (0.014)
Number of cattle	-0.003*** (0.001)
Received extension	0.050*** (0.014)
Number of workers	0.003 (0.005)
Off-farm labour participants	-0.003 (0.005)
On-farm (full-time) labour participants	0.002 (0.006)
On-farm (part-time) labour participants	-0.006 (0.005)
Migrants	0.029 (0.012)

Note: Left-hand side variable is household attrition status. Average partial effects are reported. Fully robust standard errors are in parentheses (* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$).