2016

Milk in the Data: Food Security Impacts from a Livestock Field Experiment in Zambia

Margaret Jodlowski, *Cornell University*
Alex Winter-Nelson, *University of Illinois at Urbana-Champaign*
Kathy Baylis, *University of Illinois at Urbana-Champaign*
Peter Goldsmith, *University of Illinois at Urbana-Champaign*

www.elsevier.com/locate/worlddev

World Development Vol. 77, pp. 99–114, 2016
0305-750X/

http://dx.doi.org/10.1016/j.worlddev.2015.08.009

Milk in the Data: Food Security Impacts from a Livestock Field Experiment in Zambia

MARGARET JODLOWSKI [a], ALEX WINTER-NELSON [b], KATHY BAYLIS [b] and PETER D. GOLDSMITH [b,*]

[a] *Cornell University, Ithaca, USA*
[b] *University of Illinois at Urbana-Champaign, USA*

Summary. — Smallholder livestock ownership has potential to enhance food security by raising incomes of the poor and by increasing the availability of nutrient-dense foods. This paper exploits the staggered rollout of livestock distribution by Heifer International in Zambia to identify the effects of livestock using statistically similar treatment and control groups in a balanced panel of households. Results indicate that livestock ownership improves dietary diversity through both direct consumption of animal products produced on farm and through increased consumption expenditures. Further results indicate that expanded livestock ownership alters the local food economy to influence food consumption by households lacking farm animals.

Key words — livestock, dietary diversity, Sub-Saharan Africa, Zambia, food security, asset transfers

1. INTRODUCTION

Livestock ownership is increasingly promoted in food security strategies because farm animals can provide nutrient-dense foods, regular income, and other benefits. Nonetheless, little empirical work actually demonstrates a causal link between livestock ownership and food security (FAO, 2012). Measuring the effectiveness of livestock in alleviating poverty and food insecurity is undermined by endogeneity: those households that have livestock likely differ systematically from those that do not. We use unique panel data from the rollout of a Heifer International livestock program in Zambia to identify the causal effect of livestock ownership on dietary diversity and consumption expenditure. We further explore the mechanisms through which livestock affects household food security by considering the impact of livestock ownership on income and on the consumption of specific food groups among livestock owners and other community members.

As with any agricultural technology, identifying an appropriate control group for households who adopt livestock is complicated by selection bias. Those who choose to adopt are fundamentally different from those who choose not to adopt, making non-adopters invalid as a control for adopters. Recent reviews of research on the impact of livestock on food security, nutrition, and poverty note that existing studies suffer from an absence of control groups and endogeneity problems associated with selection bias (DFID, 2014; Leroy & Frongillo, 2007). In this article, particular features of the Heifer International livestock donation program allow us to identify current and future recipients of farm animals. We use future adopters of livestock as a control group for current adopters and collect baseline data on livestock recipients and comparable non-recipients. We use a difference-in-differences approach controlling for time-invariant household characteristics to compare outcomes for the recipients against those who have selected into the program, but have not yet received animals. This approach follows suggestions from de Janvry, Dustan, and Sadoulet (2011) who note that selection bias can be overcome in part through utilization of staggered rollouts, which can be analyzed similarly to randomized control trials (RCTs) even when they lack explicit randomness. Using households who have selected into the program as controls and applying household fixed effects addresses concerns of endogeneity more completely than existing research (DFID, 2014). We run several placebo tests to rule out systematic pre-treatment differences among the groups and other possible confounding factors that could drive our results.

Our analysis uses panel data from Zambia covering 300 households over four rounds, spanning 18 months from the distribution of donated animals. To our knowledge, this work is one of the first studies to use a balanced panel of data to examine the effects of livestock on expenditure and food security. While we expect to see a direct impact of donated livestock through increased availability of animal products, we also expect an indirect effect on food security through increased revenue, which can be used to access a wider variety of foods. Moreover, we anticipate potential spillover effects throughout communities as perishable animal products become more available due to increased local production. The timing, scale and mechanisms of these effects may vary by animal species.

We find significant effects on household outcomes for recipients of dairy cattle, meat goats, and draft cattle. The receipt of livestock triggers increases in dietary diversity and in consumption expenditure per capita. In all specifications, expenditure per capita has a positive and significant effect on dietary diversity, implying that livestock ownership affects dietary diversity through two channels: first, through the direct impact

* This research was made possible by a grant from Elanco Animal Health (USA) and by the cooperation of Heifer International. We are especially grateful to Kevin Watkins (Elanco), James Kasongo (Heifer International), Joyce Phiri (Heifer International), and Djondoh Sikalongwe (Heifer International). This material is based in part upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under Hatch Project 230404. Views, opinions, and remaining errors are those of the authors. Final revision accepted: August 18, 2015.

of ownership on access to animal sourced foods, and second, indirectly, through the increase in total consumption expenditures allowed by livestock ownership. As one might expect, the direct increase in dietary diversity is driven by milk consumption and is largest in magnitude when dairy animals are distributed. We further find that non-recipients living in communities with recipients also experience increased milk consumption. In our setting, we find the benefits from livestock, particularly dairy cattle, are large. When we compare the size of effects from the livestock gift to those expected from an equivalent gift of cash, we find that the cash gift would have to yield an annual return of nearly 70% to generate the same effects on dietary diversity as the average gift of livestock. Thus, our findings imply that livestock can have an impact on food security beyond what would emerge from a cash transfer of similar scale and that livestock development may affect the local food economy to enhance food security of non-recipients as well.

This paper extends the existing literature by providing causal inference and by distinguishing mechanisms through which livestock affects outcomes. One recent article that employs quasi-experimental methods to study the impact of livestock uses a cross-sectional household survey to investigate the effects of a Heifer International livestock donation on various biometric outcomes for children and on food consumption patterns (Rawlins, Pimkina, Barrett, Pedersen, & Wydick, 2014). Using propensity score matching (PSM) to designate a control group, Rawlins *et al.* find significant impacts of dairy cow ownership on dietary diversity, but no effect from owning goats. Rawlins *et al.* acknowledge that because they are limited to cross-sectional data and have no baseline, they cannot attribute these results to the introduction of livestock as the effects may be driven by unobservable household characteristics.

Alary, Corniaux, and Gautier (2011) use an income-based approach to evaluate the contribution of livestock to poverty reduction in Mali. They find that livestock contributes "significantly" to a household reaching the poverty line in an agricultural system in which livestock are prevalent. They are able to characterize the complex role livestock plays in agricultural systems and the relationships, both direct and indirect, between livestock and poverty reduction. However, the observational nature of their data limits their ability to identify causal impacts of the animals. A number of studies have analyzed programs for training and asset transfer (often in the form of cattle), but those analyses largely focus on income effects, expenditures, time allocation, and household bargaining outcomes of the program instead of food security or dietary diversity *per se* (Bandiera *et al.*, 2012; Banerjee, Duflo, Chattppadhyay, & Shapiro, 2011; Banerjee *et al.*, 2015; Das *et al.*, 2013; Krishna, Poghosyan, & Das, 2012). Further, they do not address the specific mechanisms of livestock on food security, or use research settings involving the introduction of livestock into a market in which they are otherwise absent. The context and data for this paper allow us to explore specific effects of livestock on food security in a region with historically low rates of large animal ownership.

2. DATA

(a) *The Heifer International Program*

Heifer International projects operate in rural communities in Zambia with the following structure. Community groups must first form and organize themselves to submit applications to one of Heifer International's Zambia offices and achieve eligibility for assistance from the organization. Eligibility for individuals in approved groups is contingent on participation in training activities and on initial investments in animal facilities at their homes, as well as payments into a community insurance fund. Households are also screened to remove the non-poor from the pool of livestock recipients. Thus, households in groups that are eligible for Heifer assistance are neither the most poor in Zambia, nor are they wealthy. In absolute terms, they are certainly poor, with 72% of the participating households in our survey living on less than US$1.25 per person per day. Moreover, participant households have demonstrated a willingness to participate in organized groups with the purpose of access to livestock. Thus they have self-selected and may not be typical of all households in terms of their preferences, abilities, or other unobservable factors. Even if eligible participants are different in some ways from the average Zambian household, eligible households are similar to *each other* in that they all performed the same process of self-selection.

Within a group served by Heifer International, some households receive livestock in an initial distribution. We refer to these households as originals. Other group members receive the female offspring from the initially donated animals; these households are referred to as Pass-on-the-Gift (POG) households. Due to the limited supply of pregnant animals and other capacity constraints, animals are not initially distributed to every eligible group. Households in unserved groups (referred to as prospectives in this paper) may be a control for those in served groups, while POG households (in served groups that do not receive animals initially) are another control, albeit an incomplete control that is subject to potential spillover effects. Thus, original recipients, POGs and prospective households have self-selected to participate with Heifer International, but only the original recipients receive animals in the initial distribution. Original recipients and POGs live in the same communities and prospective recipients live in others. A final category of surveyed households is the independents, who were not interested in, or incapable of, participating in the Heifer International program, but live in the same communities as the original recipients and POGs.

Prospectives, POGs, and originals are all eligible to receive an animal through Heifer International. The selection of original beneficiaries among the eligible households is known to have been random in one community, and is assumed to have been random in other communities where the process was not observed. While eligibility to receive an animal is endogenous and based on self-selection, actual receipt can be considered exogenous. We examine the assumption of random allocation between originals and POGs through a series of robustness and validity tests. In the initial models, POGs and prospectives are pooled together as the control group on the assumption that spillovers within the treated communities are modest over the time frame considered. In a later specification, we explicitly test for spillovers from the originals to the POGs, using the prospectives as the control. We additionally look for anticipatory behavior on the part of the POG households, which could contaminate them as a control for the households that received livestock. Because POGs are very likely to receive livestock within 18 months to 3 years of the initial animal distribution but prospective households are only eligible to receive livestock in the future, we expect that any anticipatory behavior would be stronger in the POGs than in the prospectives. We test for anticipatory behavior first by comparing livestock expenditure for POGs to that of prospectives and by treating the POGs as treated and re-running the regressions on the outcome variables. In both cases we see no evidence of anticipatory behavior.

(b) *The sample and treatments*

The data used in this analysis come from the Copperbelt Rural Livelihoods Enhancement Support Project (CRLESP) in the Copperbelt Province of Zambia, which is implemented by Heifer International with funding from Elanco Animal Health (USA). The data were collected in four survey rounds, starting in January/February 2012 and continuing every 6 months thereafter (July/August 2012, January/February 2013, and July/August 2013). This schedule was chosen to capture seasonality, including fluctuations in food production and consumption. This paper uses all four survey rounds, covering a period of 18 months.

The baseline survey covers 324 households and includes nearly 2,200 individuals. These households are divided over five different communities, and can be grouped by their location and by their livestock status. Three of these communities (Kamisenga, Kaunga, and Kanyenda) contain households that received livestock from Heifer International; the remaining two communities (Chembe and Mwanaombe) contain groups that applied to Heifer for livestock assistance and were approved but had not received assistance by the fourth survey round. Because these communities are largely geographically isolated from each other, effects are unlikely to spill over across communities.

In the fourth round of the survey 308 households were interviewed. Of these 308, eight households were missing in at least one previous round, implying a full panel of 300 households, including the independent households. Table 1 presents the distribution of households by livestock recipient status and by community in Round 1 and Round 4. Given the attrition rate of 8.3% we test whether characteristics of the sample change due to attrition (Angrist, 1997). We find little evidence to suggest that attrition is systematic or influences our results.

Through the Heifer International program, the original recipients received different animals based on their community. Thirty-one (31) households in Kamisenga each received one pregnant dairy cow, 20 Kaunga households each received two female draft cattle, and 54 households in Kanyenda each received seven female meat goats and one male. Each group of draft or dairy cow recipients was also given a bull, to be kept by the group to service the households' donated cattle. For all recipients the distributed livestock constitutes a significant intervention, worth roughly US$2,000 (10,000,000 Zambian Kwacha (ZMK)), which is over five times the initial average asset level of the households.[1] The original recipients are required to pass on to POG households one female offspring for each donated female. POG households may or may not receive livestock during the study period: if they do, they receive immature livestock that do not yield income within in the short time period of this study.[2] That said, POGs may benefit from increased availability of livestock products for consumption in their communities. Spillover effects are assessed in a separate regression by treating prospectives as a control and POGs as a treated group.

Livestock systems are diversified and serve varied purposes for households in the developing world, and so the flow of benefits from a donated animal varies with the species (Randolph *et al.*, 2007). Dairy cows had been impregnated prior to distribution and were due to calve approximately 7 months after distribution, near the time of the second round of the survey. Dairy cows yield high volumes of milk: producing up to 20 liters per day if they receive good nutrition, as is the case during the rainy season (Rounds 1 and 3). Milk may be consumed in the home and small quantities could be sold in the local community, but the bulk of milk production from dairy cattle is expected to be delivered to a chilling plant and sold to the dairy processor Parmalat, a large multinational dairy firm. The dairy cows are expected to calve every 12–15 months. Dairy POG households receive calves no sooner than a year after the original recipients received cows and will need to wait at least another year before their animals produce milk.

Pairs of draft cattle had also been impregnated prior to distribution and, like dairy cows, were expected to calve just after the second round of the survey. Draft cattle are expected to enable recipients to prepare greater land areas and expand their crop production. More importantly, recipients of draft cattle are expected to earn income through hiring out the draft power for land preparation, hauling and manure production (Randolph *et al.*, 2007). Draft cattle also produce milk for home consumption and some local sales, but do not produce sufficient milk for larger distribution. As with dairy cattle, milk production and sales are expected to be higher during the rainy season when animal nutrition is likely to be better.

Recipients of meat goats received pregnant goats that were expected to kid before the second round of the survey. The goats produce a small volume of milk that is likely to be consumed entirely on farm. Seven goats can be expected to produce nine to ten kids, four to five of which are expected to be female. Male kids may be slaughtered, sold or kept. Female kids must be kept to be passed on to POGs. Given a five-month gestation period, goats are expected to kid twice within 18 months of donation, with a twinning rate of 33%. Thus, goat recipients are likely to have passed on their gifts within 18 months and have eight to ten male kids to slaughter, sell, or keep.

Table 1. *Sample size and attrition*

	Round 1 *N*	Round 4 *N*	Difference
Kamisenga (dairy cow)	87	85	−2
Kaunga (draft cattle)	55	52	−3
Kanyenda (goat)	115	105	−10
Chembe (prospective)	31	31	0
Mwanaombe (prospective)	36	35	−1
Original	105	103	−2
POG	111	103	−8
Prospective	67	66	−1
Independent	41	36	−5
Total	324	308	−16

3. EMPIRICAL APPROACH

To analyze the effects of livestock on dietary diversity and consumption expenditure patterns, we use a difference-in-differences method:

$$Y_{ilt} = \alpha + \sum_{l}\beta_l A_t T_{il} + \sum_{t}\gamma_t A_t + \sum_{l}\delta_l T_{il} + \mu' X_{ilt} + \phi_i + \varepsilon_{ilt} \quad (1)$$

where y_{ilt} is the outcome of interest (e.g., dietary diversity) for household i in species-specific treatment group l and round t. The term $A_t T_{il}$ is an interaction between an indicator variable representing an original treated household i, receiving species l (T_{il}) and another indicator variable for after treatment (A_t), where $t = 2, 3, 4$. In an alternative specification, we define distinct indicator variables for reach round of the survey to estimate separate treatment effects for each of the three rounds after baseline and for each of the three species. The estimated coefficient on A_tT_{il} is the treatment effect. Because there are three species distributed with potentially different impacts, we allow for three coefficients on A_tT_{il}: one for each species of livestock (l). The vector X_i represents time-varying household characteristics, including: natural log of weekly total expenditure per capita, household size, dependency ratio (evaluated as a ratio of the number of children under 16 years of age to the total number of household members), and two shock dummies, one for positive shocks and one for negative shocks.[3] For our primary specifications, we use household fixed effects, φ_i, cluster the standard errors, ε_{ilt}, at the household level and control for hetereoskedasticity with robust standard errors.

This model specification is based on the assumption that outcomes of the original, prospective, and POG group would change at similar rates in the absence of treatment. In support of this assumption, we find that the groups are similar over observable characteristics at the baseline (Table 2). Further, since originals and POGs live in the same communities and have membership in the same livestock support groups, we can control for systemic differences in community outcomes with either community or household fixed effects. Given that at least the draft cattle and the goats are unlikely to yield large benefits in the first 6 months of ownership, we also explore whether there are differences in the first and second round outcomes between the recipients, the POGs and the prospectives as a way of testing for differences in pre-treatment trends. We find none. The data indicate a substantive similarity of the treated and control groups.

(a) *Dependent variables*

(i) *Household Dietary Diversity Score (HHDDS)*

We use household dietary diversity as a measure of food security because families tend to diversify diets away from the local starchy staple as they accrue more income and more reliable sources of food, as per Bennett's law. Increased household dietary diversity may indicate a diet richer in certain important nutrients and protein and is associated with a variety of improved anthropometric and physical outcomes (Hoddinott & Yohannes, 2002). Because dietary diversity is strongly related to other measures of food security and nutritional health but is easier and quicker to obtain, it is an efficient measurement tool for gauging a household's or individual's access to food (Carletto, Zezza, & Banerjee, 2013; FAO, 2013; Ruel, 2002). There are various methodolog-

Table 2. *Sample means and standard deviations, baseline survey*

	Did not receive livestock (prospective and POGs) mean	Received livestock (originals) mean	Not eligible to receive livestock (independents) mean	Full sample mean
n	178	105	41	324
Dependency ratio	0.475	0.453	0.534	0.468
	(0.196)	(0.215)	(0.203)	(0.203)
Household size	6.842	7.165	5.881	6.883
	(2.842)	(2.474)	(2.391)	(2.687)
Number of children under age 6	1.278	1.5	1.675	1.377
	(1.020)	(1.10)	(1.162)	(1.061)
Number of children between 6 and 16	1.795	1.967	2.177	1.872
	(1.434)	(1.493)	(1.514)	(1.461)
Education of head	2.55	2.46	2.09**	2.48
	(0.091)	(0.118)	(0.210)	(1.178)
Age of head	43.994	50.784*	42.524	46.023
	(13.509)	(12.524)	(13.608)	(13.276)
Weekly expenditure per capita (ZMK)[a]	38,203	32,801	29,562**	35,972
	(27,164.12)	(24,145.39)	(19,310.92)	(27,044.66)
Weekly expenditure per capita (USD)[a]	$7.64	$6.56	$5.91	$7.19
	(5.43)	(4.83)	(3.86)	(5.41)
Food share as% of expenditure	0.560	0.552	0.595	0.563
	(0.179)	(0.175)	(0.178)	(0.178)
Value of household and farm assets (ZMK)[a]	1,593,858	1,818,388	1,167,393**	1,621,538
	(1,290,305)	(1,388,922)	(1,162,973)	(1,328,755)
Value of household and farm assets (USD)	$318.77	$363.68	$233.48**	$324.31
	(258.06)	(277.78)	(232.59)	(265.75)
Amount of cultivated land (Hectares)[b]	3.00	4.675*	1.956**	3.703
	(3.229)	(6.577)	(1.377)	(4.727)
Percentage with livestock revenue, last 3 months	2.8%	0.30%	0%	1.9%
HHDDS	5.747	5.86	5.610	5.77
	(1.774)	(1.848)	(1.531)	(1.79)
% female headed	28.1%	27.6%	31.7%	29.3%

Standard deviations in parenthesis.
*, **, ***Significantly different from Column A at 10%, 5%, 1%, respectively.
[a] Monetary values given in Zambian Kwacha prior to 2013 rebasing (exchange rate of approximately ZMK5,000 to US$1).
[b] One treated household largely drives the difference in average cultivated land area with 50 hectares of land; about twice the amount of the next largest farm. It is likely that the respondent included community grazing land as 'cultivated land area'. When this outlier is removed from the sample, the significant difference between originals and households that did not receive livestock disappears.

ical approaches to measuring dietary diversity. We present measures based on 24-h recall and on reported frequency of consumption over 7 days.

Dietary diversity is first measured using a Household Dietary Diversity Score (HHDDS), which represents a count of the number of food groups consumed in the household over the past 24 hours (FAO, 2013). The questionnaire identifies 13 food groups chosen to indicate a household's economic ability to access food, rather than to explicitly measure a household's nutritional status. These food groups are recalled by the family member responsible for food preparation and recorded on the survey instrument.[4] The HHDDS is calculated by adding up the number of consumed food groups and can take a value of 1–13.[5]

(ii) *Probability-weighted Dietary Diversity Score (DDS)*

Although the HHDDS captures important information about the consumption patterns of the household, it is not a perfect representation of a household's consumption or the diets of household members. For example, if a household consumed one of the food groups, say meat, only once a week, but that consumption happened to be in the 24-h period before the survey was taken, it would appear that their dietary diversity was the same as a household that ate meat every day. In our data, in Round 4, one household reported no consumption of any food groups over the last 24 hours, implying a HHDDS of 0, which could not be the household's sustained diet. Based on reported frequency of consumption over the last week, data show that had the survey been conducted any other day of the week, that household's dietary diversity score would have been between 1 and 4. To mute the effect of daily variation in diet on the measurement of dietary diversity, this study generates a probability-weighted dietary diversity score. The reported frequency of consumption by food group over the last 7 days is used to calculate the number of food groups a household is expected to consume on any given day of the week. A household that consumes more food groups each day on average will have a higher probability-weighted DDS than a household that consumes fewer food groups on average, even if the reverse was true the day of the survey.

The probability-weighted DDS is the sum of the probability of each food group being consumed in the last 24 hours based on the reported frequency of consumption over the last 7 days, using the following formula:

$$\sum_{i=1}^{13} \frac{n_i}{7}$$

where n is the number of times per week food group i is consumed.[6]

The value of the probability-weighted DDS ranges from 1/7 to 13, with a 13 indicating that a household ate each food group every day of the week. The minimum value is not zero, as that would indicate a household ate nothing over the past week. The observed minimum over all households in all rounds in our data is 1.28, which, in the case of this household, reflects the fact that they consumed maize every day of the week, and potatoes and oil one day of the week each.

(iii) *Weekly per capita consumption expenditure*

Total consumption expenditure is a widely used measure of household economic well-being and a proxy for income. Income in rural areas of developing countries may be erratic and piecemeal and thus difficult to record or recall. Consumption expenditures, however, often give a more accurate sense of the economic situation of a household. We would expect livestock ownership to lead to increased income, demonstrated by increased expenditure. Consumption expenditure is measured by calculating food expenditures and non-food expenditures, specifically excluding expenditure that could be related to livestock maintenance and care. Non-food expenditures are measured based on reported purchases.[7] Food expenditure includes both the reported total cost of purchased food and the value of consumption of home-produced foods and gifts, with an imputed price based on reported community-level data in each round. As a robustness check, expenditures were calculated using prices fixed first at the baseline and second at the endline levels. These alternative treatments of prices did not substantively affect our results.

(b) *Summary statistics*

Table 2 presents summary statistics for the full sample at baseline: the originals, the prospective and POG groups, and the independent households. The majority of means for key variables are not statistically different across the original recipients, POGs and prospectives, while the independent households do differ from other groups. These observable differences may reflect unobservable factors that contribute to their self-selection out of participation and lead to their exclusion from econometric analysis to follow. These data also reveal the limited role of livestock prior to donation. Substantial livestock assets were rare and livestock revenue was negligible among all groups prior to the Heifer International distributions. Negligible presence of livestock in the area reflects historical reliance on mining employment in the region, rather than inappropriate environmental conditions for livestock. The households do have agricultural experience, cultivating a median of about 2.5 hectares of land per household. The data also reveal a high degree of food insecurity in the form of the low income, infrequent consumption of non-staples, and high shares of expenditures devoted to food.[8] In all groups, households include considerable numbers of children whose development could be affected by poor quality diets.

Although the original, POG, and prospective groups appear similar in the full sample, there may be differences among these groups within communities. Table 3 presents key summary statistics for the different communities by livestock group for key outcome variables.

Except in Kamisenga, where dairy cows were distributed, original and POG groups are not different across observable factors, which supports the premise of random assignment into these groups. Differences do exist among the villages, with Kaunga (where draft cattle are distributed) appearing better off than other communities. Nonetheless, all sampled households, regardless of their livestock status or village, are poor in absolute terms. The value of the total asset base averages roughly US$325 at the baseline and average daily expenditures range from US$0.75 per capita per day among POGs in Kamisenga to US$1.35 per capita per day in one of the prospective communities.

Receipt of an asset as valuable as those distributed by Heifer is expected to be lucrative and transformative. To indicate the potential impact of livestock, Fig. 2 presents the average gross revenues from livestock products (milk, draft power, manure, and meat) and sale of live animals before and after the receipt of livestock. The values of the draft power and manure are calculated using the amounts that the households received for their animals' services, either monetary or in-kind, and then imputed into ZMK using the local prices in each round. The observed increase in livestock-based income of over

Table 3. *Disaggregated summary statistics, baseline survey*

Community and household group	*n*	Total Expenditure per capita (ZMK per week)[a] Total Expenditure per capita (USD per week)[a]	HHDDS	Probability-weighted DDS
Kamisenga (Dairy) Originals	31	33,319 $6.66	6.53	5.70
Kamisenga (Dairy) POG	42	26,147* $5.22	5.97**	5.16**
Kaunga (Draft) Originals	20	32,724 $6.54	7.25	5.91
Kaunga (Draft) POG	20	39,946 $7.99	6.79	6.05
Kanyenda (Goat) Original	54	31,886 $6.38	4.98	4.54
Kanyenda (Goat) POG	49	35,925 $7.19	5.15	4.95
Prospectives	67	47,420 $9.48	5.75	5.26
Independents	41	28,879 $5.78	5.56	5.15

*, **, ***Significantly different from Original group in the same village at 10%, 5%, 1%, respectively.
[a] Monetary values given in Zambian Kwacha prior to 2013 rebasing (exchange rate of approximately ZMK5,000 = US$1).

ZMK371,500 per household over 3 months amounts to ZMK4,321.5 or US$0.86 per capita per week. Compared to an average consumption expenditure among original households of ZMK32,801 (US$6.56) per capita per week (Table 2) this new animal-based income stream could be significant.[9]

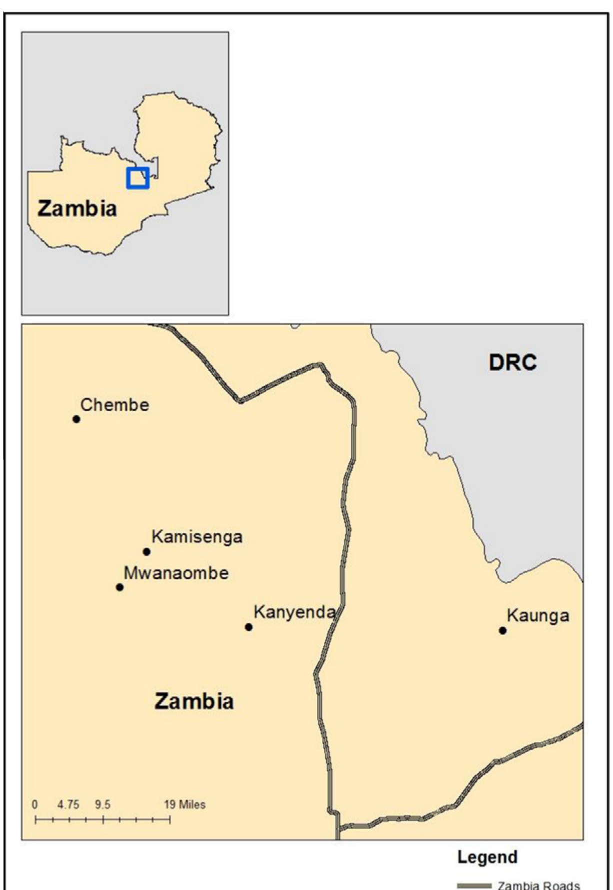

Fig. 1. *Map of villages and major Zambian roads. (Note: intended for color reproduction on the web and black and white in print.)*

The gross revenue calculations mask the significant costs associated with keeping livestock and substantial variation in cost and revenue streams by species. We are unable to provide a reliable estimate of net revenue from livestock as our cost data do not account for household labor and are likely to conflate long-term investments with variable costs. Moreover, measured revenue from the occasional sale of live goats and draft power is likely to be less accurate than recorded revenue from daily milk sales. Nonetheless, the scale of the estimated gross revenue suggests that receipt of animals could be expected to have an impact on household consumption. Rather than attempt to precisely quantify total revenues and the costs of labor, capital, and other inputs to calculate net revenues, we focus on consumption expenditure and dietary diversity as outcomes of greater concern.

Fig. 3 shows the mean values for HHDDS and probability-weighted DDS over time for original recipients compared to prospective households and POGs. The figures show that in Rounds 2 through 4, both HHDDS and probability-weighted DDS increase more for households who receive

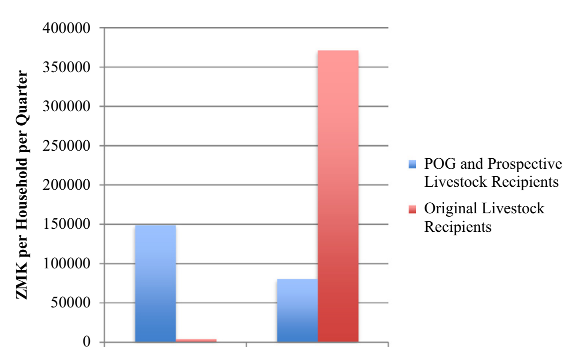

Fig. 2. *Revenue from livestock (products and live animal sales), per household. (Note: intended for color reproduction on the web and black and white in print.)*

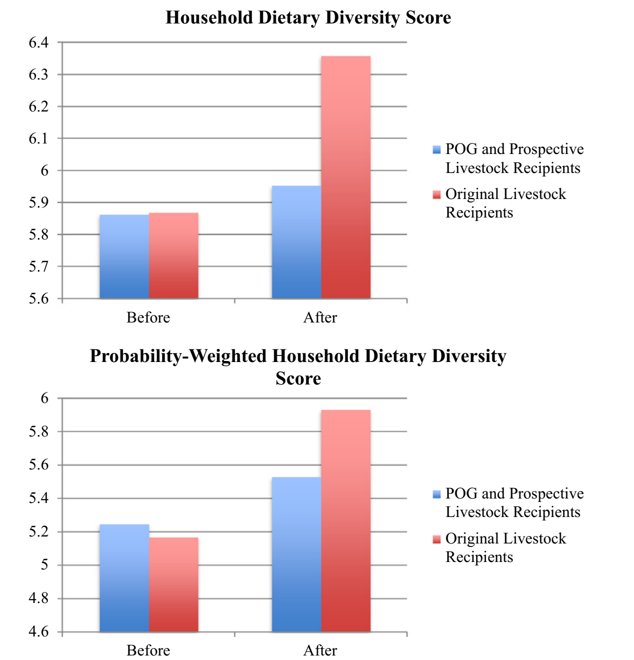

Fig. 3. *Mean HHDDS and Probability-weighted DDS. (Note: intended for color reproduction on the web and black and white in print.)*

livestock than for households who did not receive livestock. Thus, simple summary statistics that do not account for household characteristics suggest that livestock may be associated with an increase in dietary diversity and that the mechanism for this impact could be through income as well as through direct consumption of animal products.

4. RESULTS AND DISCUSSION

The results of the difference-in-difference regressions for HHDDS, probability-weighted DDS, and total expenditure are presented in Table 4. The independent households were not included in the regressions due to their observed differences from the other groups and the likelihood of unobservable differences through self-selection. Hence we have a final balanced panel of 265 households over four rounds. Due to the presence of hetereoskedasticity, robust standard errors clustered at the household level are reported throughout. Results shown in Table 4 are based on a model with household fixed effects. We test for statistically significant differences in estimated coefficients among OLS with no fixed effects, community-level fixed effects, and household fixed effects. While the coefficients on our treatment effects have similar magnitudes and signs, we find significantly different coefficients between the more restrictive model with household fixed effects and the model with just the community-level fixed effects (with a p-stat of 0.0019 for HHDDS and 0.000 for probability-weighted DDS). This result implies that time-invariant household characteristics bias the estimation when we do not control for them by using a household fixed effects formulation. Thus, we favor the household-level fixed effects specification, and report those results here.[10] (Results from the OLS and community-level fixed effects models are

Table 4. *Panel regression on HHDDS, probability-weighted DDS, and Expenditure per Capita*

	HHDDS	Probability-weighted DDS	ln Expenditure per Capita
After × dairy cow	0.248	0.646***	0.229**
	(0.320)	(0.188)	(0.110)
After × draft cattle	−0.564*	−0.211	0.262**
	(0.340)	(0.258)	(0.134)
After × goats	0.303	0.428**	0.215**
	(0.270)	(0.192)	(0.091)
Round 2	0.746***	−0.098	−0.129*
	(0.208)	(0.131)	(0.065)
Round 3	0.576***	0.203	0.041
	(0.202)	(0.130)	(0.065)
Round 4	0.267	−0.123	0.157**
	(0.202)	(0.156)	(0.066)
ln Expenditure per Capita	0.699***	1.117***	
	(0.115)	(0.097)	
Dependency ratio	−0.760	0.470	
	(0.523)	(0.465)	
Household size	0.101**	0.224***	
	(0.046)	(0.033)	
Negative shock	−0.464***	0.125	0.047
	(0.165)	(0.112)	(0.050)
Positive shock	−0.114	0.126	0.043
	(0.146)	(0.103)	(0.046)
Constant	−1.668	−8.02***	10.264***
	(1.367)	(1.099)	(0.030)
Household FE	Yes	Yes	Yes
F	5.84	25.03	9.76
R^2	0.1151	0.3267	0.040
n	1060	1060	1060

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors clustered at HH level recorded in parenthesis.

provided in Table 14.) Because the outcomes are likely correlated across households, we also estimate the three regressions as a seemingly unrelated regression and find results qualitatively unchanged. (These results are provided in Table 15.)

The results for HHDDS in the first column of Table 4 show very little effect of livestock receipt, and if anything, a slightly negative effect of the receipt of draft animals. The statistically insignificant result could reflect highly variable consumption through the week that adds noise to HHDDS as a measure of dietary diversity, as suggested by the relatively high standard error terms on all of the coefficients in the HHDDS specification.

The second column presents the effect of livestock on the probability-weighted DDS. Here we observe significant positive direct effects of both dairy cows and goats, with coefficients of 0.646 and 0.428 respectively. Thus, controlling for consumption expenditures and other factors, the receipt of these livestock types directly increases the probability of consuming an additional food group each day by 43–65%. These coefficients imply that the receipt of a dairy cow directly leads to 4.5 more days in a week during which the household consumes an additional food group. Goats have a direct effect on household dietary diversity of an additional food group 3 days of the week. To address concerns that male adults might disproportionally consume the additional food products, the respondents were asked if every member of the household consumed each food product consumed in the household. Based on these responses, there is no evidence of a differential impact on dietary diversity among household members.

Since we control for per capita consumption expenditure in the above dietary diversity regressions, we isolate the direct effect of livestock on dietary diversity from the indirect effect of the livestock gift through increasing expenditure. The estimate of the effects of livestock on consumption expenditures is estimated in column 3 of Table 4. For the three livestock types, receipt of animals is associated with an increase in per capita consumption expenditure of 22–26% over baseline, equivalent to an increase of from ZMK8,629 ($1.73) per week for goats to ZMK10,775 ($2.16) per week for draft cattle.

To calculate total effects of livestock on dietary diversity, we consider both direct and indirect effects together. For both measures of dietary diversity, results in Table 4 show coefficients on expenditure per capita that are highly significant and positive, with a 1% increase in consumption expenditure per capita resulting in an increase in HHDDS of 0.007 food groups and an increase in probability-weighted DDS of 0.0112. The total impact of receipt of a dairy cow on dietary diversity is the sum of the direct effect (0.646), plus indirect effect of a 23% increase in consumption expenditures (0.229 times 1.117) for a total effect of raising the probability of an additional food group consumed on any day by 0.90. The combined direct and indirect effect of receiving goats is to raise probability-weighted DDS by 0.67 and the figure for draft animals is 0.08. Coefficients on HHDDS suggest recipients of goats and dairy cows increase their dietary diversity by 0.4 food groups per day, while draft animal recipients see a small decline, although these measures are noisy and highly dependent on the day on which the survey was conducted.

Household size also significantly increases the probability-weighted dietary diversity, which is consistent with there being some fixed costs of adding food types to the diet. Experiencing a negative shock significantly decreases the HHDDS, but has little effect on the probability-weighted DDS. These results indicate that negative shocks may cause households to drop unique food groups and consume a less diverse diet.

Table 5 presents a regression that excludes expenditures to address the concern that expenditure may be endogenous in the regressions estimated in Table 4.[11] As one would expect, the measured impacts of receipt of livestock on probability-weighted DDS remain statistically significant for goats and dairy cattle but the size of the coefficient increases, reflecting the combined impact of the increase in home-produced animal products plus the increase in dietary diversity driven by the growth in consumption expenditures. The coefficient on draft cattle remains statistically insignificant, but is positive in sign.

To explore the timing of the effect of livestock on expenditure, we first pool all the livestock recipients and interact the original recipient group with an indicator variable for each round. We then repeat this process for each species. As results in Table 6 show, the Round 2 interaction terms are not significantly different from zero for any animal species, which supports the assumption of similar pre-treatment trends across originals and their controls. We first see the effect of the livestock receipt 12 months after households receive the animal. The Round 3 × original and Round 4 × original interaction terms are both significant and positive: having received livestock is associated with a 28.2% increase in consumption expenditure per capita in Round 3 and a 32.2% increase in Round 4, compared to the baseline. These results indicate that the positive relation between livestock ownership and expenditure takes a year to manifest, but increases thereafter. The effects of livestock on dietary diversity are thus likely growing over time and are underestimated in the regression results shown in Table 4, which include Round 2 in the after period.

Breaking down these results by species reveals slightly different dynamics for each type of livestock. The dairy households

Table 5. *Panel regression on HHDDS and probability-weighted DDS, ln Expenditure per Capita excluded from regressors*

	HHDDS	Probability-weighted DDS
After × dairy cow	0.358	0.801***
	(0.314)	(0.196)
After × draft cattle	−0.432	0.013
	(0.354)	(0.246)
After × goat	0.396	0.589***
	(0.283)	(0.210)
Round 2	0.681***	−0.221
	(0.213)	(0.147)
Round 3	0.640***	0.300**
	(0.206)	(0.152)
Round 4	0.419**	0.113
	(0.206)	(0.178)
Dependency ratio	−0.834	0.351
	(0.531)	(0.511)
Household size	0.004	0.070**
	(0.043)	(0.031)
Negative shock	−0.431***	0.171
	(0.167)	(0.127)
Positive shock	−0.095	0.165
	(0.148)	(0.115)
Constant	6.204***	4.563***
	(0.384)	(0.348)
Household FE	Yes	Yes
F	2.72	10.51
R^2	0.0343	0.0876
n	1,060	1,060

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors clustered at HH level recorded in parenthesis.

Table 6. *Coefficients from difference-in-differences regression on interaction of round and species dummies on ln Expenditure per Capita.*

	Treatment			
	(1) Original	(2) Dairy Cow	(3) Draft Cattle	(4) Goat
Round 2 × treatment	0.081	0.057	0.195	0.049
	(0.083)	(0.135)	(0.164)	(0.109)
Round 3 × treatment	0.282***	0.238*	0.322**	0.294***
	(0.083)	(0.134)	(0.164)	(0.109)
Round 4 × treatment	0.322***	0.401***	0.272*	0.293***
	(0.083)	(0.134)	(0.164)	(0.109)
Household FE	Yes	Yes	Yes	Yes

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors clustered at HH level recorded in parenthesis.
Independent variables not reported: after, original (column (1) only), dairy cow (column (2) only), draft cattle (in (3) only), goats (in (4) only), dependency ratio, ln of total assets, gender of household head, education of household head, negative shock, positive shock, and household fixed effects.

Table 7. *Placebo test on round 1 data to test for differences in baseline*

	Probability-weighted DDS Linear Regression, R1 only	Expenditure per Capita Linear Regression, R1 only
Dairy cow	0.231	0.153
	(0.216)	(0.140)
Draft cattle	−0.151	−0.163
	(0.325)	(0.135)
Goat	−0.251	−0.170
	(0.232)	(0.127)
Household FE	Yes	Yes
F	17.70	19.08
R^2	0.4739	0.4267
n	265	265

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors reported in parenthesis.
Independent variables not reported: dependency ratio, log of expenditure per capita (column 1 only) log of total assets, gender of household head, education of household head, negative shock, positive shock and household fixed effects.

Table 8. *Panel regression: non-farm income*

	Non-farm income ('000 ZMK)
After × dairy cow	82.43
	(237.92)
After × draft cattle	61.67
	(413.01)
After × goat	−114.46
	(468.48)
Household FE	Yes
F	3.60
R^2	0.0989
n	1,060

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors clustered at HH level recorded in parenthesis.
Independent variables not reported: dependency ratio, ln expenditure per capita, ln of total assets, gender of household head, education of household head, negative shock, positive shock, and household fixed effects.

see the smallest effect on expenditures in Round 3 but the largest effect in Round 4. This pattern may reflect milk production cycles or high initial production costs. Rounds 1 and 3 were conducted during the rainy season when milk production is likely to be high. Consumption for dairy cow recipients would be expected to rise in Round 3, but that increase could be muted by high initial production costs and a tendency toward investment in assets. The draft cattle recipient households see a larger impact in Round 3 than Round 4. This result is likely related to the timing of field preparation, which occurs between Rounds 2 and 3 and would increase demand for the cattle's draft power and thus their owners' income streams just prior to Round 3. Milk production and sale of draft services and manure are likely drivers of consumption increases in Round 4 for recipients of draft cattle, but benefits would have probably peaked just prior to Round 3. Finally, the goat recipients see similar magnitude impacts in both Round 3 and Round 4, possibly indicating staggered sales of male goats from the herds to stabilize income and consumption impacts over time.

(a) *Robustness checks*

One might be concerned that the treated households have different conditions from the control households at the baseline that explain the later improvements in food security. To confirm that households were not chosen to receive livestock because of higher initial likelihood of success, we run a placebo test using the main regressions described above with a cross-section of only the baseline (Table 7). At the time these data were collected, the livestock could not have had an impact on production or consumption: measured differences in outcome would suggest a selection bias.

As the results in Table 7 demonstrate, coefficients on each species are insignificant. Nothing indicates that the livestock recipient households are better off in terms of dietary diversity or consumption expenditures when they first receive livestock.

Second, there might be concern that the treated households were chosen because they are expected to have higher income in the future over and above the revenue coming from the donated livestock. This potential higher income might explain both their selection into treatment and their increase in food security. To address this concern we run a second placebo test using the main regression specification with non-farm income as the outcome, thereby testing whether these households were targeted due to their potential for other forms of financial success. Results in Table 8 demonstrate that treatment had no relationship to non-farm income, confirming that outcomes are attributable to receipt of livestock rather than spurious correlation with other income streams.

Another valid concern is that the POGs may not serve as good controls if they change their behavior in anticipation

Table 9. *Anticipatory consumption and spillover effects among POGs*

	Probability-weighted DDS	ln Expenditure per Capita	Livestock expenditure
After × dairy cow	0.575**	0.271**	259,593.2***
	(0.274)	(0.123)	(79,395.21)
After × draft cattle	−0.282	0.303**	−129,660.2
	(0.321)	(0.144)	(115,025.9)
After × goat	0.356	0.256**	−256,391.8**
	(0.237)	(0.106)	(125,987.3)
After × POG	−0.117	0.068	−73,481.81
	(0.200)	(0.089)	(67,720.82)
ln Expenditure per capita	1.117***		260,674.4***
	(0.084)		(76,660.69)
Household FE	Yes	Yes	Yes
R^2	0.3284	0.0322	0.0313
n	1,060	1,060	1,060

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors clustered at HH level recorded in parenthesis.
Independent variables not reported: dependency ratio, household size, negative shock, positive shock, and household fixed effects.

of their impending livestock gift. To test this possible effect, we compare POG households to prospective households to see if we observe differences in behavior. Specifically, we treat POG status as a form of treatment in the difference-in-differences model for probability-weighted DDS and consumption expenditures. In these regressions, the prospective households serve as the control group. As results in Table 9 show, neither dietary diversity nor consumption expenditures is significantly affected by POG status. The one place where we might expect to see anticipatory behavior among POGs is in expenditure in preparation for the livestock they are to receive in the future. However, even in terms of livestock-related expenditure, we see no systematic anticipatory effect on the part of POGs. This result confirms the validity of including POGs in the control for analysis of these outcomes, at least over the timeframe considered here. It also indicates that there is little anticipatory behavior from the POGs.

(b) *Mechanisms*

The results above imply that livestock ownership does influence dietary diversity through several mechanisms. First, we observe an increase in dietary diversity through the direct consumption of animal products. Second, livestock indirectly increases dietary diversity by increasing income: expenditure plays a key role in determining dietary diversity as greater expenditure leads to a greater ability to purchase food from a variety of food groups. A third mechanism posited in the literature is that livestock may provide some resiliency in the presence of negative shocks (Randolph *et al.*, 2007). We do not find evidence of this resilience when we interact the treatment and shock dummy variables.

To better understand the first mechanism and specifically which food groups are affected, we use both the total value of milk consumed and the total value of meat, chicken, and fish consumed as outcome variables.[12] These food groups were chosen because, as animal products, they are most likely to be directly affected by the receipt of livestock, and because they are typically considered luxury foods, or at the very least are not consumed daily. We find no significant effects of any of the treatments on the consumption of meat, chicken, and fish, indicating that the increase in dietary diversity is not driven by increased consumption of those animal products.[13] On the other hand, the impact of dairy cow ownership on milk consumption is strong and significant, as expected; draft cattle also have some impact, while goats do not show any significant impact. The results for the milk regression are presented below in Table 10. These results are congruent with the milk production of the animals: dairy cows produce the most, draft cattle produce some, and the goats produce very little. The control variables play a similar role as they did when explaining dietary diversity: expenditure and household size both have a positive relationship with milk consumption.

Table 10. *Panel regression: consumption of milk, ZMK/week*

	Value of milk consumption
After × dairy cow	20,310.38***
	(3,822.563)
After × draft cattle	16,174.88**
	(7,919.601)
After × goat	2,618.156
	(1,845.825)
Round 2	4,267.368**
	(1,973.134)
Round 3	2,425.499
	(1,904.853)
Round 4	−3,297.037
	(2,520.461)
ln Expenditure per capita	10,660.96***
	(1,893.512)
Dependency ratio	2,774.326
	(3,076.991)
Household size	1,556.043***
	(476.024)
Negative shock	172.090
	(1,811.44)
Positive shock	−877.847
	(1,950.551)
Intercept	−117,262.6***
	(21,169.16)
Household FE	Yes
R^2	0.1653
N	1,060

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors clustered at HH level recorded in parenthesis.

Table 11, which presents the average quantity of milk consumed and milk sold by round and by livestock group, shows similar results, and emphasizes that livestock provides milk directly for home consumption and for market sales. While a dramatic increase in milk consumption by a small number of households does not necessarily translate to broader nutritional benefits, we find that the number of households consuming any milk increases dramatically for those households who received dairy cattle, from approximately one-third in Round 1 to well over two-thirds afterward (Table 11). As anticipated, the pattern is less clear for recipients of either draft cattle or goats. We observe that more POG households consume milk in the last round, suggesting possible spillover effects as milk becomes more plentiful in the recipient communities.

(c) *Spillover effects of livestock ownership within communities*

Members of Heifer-supported groups that are not original recipients (the POGs) might be expected to receive spillover benefits through their relationships with group members who receive livestock in the initial distribution. Spillover effects of this kind would contaminate the control used in earlier regressions and attenuate our estimates of treatment, but they would also suggest that livestock development has a positive effect on the local food environment. The results in Table 9 form a test to identify these spillover benefits by treating POG status as a form of treatment in the difference-in-differences model for probability-weighted DDS and consumption expenditures. As noted above in Table 9, POGs do not have significantly different levels of dietary diversity nor consumption expenditures compared to prospectives. Table 12 presents results of a similar regression that takes the value of milk consumption as the outcome of interest. We do find significant treatment effects in milk consumption for POGs. As would be expected, the spillover effects on POGs are smaller in scale than the effects on the recipients themselves. For example, recipients of dairy cows see the value of milk consumption increase by ZMK23,855 ($4.77) (roughly ten liters per week per household) while the POG households in their community experience an increase of ZMK5,817 ($1.16) (two liters per week).[14] This spillover effect is limited to milk. As noted above, we do not observe an increase in meat consumption by livestock recipients; neither do we observe a spillover effect of increased meat consumption in non-recipient POG households. Donating livestock, especially animals that produce milk, is an effective way to increase milk consumption in a community at large, including households that do not receive an animal.

As further evidence of a change in the local food environment, community level data suggest that a drop in milk prices occurred in the after period in the dairy cow recipients' village and that a smaller price decrease occurred in nearby communities. While we do see changes in relative prices, even for this relatively small project, the scope for declines in prices is limited in our context due to the degree of integration with national and regional markets. Owners of dairy cows are able to reach a chilling facility by bicycle, which gives them access to a national market through the dairy processor Parmalat. The contracted Parmalat price implies a floor on local prices. The market for meat goats is also large and unlikely to become saturated as the goats may be sold to traders serving the regional market in the nearby Democratic Republic of Congo as well as Zambia (see Fig. 1). While dampening the potential for increased production of animal products to stimulate spillover consumption benefits through low prices, the presence of these large markets may contribute to the sustainability and scalability of income increases through livestock ownership.

(d) *Discussion*

We see positive and significant results of livestock donation on probability-weighted DDS that are consistent across all model specifications. Both dairy cow and goat ownership have a positive, direct impact on the expected number of food groups eaten by a household on any given day. This result implies that in our setting, expanded animal agriculture leads to increased food security through direct consumption of home-produced animal products. Expanded livestock activities also contribute indirectly to increased dietary diversity through increased expenditure. Long-term ownership of livestock could lead to increased income from the sale of animals, animal products such as milk, and animal services for hauling and plowing. The survey data show that livestock revenue for dairy cow recipients increases more than 100 fold, from less than ZMK5,000 ($1.00) per household per quarter in Round

Table 11. *Milk consumed and milk sold, by livestock group by round*

Milk Consumed (Liters per household per week)			
	Dairy	Draft	Goat
Round 1	0.897	1.495	0.73981
Round 2	7.897	2.35	2.316
Round 3	15.3109	11.7225	3
Round 4	5.4375	3.45	1.939

Milk Sold (Liters per household per month)			
	Dairy	Draft	Goat
Round 1	0	0	0
Round 2	160.017	0	0
Round 3	228.225	37.5	0
Round 4	192.722	17.5	0

Percent of HHs Consuming Milk					
	Dairy (%)	Draft (%)	Goat (%)	POG (%)	Prospectives (%)
Round 1	34	50	36	31	37
Round 2	94	20	34	36	40
Round 3	81	80	48	37	31
Round 4	72	55	44	45	31

Table 12. *Spillover effects of treatment onto POGs*

	Value of milk consumption per household, ZMK/week
After × dairy cow	23,855.21***
	(4,838.135)
After × draft cattle	17,478.35*
	(8,959.341)
After × goat	5,744.129**
	(2,406.066)
After × POG × dairy cow	5,817.752**
	(2,422.512)
After × POG × draft cattle	−2,746.074
	(2,931.785)
After × POG × goats	17,478.35*
	(8,959.341)
ln Expenditure per Capita	10,654.19
	(1,900.884)
Household FE	Yes
F	4.79
R^2	0.1159
n	1,060

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors clustered at HH level recorded in parenthesis.
Independent variables not reported: dependency ratio, household size, negative shock, and positive shock.

1 to over ZMK774,525 ($154.91) in Round 4. Goat and draft cattle recipients see gains as well: going from no revenue in Round 1 to ZMK349,300 ($69.86) and ZMK94,980 ($19.00) in Round 4, respectively.

A pertinent question associated with the gift of livestock is whether it improves household food security more than a cash gift of equivalent value. As noted above, these livestock gifts have large financial value, and it would be surprising if they had no effect on household welfare. If markets function perfectly, and households are otherwise unconstrained, one might anticipate that a cash transfer would, if anything, have a greater impact on welfare than would a livestock gift given that the household is unconstrained in its use of the funds. On the other hand, if livestock development enhances the local food economy by reducing the transactions costs associated with consuming nutritious foods, it could yield benefits beyond what would emerge from cash transfers.

To explore this question, we compare the direct and indirect effect of the livestock gift on probability-weighted DDS to the potential return from a cash gift of the same amount, evaluated at approximately ZMK12,000,000 ($2,400) (ZMK10,000,000 ($2,000) for the animal(s), and ZMK2,000,000 ($400) in support services). Table 13 reports the total effect of livestock receipt on probability-weighted DDS and expenditure using the results from Table 4, where the total effect on probability-weighted DDS includes the direct effect and the effect through increased expenditure as discussed above. The direct effect of the livestock gift on probability-weighted DDS is given simply by the coefficients on livestock in Table 4, and ranges from an increase in 0.65 food groups per day for recipients of a dairy cow, to an increase of 0.43 food groups per day for recipients of goats to a decrease in 0.2 food groups per day for recipients of a draft cattle. The second column of Table 13 presents the rate of return on the cash gift required to generate the same change in dietary diversity, assuming all returns on the investment go to consumption expenditures.

By increasing expenditures, livestock also indirectly contribute to increased dietary diversity. In column 3, we present the increase in consumption expenditures that result from the receipt of animals, based on the impact on expenditures reported in Table 4. In column 4, we report the return to a cash donation that would need to be generated to match this increase in expenditures. Just to meet the increase in expenditure generated by the average livestock gift, a cash gift would have to return an average of 28.5%.

The combined direct and indirect effect of livestock gifts on dietary diversity are given in column 5. The combined effect of a dairy cow is an increase of 0.902 unique food groups per day, while the combined effects for draft cattle and goats are 0.08 and 0.67 respectively. To match these increases in dietary diversity, a cash gift of equivalent value to the livestock donation would need to generate returns of 8.2% for draft cattle, 88% for goats, and 133% for dairy cows. We also calculate the total effect of livestock on probability-weighted DDS using the results from Table 5, which combine both direct and indirect effects into a single coefficient for each livestock type. Using these results, we obtain a required rate of return of 62% on the cash gift to generate the same results on dietary diversity as the average livestock gift (113% for dairy cattle, 14% for draft cattle, and 75% for goats).

In sum, to generate the same total effect on dietary diversity as we observe from the average livestock gift, the cash gift would need to generate an annual return of between 60% and 70%. These compare to average rates of return on agricultural research investments in small developing countries of 17% (Fuglie & Rada, 2013).[15] The relative strength of the effect of livestock on dietary diversity suggests that in our setting, animal donations, particularly dairy cattle, change the local food economy, making nutrient dense foods more available and accessible in addition to raising incomes.

One limitation of our study is that it does not evaluate the long-run effects of this program, or its scalability. The sustainability of this project, and others like it, is another pertinent area of concern. Scaling up the project only works to the point where the market is overwhelmed with animal products. Livestock products, however, are in high demand, especially in urban areas across the developing world, and Zambia and its cities are no exception. Of course, there are environmental limits on producing some livestock products more than others, and livestock production carries the risk associated with livestock disease and other production shocks. Further, animal husbandry is not without significant costs. But as a whole, the diversity of livestock production options is substantial and the market for them in Southern Africa is unlikely to be saturated in the foreseeable future.

5. CONCLUSION

Livestock are a controversial agricultural technology: they require expenditure for their maintenance and may significantly increase a household's work burden, an impact that may disproportionately affect women (Ssewamala, 2004). While some international agencies and NGOs emphasize livestock as an anti-poverty strategy with the potential to enhance nutritional and dietary outcomes, others stress that livestock ownership is not feasible for the poorest households. Previous evidence for these competing claims has generally been weak, based on observational analysis subject to serious endogeneity problems emerging from self-selection. The Heifer International program in Zambia provides an opportunity to use well-defined treatment and control groups to test how the

Table 13. *Expected change in outcomes generated by livestock gifts compared to the required return to an equivalent cash gift*

	Direct effect on probability-weighted DDS		Effect on expenditure (ZMK)		Total effect on probability-weighted DDS		Total effect (on probability-weighted DDS) *based on* Table 5	
	From livestock gift	Required return to cash gift (%)	From livestock gift	Required return to cash gift (%)	From livestock gift	Required return to cash gift (%)	From livestock gift	Required return to cash gift (%)
Dairy Cow	0.65	84	9,257	28	0.90	133	0.80	113
Draft Cattle	−0.21	−18.5	10,775	32	0.08	8.2	0.13	14
Goats	0.43	58	8,629	26	0.67	88	0.59	75
Average Livestock	0.29	31.5	9,554	28.5	0.55	68	0.51	62

For the direct effects from a dairy cow, draft cattle, or goats, we use the estimates of how much each animal gift increases probability-weighted DDS (from column 2 of Table 4). For the indirect effects, we calculate how much these gifts increase logged expenditure per capita from the results in column 3 of Table 4. We then multiply the estimated increase in expenditure times the effect of an increase in expenditure on probability-weighted DDS and add that to the direct effect to obtain the total effect. To obtain the return on a cash gift of ZMK12,000,0000 needed to generate the same benefits as the average livestock gift, we solve for the increase in potential household expenditure needed to generate the same dietary diversity as we estimate are generated by the livestock. Note that the return to the cash gift needed to generate the combined direct and indirect effect is greater than the sum of the return needed for each individual effect because the impact of expenditure on dietary diversity is non-linear. In the last column, we repeat this exercise using estimates from Table 5 that combine both the direct and indirect effects of livestock gifts.

expansion of livestock affects food security and consumption expenditures in a specific setting. Although these households are not the poorest in their communities, they are certainly resource poor by any absolute standard. We observe households beginning to move out of poverty after receiving animals. In the pre-treatment period, 78% of original recipient households lived on less than US$1.25 per person per day. That figure fell to 59% of households by Round 4. The increase in average per capita expenditures for original recipients of ZMK9,553 per week amounts to US$0.28 per day (Table 13). This represents a marked increase from a base of US$0.94 per day (Table 2), but the households clearly remain vulnerable, and near the absolute poverty line of US$1.25 after 18 months with livestock. While the increase in consumption is economically significant, whether livestock development can transform households fundamentally through sustained asset accumulation and scaling can only be revealed over a longer time frame.

Although a basic lack of access to sufficient food is a pressing concern, food insecurity often appears not as deficient quantity of food, but rather as deficient quality of diet, which can be measured through dietary diversity. The effects of livestock on dietary diversity are both direct, through greater access to animal products for consumption, and indirect, through increased incomes and consumption expenditures. Because livestock production can raise incomes while increasing the availability of nutrient dense foods, livestock donation has a qualitatively different impact on households than other interventions to increase consumption expenditures. Recipients of livestock experience increases in income that contribute to changes in diet and additionally show direct changes in dietary diversity that are not explained by increased total expenditures. Thus livestock donation both increases income and skews expenditures toward food security. The results of this analysis are conclusive: livestock development among resource poor smallholders in Zambia's Copperbelt increases household dietary diversity and total consumption expenditures, with dietary impacts that are substantially greater for animals that produce food products for direct consumption.

This analysis uses a livestock donation program to examine the impact of expanded animal agriculture on food security and expenditure. The significance of the analysis, however, is not as an evaluation of the livestock donations. Rather, the livestock donation program provides an experimental setting in which to examine the effects of expanded animal agriculture in an impoverished rural community, where livestock was not already prevalent. Although assessing the external validity of these results warrants further analysis, results show that in this sample and specific context, livestock development increases income, raises the food security of those holding animals, and alters the food environment to enhance the diets of the recipients' communities.

NOTES

1. Values in Zambian Kwacha are based on currency prior to currency reform of 2013. The exchange rate is US$1 to ZMK5,000 with a purchasing power parity factor of 0.9. Rebasing in 2013 introduced the new Zambian Kwacha (KMW) with the rate ZMK1,000 = KMW1.

2. By Round 4, 27 POG households received immature goats and an additional 27 POG households received dairy calves. No POG household had yet received draft cattle.

3. Positive and negative shocks are each represented by a binary variable equal to 1 if the household experienced *any* shock out of a list of positive or negative events. Positive events included: getting a new job, major business expansion or success, new source of remittance income, and receipt of a large gift or inheritance. Negative events were: illness lasting one week or more, injury with recovery time longer than one week, victim of theft or robbery, victim of other crime, loss of employment, major loss or failure in business, loss of usual source of remittance/gifts, losses due to fire or flood, costs of wedding or family event, and loss of crops due to pests or disease.

4. The households were given the option to have a new respondent take over in this section of the survey so that the person responsible for the preparation of food could respond.

5. This range is based on the assumption that all households will have eaten something over the past 24 hours and thus have consumed at least one food group. These food groups were: (1) Cereals, (2) White tubers and roots, (3) Yellow tubers (4) Dark leafy green vegetables, (5) Orange or

red-fleshed fruits, (6) Other fruit (7) Meat or chicken, (8) Eggs, (9) Fish and other seafood, (10) Legumes, nuts, and seeds, (11) Milk and milk products, (12) Oils and fats, and (13) Beverages and sweets.

6. Note that this metric is slightly different than a weekly dietary diversity score in that it does not measure the total number of food groups consumed in a week, but the average number of food groups consumed each day.

7. Non-food consumption categories were: clothes and shoes, kitchen equipment, bedding, furniture (depreciated using a five-year straight line depreciation), lamps and other electrical items, transportation, ceremonial expenses and gifts, offerings to church or another group, taxes or levies and fines, medicine or medical care, school fees, school/educational material, cigarettes or tobacco, alcoholic beverages, matches, candles, batteries etc., laundry and bath soap, costs of telephone, fuel, and other miscellaneous consumables.

8. Eggs, milk, and meat/chicken were all served an average of about once per week in sampled households. Legumes were served an average of 1.5 times per week.

9. This average includes all the households who received livestock, not just those who reported receiving income from livestock or livestock product sales. There were a significant number of households that did not report any livestock income.

10. Because the Hausman test is inconsistent in the presence of heteroskedastic and clustered error terms, we use a seemingly unrelated regression and a Chow test to jointly test whether the coefficients differ across the specifications.

11. This regression is also robust to different price specifications, including one where all expenditures are calculated at the same, baseline price rather than different prices per round, to address another potential source of endogeneity.

12. These values were calculated using the process described in Section 2 (b), where the total value of the home produced product was multiplied by its market price to derive a value in Kwacha for total amount consumed. Meat, chicken, and fish were aggregated together.

13. This result is expected as the livestock recipients were not initially supposed to consume the animals they had received from the project.

14. This result is robust to using different prices for the value of milk consumed, including equalizing the price of milk to be equal to the price in Round 1 across all four rounds.

15. This value is for countries with an annual agricultural GDP of less than PPP$1 billion, which includes Zambia (annual agricultural GDP of PPP$0.92 billion). Please see Fuglie and Rada (2013) Table 8 (pp. 34–35) for more details.

REFERENCES

Alary, V., Corniaux, C., & Gautier, D. (2011). Livestock's contribution to poverty alleviation: how to measure it?. *World Development, 39*(9), 1638–1648.

Angrist, J. (1997). Conditional independence in sample selection models. *Economics Letters*.

Bandiera, O., Burgess, R., Das, N. C., Gulesci, S., Rasul, I., Shams, R., & Sulaiman, M. (2012). *Asset transfer programme for the ultra poor: A randomized control trial evaluation. CFPR Working Paper No. 22*. Dhaka, Bangladesh: BRAC Research and Development Division.

Banerjee, A., Duflo, E., Chattppadhyay, R., & Shapiro, J. (2011). *Targeting the hard-core poor: An impact assessment*. MIMEO, CGAP, Consultative Group to Assist the Poor.

Banerjee, A., Duflo, E., Goldberg, N., Karlan, D., Osei, R., Parienté, W., ... Udry, C. (2015). A multifaceted program causes lasting progress for the very poor: Evidence from six countries. *Science, 348*(6236), 1260799.

Carletto, C., Zezza, A., & Banerjee, R. (2013). Towards better measurement of household food security: Harmonizing indicators and the role of household surveys. *Global Food Security, 2*, 30–40.

Das, N., Yasmin, R., Ara, J., Kamruzzaman, Md., Davis, P., Behrman, J., ... Quisumbing, A. (2013). *How do intrahousehold dynamics change when assets are transferred to women? IFPRI Discussion Paper 01317*. Washington, DC: International Food Policy Research Institute.

de Janvry, A., Dustan, A., & Sadoulet, E. (2011). *Recent advances in impact analysis methods for ex-post impact assessments of agricultural technology: Options for the CGIAR*. Berkeley, CA: University of California at Berkeley.

DFID (2014). *Can agriculture interventions promote nutrition: Agriculture and nutrition evidence paper*. United Kingdom: Department of International Development, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/292727/Nutrition-evidence-paper.pdf.

FAO (2012) *Livestock sector development for poverty reduction: an economic and policy perspective—Livestock's many virtues*, by J. Otte, A. Costales, J. Dijkman, U. Pica-Ciamarra, T. Robinson, V. Ahuja, C. Ly and D. Roland-Holst.

FAO (2013). *Guidelines for measuring household and individual dietary diversity*.

Fuglie, K. O., & Rada, N. E. (2013). *Resources, policies, and agricultural productivity in Sub-Saharan Africa, ERR-145*. U.S. Department of Agriculture, Economic Research Service.

Hoddinott, J., & Yohannes, Y. (2002). *Dietary diversity as a food security indicator (FCND Discussion Paper No. 136)*. Washington, DC: International Food Policy Research Institute.

Krishna, A., Poghosyan, M., & Das, N. (2012). How much can asset transfers help the poorest? Evaluating the results of BRAC's ultra-poor programme (2002–2008). *Journal of Development Studies, 48*(2), 184–197.

Leroy, J. L., & Frongillo, E. A. (2007). Can interventions to promote animal nutrition ameliorate undernutrition?. *The Journal of Nutrition, 137*, 2311–2316.

Randolph, T. F., Schelling, E., Grace, D., Nicholson, C. F., Leroy, J. L., Cole, D. C., ... Ruel, M. (2007). Invited review: Role of livestock in human nutrition and health for poverty reduction in developing countries. *Journal of Animal Science, 85*(11), 2788–2800.

Rawlins, R., Pimkina, S., Barrett, B., Pedersen, S., & Wydick, B. (2014). Got milk? The impact of Heifer International's livestock donation programs in Rwanda on nutritional outcomes. *Food Policy, 44*, 202–213.

Ruel, M. T. (2002). *Is dietary diversity an indicator of food security or dietary quality? A review of measurement issues and research needs (Food Consumption and Nutrition Division Discussion Paper No. 140) (pp. 1–58)*. Washington, DC: International Food Policy Research Institute.

Ssewamala, F. M. (2004). Expanding women's opportunities: The potential of heifer projects in Sub-Saharan Africa. *Development in Practice, 14*(4), 550–559.

APPENDIX A.

Table 14. *Results from difference-in-difference regression with ols and community-level fixed effects*

	HHDDS		Probability-Weighted DDS		ln Expenditure per Capita	
	(1) DiD	(2) DiD with community FE	(1) DiD	(2) DiD with Community FE	(1) DiD	(2) DiD with community FE
After × dairy cow	0.160	0.109	0.548**	0.399	0.156*	0.158*
	(0.340)	(0.386)	(0.247)	(0.263)	(0.097)	(0.098)
After × draft cattle	−0.645	−0.687	−0.281	−0.432	0.206**	0.207**
	(0.483)	(0.516)	(0.326)	(0.335)	(0.093)	(0.094)
After × goat	0.260	0.206	0.366	0.214	0.161*	0.162*
	(0.292)	(0.346)	(0.235)	(0.252)	(0.094)	(0.094)
Round 2	0.665**	0.675**	−0.152	0.003	−0.25***	−0.249***
	(0.219)	(0.290)	(0.163)	(0.186)	(0.060)	(0.060)
Round 3	0.473	0.545**	0.261	0.411**	0.036	0.034
	(0.212)	(0.278)	(0.161)	(0.182)	(0.056)	(0.056)
Round 4	0.116	0.215	−0.055	0.095	0.165***	0.163***
	(0.203)	(0.272)	(0.172)	(0.193)	(0.062)	(0.062)
Dairy cow	0.720***	0.513	0.503**	0.343*	−0.002	0.064
	(0.287)	(0.317)	(0.199)	(0.224)	(0.095)	(0.110)
Goats	−0.737***	−0.297	−0.564***	−0.432**	−0.157	−0.126
	(0.253)	(0.283)	(0.191)	(0.219)	(0.100)	(0.115)
Draft cattle	1.378***	0.721	−0.787***	0.313	−0.011	0.025
	(0.414)	(0.458)	(0.266)	(0.297)	(0.100)	(0.129)
Chembe		0.388*		0.187		0.168
		(0.211)		(0.152)		(0.107)
Kamisenga		0.662**		0.399**		−0.059
		(0.296)		(0.196)		(0.095)
Kanyenda		−0.046		0.101		−0.020
		(0.291)		(0.198)		(0.095)
Kaunga		1.162***		0.715***		−0.023
		(0.327)		(0.211)		(0.112)
ln Expenditure per Capita	1.019***	0.788***	1.018***	1.019***		
	(0.092)	(0.082)	(0.064)	(0.064)		
Dependency ratio	0.061**	0.572**	1.115***	1.133***	−0.099	−0.078
	(0.272)	(0.259)	(0.202)	(0.201)	(0.117)	(0.116)
ln Total assets	0.044***	0.185***	0.160***	0.172***	0.205***	0.196***
	(0.056)	(0.053)	(0.041)	(0.042)	(0.029)	(0.028)
Gender of HHH	0.042	−0.057	−0.035	−0.066	0.087	0.092*
	(0.120)	(0.152)	(0.088)	(0.087)	(0.056)	(0.055)
Education of HHH	0.147***	0.131***	0.057*	0.046	0.073***	0.066***
	(0.044)	(0.045)	(0.034)	(0.034)	(0.023)	(0.023)
Negative shock	−0.414**	−0.360**	0.097	0.103	0.085*	0.088**
	(0.151)	(0.152)	(0.114)	(0.116)	(0.044)	(0.044)
Positive shock	0.096	0.058	0.317***	0.296***	0.072*	0.070*
	(0.130)	(0.134)	(0.101)	(0.102)	(0.040)	(0.040)
Intercept	−6.715***	−5.87***	−8.163***	−8.52***	7.965***	8.071***
	(1.071)	(1.057)	(0.807)	(0.826)	(0.410)	(0.404)
F	17.38	14.74	35.90	30.57	14.05	12.70
R^2	0.2340	0.2358	0.3594	0.3695	0.3494	0.3576
n	1,060	1,060	1,060	1,060	1,060	1,060

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Robust standard errors reported in parenthesis.

APPENDIX B.

Table 15. *Results from seemingly unrelated regression*

	HHDDS (SUR)	HHDDS (from Table 5)	Probability-weighted DDS (SUR)	Probability-weighted DDS (from Table 5)	ln Expenditure per Capita
After × dairy cow	0.348	0.358	0.822***	0.801***	0.157*
	(0.299)	(0.314)	(0.234)	(0.196)	(0.09)
After × draft cattle	−0.436	−0.432	0.012	0.013	0.199*
	(0.361)	(0.354)	(0.282)	(0.246)	(0.108)
After × goat	0.392	0.396	0.588***	0.589***	0.143**
	(0.247)	(0.283)	(0.193)	(0.210)	(0.074)
Round 2	0.684***	0.681***	−0.221	−0.221	−0.110**
	(0.177)	(0.213)	(0.139)	(0.147)	(0.053)
Round 3	0.644***	0.640***	0.300**	0.300**	0.088*
	(0.178)	(0.206)	(0.139)	(0.152)	(0.053)
Round 4	0.422**	0.419**	0.113	0.113	0.211***
	(0.18)	(0.206)	(0.141)	(0.178)	(0.054)
Dependency ratio	−0.832*	−0.834	0.353	0.351	−0.105
	(0.498)	(0.531)	(0.389)	(0.511)	(0.149)
Household size	0.003	0.004	0.068**	0.070**	−0.139***
	(0.039)	(0.043)	(0.031)	(0.031)	(0.012)
Negative shock	−0.430***	−0.431***	0.173	0.171	0.043
	(0.136)	(0.167)	(0.106)	(0.127)	(0.041)
Positive shock	−0.095	−0.095	0.165*	0.165	0.035
	(0.124)	(0.148)	(0.097)	(0.115)	(0.037)
Intercept	6.787***	6.204***	4.652***	4.563***	11.167***
	(0.816)	(0.384)	(0.638)	(0.348)	(0.245)
Household FE	Yes	Yes	Yes	Yes	Yes
R^2	0.4943	0.0343	0.5396	0.0876	0.6594
n	1,060	1,060	1,060	1,060	1,060

*Significant at 10%, **Significant at 5%, ***Significant at 1%; Standard errors reported in parenthesis.