Spilt Milk: Measuring the Indirect Effects of Livestock Ownership in Rural Zambia

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1 Introduction

The United Nations Food and Agriculture Organization (FAO) estimates that 815 million people worldwide suffer from chronic hunger, which is defined as insufficient food intake to meet dietary energy requirements. In Eastern Africa, it is estimated that nearly a third of the population is affected. Malnutrition, which includes undernourishment, overnutrition, and specific micronutrient deficiencies, has led to simultaneous observance of obesity, stunting, wasting, and anaemia. Children have been particularly affected across the globe: approximately 155 million under the age of five suffer from stunting (low height for age) and 51.7 million suffer from wasting (low weight for height) (FAO et al., 2017).

Deficiencies in macronutrients such as protein and micronutrients like vitamin A and iron, have been shown to relate to health, nutrition, and productivity outcomes later in life (Hoddinott et al., 2015; Victora et al., 2008). Animal-source foods (ASFs) are the most prevalent source of these nutrients, and thus programs to increase the quantity of animal products available for consumption have been deployed in the developing world (Whaley et al., 2003). Livestock ownership can affect nutrition outcomes in multiple ways: through increased availability of dairy or meat products, and through increased household income leading to increased consumption (Nicholson et al., 2003; Jodlowski et al., 2016; Kafle et al., 2016). The identification of the causal impact of livestock ownership has been hindered by endogeneity in the decision to own livestock. Using data from the staggered rollout of a Heifer International (HI) livestock donation in Zambia, this paper contributes to literature on the medium-term effects of livestock ownership on nutrition outcomes.

A focus of this paper is the broader within-village effects of livestock donation programs. As livestock may produce more milk, meat, or labor than the household can use, programs providing livestock at the household level may have spillover effects on other households. This paper reviews the existing literature and compares results from two different estimation approaches to spillover effects: spatial and program design. I also attempt to disentangle price effects due to village-specific markets for animal-source foods. The results provide empirical evidence for policymakers who are interested in maximizing the benefits of development interventions, as traditional measures that do not consider spillover effects may underestimate the total effect of the treatment.

I find evidence of direct and indirect treatment effects. For the households that received a dairy cow, livestock ownership results in about an 90% increase on average in the value of weekly per capita milk consumption. Households that participated in the Heifer International training program in the village that received dairy cows, but did not receive an animal by the end of the survey, saw an increase of about 15% on average in the per capita value of weekly milk consumption from gifts, an example of an indirect benefit from program design. Households that participated in the Heifer International training program in the village that received goats, but did not receive an animal by the end of the survey, saw an increase of about 45% on average in the per capita value of weekly meat consumption from gifts, an example of an indirect benefit from program design.

2 Background

2.1 Livestock ownership

There are many pathways through which livestock ownership can lead to improvements in household welfare outcomes. The existing literature focuses on the direct impacts of livestock ownership; however there is limited evidence of the indirect effects of livestock ownership on other households. Animal source foods provide micro and macro nutrients as well as income from sales of livestock products such as milk, meat, manure, or draft labor (Whaley et al., 2003; Randolph et al., 2007; Headey et al., 2018). Livestock can increase access to market opportunities and serve as an investment vehicle for the household (Randolph et al., 2007; Nicholson et al., 2003). Livestock ownership may be associated with an increase in womens' bargaining power within the household based on gendered livestock management practices, which may lead to gender-based differences in food expenditure or consumption choices (Doss and Mcpeak, 2005; Kafle et al., 2018).

Rawlins et. al. (2014) used a similar Heifer International livestock donation program to study biometric outcomes for children in Rwanda, however their study was non-randomized, cross sectional only and relied on propensity score matching. The study found that livestock ownership increased dietary diversity for households that received dairy cows. Hoddinott et al. (2015) also used cross-sectional data and found ownership of a cow was associated with increased consumption of milk and decreased rates of stunting in rural Ethiopia. This study identified stronger effects on households in areas with limited local markets.

Two papers have been published based on the first four rounds of the same data used in this paper. Jodlowski et. al (hereafter ”Jodlowski”) (2016) found increases in total household expenditure for all treatment households and increases in probability weighted household dietary diversity for goat and dairy cow-recipient households. Kafle, et. al. (hereafter ”Kafle”) (2016) found similar increases in both food and nonfood expenditures and livestock revenues for all treatment households, with the largest increases for dairy cow recipients, and decreased subjective feelings of poverty by all treatment households. A third paper used six rounds of the same data and found positive impacts of livestock transfers on households resilience. (Phadera et al., 2019) This paper will extend those analyses to include all eight rounds of data, to look beyond short-term impacts and consider the medium-term impact of livestock donation programs. In addition, I estimate spatial spillover effects using a measure of geographic proximity.

2.2 Estimation of Spillover Effects

The estimation of spillover effects in the economic literature has grown since 2000 and in general preceded estimation in the public health literature. Spillover effect estimation has been used for technology adoption, education, and food aid interventions. The approaches can be separated into general equilibrium effects, structural models of social or spatial learning, program design, and partial equilibrium effects along social or spatial dimensions. However, these approaches are not necessarily independent, and identification requires accounting for alternative explanations.

General equilibrium effects are the result of household and firm interactions affecting market prices and therefore equilibrium solutions. Heckman, Lochner, and Taber (1998) used an rational expectations, overlapping generations general equilibrium model to look at the effects of a tuition subsidy on school attainment and earnings. They show that the treatment effect framework is insufficient because the individuals who are affected are not just those who receive benefits, and the impact of the program on equilibrium skills prices and taxes is not captured by the framework. Because no true ”treatment-free” group can be identified, the differences-in-differences (DID) method of estimation will yield conservative estimates when spillover effects are present. This method requires data on market prices, quality, and participation.

The structural approach defines models where decision-makers update own beliefs after observing the actions and outcomes of other individuals within social or spatial networks. This method typically induces heterogeneity in information dispersion through various network structures in a controlled experiment. There is an extensive literature looking at spillover effects from technological adoption. Conley and Udry (2010) explored spillover effects from agricultural adoption to see how the benefits of a new technology move through social networks in Ghana using staggered adoption times and found evidence of social learning. Munshi (2004) demonstrated that information flows are weaker in heterogenous populations when the underlying characteristics are unknown, using data on wheat and rice growers during the Green Revolution in India . Chandrasekhar, Larreguy, and Xandri (2016) conducted experiments to test Bayesian and DeGroot learning models and found that agents were more likely to follow the DeGroot method of updating based on simple majorities. This literature focuses more on the determination of optimal network formation for information diffusion. Beaman et.al. (2018) design a field experiment with different models of entry points and diffusion strategies across social networks and find that the targeting strategy matters, and that spatial networks are a poor substitute for social networks. Chuang and Schecter (2015) provide an overview of the social network in developing countries and identify a gap in the literature in separating the mechanisms behind the network effects, such as the difference between the network's role in sharing information and its role in monitoring and enforcing monetary transfers. (2015)

Spatial spillovers have also been identified through program design. Miguel and Kremer's (2004) evaluation of a deworming program in Kenya used a step design of treatment delivery, allowing eligible groups that did not yet receive the treatment to serve as counterfactuals for the treatment group. Partial treatment within clusters yields unbiased estimates, but does not explain how the estimates vary with treatment intensity within a cluster (Moffitt et al., 2001). The economics literature has pointed out that randomization at the treatment level (or assignment to treatment level) does not guarantee that spillover effects are themselves random. Baird, et. al. (2016) recommend using a randomized saturation design where each cluster is assigned a treatment saturation and each individual within the cluster is randomly assigned a treatment status, given the assigned cluster saturation.

Spatial econometric models use geographic proximity to identify neighborhood effects using a weighting matrix to represent the intensity of influence of neighbors and use maximum likelihood estimation to address geographic endogeneity. (De Giorgi et al., 2010; fei Lee and Yu, 2010)

3 Indirect Effects Methodology

As milk and meat are perishable items, it is likely that households would prefer to sell or gift any production in excess of household consumption in lieu of storage. These transfers, via formal markets or informal channels, represent indirect benefits to non-recipient households in the form of increases in consumption. There are various pathways through which indirect effects may result from livestock ownership.

This paper focuses on three:

- Program Design Effects: ”Pass on Gift” (POG) households were required to attend Heifer training alongside Original households. In addition, there was a staggered distribution of second generation livestock to POG households in arbitrary order. If treated households have excess meat or milk, they may prioritize sharing with other households that are participating in the Heifer program as a form of consumption smoothing. Original and (POG_y) households might prioritize sharing with POG households that have not yet received animals (POG_n) to compensate those households for not yet receiving an animal. For POG_y households, the direct program effect would be increased consumption from home production, while the indirect program effect would be increased consumption from gifts.
- Spatial Spillovers: Households may share information or goods with geographically proximate households. The survey design covered Original and POG households in villages with treated households, thus it is not possible to identify any direct or indirect effects on untreated households in those villages. Independent households are not considered a control for any other household.
- Price Effects: The increase in supply of animal-source foods brought to village markets may lead to lower market prices resulting in increased average consumption of animal source foods in the village. However, lower market prices combined with transaction costs in bringing meat or milk to formal markets might encourage households to trade with each other rather than incur those costs. Additionally the increase in purchasing power by recipient households might drive up prices in those villages if supply does not expand accordingly.

Disentangling these pathways can support the identification of the optimal village network structure for maximizing the direct and indirect benefits of livestock transfer programs. If sharing occurs due to spatial proximity, then villages with tightly clustered households may benefit more than villages with dispersed households. If spillovers are concentrated within POG households who did not receive any animals (POG_n), then program benefits be maximized under a design which designates additional households as POG, but does not necessarily provide those households with animals. The benefits from the first pathway are costless, while the inclusion of additional households in training programs has a minimal cost, but is substantially less than the cost of providing livestock. Without an intervention design that incorporates spatial structure and program design simultaneously, it is not possible to identify which pathway maximizes program benefits. However, the results from these estimations may provide evidence to support future research to fully identify relative spillover effects.

3.1 Spatial Spillovers

Spatial econometrics provides the tools for estimating spatial spillovers. Initially spatial econometrics focused on two separate approaches: spatial autocorrelation models and modelling spatial heterogeneity (Anselin, 2001). The former approach specifies a model which includes a spatially lagged version of the dependent variable. The latter is used when spatial autocorrelation is present, but tests do not indicate that the inclusion of a spatial lag in the model would be useful, and thus the spatial component of the error term must be addressed through other econometric means. These approaches were combined into SARAR models that incorporate both spatial lags and spatially autocorrelated errors (Kelejian and Prucha, 1998; Baltagi et al., 2003). There is also support for Spatial Durbin models that incorporate lags of explanatory variables (Paul Elhorst, 2014). Spatial panel models extend these approaches to an additional dimension and allow for spatial and serial correlation (fei Lee and Yu, 2010; Kapoor et al., 2007; Baylis et al., 2011). Estimation of spatial panel models is implemented either by maximum likelihood (ML) or generalized method of moments (GMM) (fei Lee and Yu, 2010; Kelejian and Prucha, 1998; Kapoor et al., 2007). Both approaches require restrictions on the spatial weighting matrix, and on the distribution of the outcome variable to produce consistent and asymptotically efficient estimators.

If households are sharing excess goods or training information with geographically proximate households, then the mechanism for the spillover is program participation and a spatial lag on treatment is most appropriate. If there is correlation between proximate households due to other unobservable factors, that would justify a spatially lagged error. This model is defined as a Spatial Durbin Error Model that includes lagged covariates and an autoregressive error (Paul Elhorst, 2014).

$$Y = X\beta + (I_T \otimes W_N)X\theta + (\iota_N \otimes I_T)\alpha + u \tag{1}$$

where y is an NTx1 matrix of observations of the dependent variable, X is a NTxk matrix of finite exogenous regressors including dummies for treatment categories, I_T is an identity matrix of dimension T, W_N is an NxN spatial weighting matrix, ι_N is a Nx1 vector of ones, I_T is an identity matrix of dimension T, α is a Tx1 matrix, and θ is the spatial parameter of interest for the exogenous variables. Both the household effect and the disturbances can be spatially correlated (Kapoor et al., 2007). The disturbances can thus be decomposed:

$$u = \rho(I_T \otimes W_N)u + \varepsilon \tag{2}$$

The spatial parameter of interest for the disturbances is ρ and ε are innovations correlated over time and households:

$$\varepsilon = (\iota_T \otimes I_N)\mu + \nu \tag{3}$$

where ι_T is a Tx1 vector of ones, I_N is an identity matrix of dimension N, μ is Nx1 a vector of time-invariant household effects, and ν are assumed to be independent and identically distributed over households and time with mean zero and variance σ_ν^2 with finite absolute $4+\psi_\nu$ moments for some $\psi_\nu > 0$. T and N are fixed.

The spatial weights in W are assumed to be identical and non-stochastic. Formally, W is a row-normalized positive NxN matrix with elements $w_{ij} = \frac{1/d_{ij}}{\sum_j \frac{1}{d_{ij}}}, i = 1,...,N \quad \text{for} \quad d_{ij} < 100km$ where d_{ij} is the euclidean distance between household$_i$ and household$_j$ for $j = 1,..,N$ households, with $w_{ii} = 0$. Thus matrix $(I_N - \rho W_N)$ is non-singular and uniformly bounded in absolute value. Row-normalization yields a weight that is interpreted as the fraction of all spatial influence on household$_i$ that can be attributed to household$_j$. It does however have other effects, most notably when a lagged dependent variable is included.

In the fixed effects panel model, the incidental parameter problem prevents identification of the fixed effects. The within transformation using deviations from the time mean would result in linear dependence over time in the ν term. Thus Lee and Yu (2010) utilize a transformation based on the orthonormal eigenvector matrix of the time mean operator. This transformation does not induce serial correlation in the errors, but does require that the weighting matrix be row normalized. For short T, the time effects are estimated as additional regression coefficients and only one transformation is performed.

Formally, equation (8) is pre-multiplied by the TxT matrix J

$$\text{where } J = \begin{pmatrix} \sqrt{\frac{T-1}{T}} & \frac{-1}{\sqrt{T(T-1)}} & \frac{-1}{\sqrt{T(T-1)}} & \cdots & \frac{-1}{\sqrt{T(T-1)}} & \frac{-1}{\sqrt{T(T-1)}} \\ 0 & \sqrt{\frac{T-2}{T-1}} & \frac{-1}{\sqrt{(T-1)(T-2)}} & \cdots & \frac{-1}{\sqrt{(T-1)(T-2)}} & \frac{-1}{\sqrt{(T-1)(T-2)}} \\ 0 & 0 & \sqrt{\frac{T-3}{T-2}} & \cdots & \frac{-1}{\sqrt{(T-2)(T-3)}} & \frac{-1}{\sqrt{(T-2)(T-3)}} \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & \sqrt{\frac{1}{2}} & -\sqrt{\frac{1}{2}} \end{pmatrix}$$

This transformation yields:

$$Y_{nt}^{*} = X_{nt}^{*}\beta + \theta W_n X_{nt}^{*} + \rho W_n U_{nt}^{*} + \alpha_{nt}^{*}\iota_n + V_{nt}^{*}\text{ , for } t = 1...T-1 \tag{4}$$

For i.i.d. $v_i t$, $E(V_{n1}^{*'}...V_{n,T-1}^{*'})'(V_{n1}^{*'}...V_{n,T-1}^{*'}) = \sigma_v^2 I_{n(t-1)}$ and thus the $v_{it}^{*}{}'s$ are uncorrelated for all i and t and independent under normality. The resulting likelihood function is conditional based on time averages $\bar{Y_{nT}}$, which are a sufficient statistic for the time-invariant household effect under the assumption of normality of the original residuals. Let $Z = [X\ WX]$ and $\delta = [\beta\ \theta\ ]$. K is the number of parameters in β which is equal to the number of parameters in θ. Then the log likelihood function for normally distributed disturbances is:

$$ln\, L_{n,T}(\delta,\rho,\sigma^2|y) = \frac{-n(T-1)-2k}{2} ln(2\pi\sigma_v^2) + (T-1)[ln|I_n - \rho W_n|] - \frac{1}{2\sigma_v^2}\sum_{t=1}^{T-1} V_{nt}^{*'}(\delta)V_{nt}^{*}(\delta) \tag{5}$$

The estimation procedure iterates between the reduced likelihood function and Generalized Least Squares (GLS) until convergence: estimates of the residuals of the transformed model are used to estimate ρ, which is then used to estimate β, θ,γ, and σ_v as feasible GLS estimators. The parameters of the household fixed effect terms are not identified under this approach. Any spatial correlation in the household effect is also not identified under any fixed effect transformation. This approach is chosen over a method of moments approach because of multicollinearity between the lagged covariates and the instruments, and because it eliminates AR(1) serial correlation in the errors.

The QMLEs of δ and σ^2 given ρ are:

$$\hat{\delta}_{nT}(\rho) = \left[\sum_{t=1}^{T}\tilde{Z}_{nt}'(I_n - \rho W_n)'(I_n - \rho W_n)\tilde{Z}_{nt}\right]^{-1} \times \left[\sum_{t=1}^{T}\tilde{Z}_{nt}'(I_n - \rho W_n)'(I_n - \rho W_n)\tilde{Y}_{nt}\right] \tag{6}$$

$$\hat{\sigma^2_{nT}}(\rho) = \frac{1}{n(T-1)} \sum_{t=1}^{T} \left[\tilde{Y}_{nt} - \tilde{Z}_{nt}\hat{\delta}'_{nT}(\rho)\right]' \times \left[(I_n - \rho W_n)'(I_n - \rho W_n)\right] \left[\tilde{Y}_{nt} - \tilde{Z}_{nt}\hat{\delta}'_{nT}(\rho)\right] \tag{7}$$

where $\tilde{Z}$ are from estimation of equation (11). Substituting back in to equation 12 yields the concentrated likelihood function:

$$\text{lnL}_{n,T}(\rho|y) = \frac{-n(T-1)-2k}{2} ln((2\pi)+1) - \frac{n(T-1)-2k}{2} ln\hat{\sigma^2_{nT}}(\rho) + (T-1)ln|I_n - \rho W_n| \tag{8}$$

This is the concentrated likelihood function that will use for the spatial spillover analysis.

3.2 Price Effects

A general equilibrium (GE) model is required to determine whether consumption changes are due to market effects. However, this requires extensive data and fully functioning markets, which is unlikely to be true of the villages participating in the CRLESP program. It is instructive however to look at the spatial-temporal changes to understand the structure of local markets.

In Appendix Figures B.1 and B.2, the mean per capita weekly milk and meat consumption values are disaggregated into purchases, production, and gifts by round and by village. The solid lines represent the median purchase prices derived by round and village from reported purchase values and quantities. Total value and prices are normalized to 2012 ZMK. The dotted lines represent the expected price of the good that is used to calculate production value and gift value from reported production and gift quantities. Further information about these variables is included in Appendix A.

Figure B.1 shows milk purchase price spikes in Chembe and Kaunga in Round 7, and fluctuations in Kanyenda that do not appear to correlate with decreases in purchases. This may be because of poorly functioning markets without complete price transmission. Milk prices appear relatively stable over time in Kamisenga. In Figure B.2, price spikes occur in all villages in Round 7. With the exception of Round 6, meat prices increased over time in Kamisenga, where households received dairy cows. If dairy cow ownership increases household income, recipient households might demand more meat, resulting in a higher market price. There was high inflation in Zambia in 2016 when survey Rounds 5 and 6 occurred.

In order to test the behavior of prices within villages I regressed the nominal household-level purchase price on village, round, village*round interaction, and the number of treated in each village, where treatment includes all original and POG_y households. These results are included in Table B.1 in the Appendix, with the round dummies suppressed, none of which are significant. The base case is Round 1 in Chembe, a control village. There is significant evidence of depressed meat prices in Kamisenga relative to Chembe, and a milk price spike in Kanyenda in round 2. The positive coefficient on the number of treated individuals in Kamisenga may be the result of increased demand for meat due to increased dairy cow income for treatment households, with no accompanying supply expansion to meet the demand shift. This hypothesis is also supported by the significant coefficients on the Round*Kamisenga interactions in Rounds 3,5, and 7, which were surveys held during the rainy season when dairy cows are more productive.

A potential strategy to isolate price effects is to compare disaggregated consumption streams. Households can acquire animal source foods as gifts from other households, or purchase items from households or local markets. If the program increases the quantity and decreases the price of meat or meat available in the market, then it is more likely that meat and milk purchases would increase. If spillovers occur through spatial mechanisms and not through market effects, it is more likely that meat and milk gifts would increase. While the Round 8 survey asked for the location of milk purchases, prior rounds did not. Therefore these two pathways are not able to be identified with this data set. While estimating the consumption streams separately might help understand sharing mechanisms, this strategy will not definitively identify price effects.

4 Data and Replication

4.1 Data

The Copperbelt Rural Livelihood Enhancement Support Project (CRLESP) is a HI-implemented project in five villages in the Copperbelt region of Zambia, with funding from Elanco Animal Health. HI projects require community groups to form and organize themselves in order to submit applications for assistance. Eligibility for donation is contingent on household participation in training activities, initial investments into facilities for animals in households, and contributions of 10 percent of the total cost of livestock received to a community insurance fund. Thus community groups that apply may be in villages that are relatively better off than other villages in the region, however these villages are similar in meeting the HI eligibility characteristics and self-selecting into the program. The selection of treatment and control villages among successful applicants was based on timing of application and availability of resources.

The program provided livestock to households in the form of dairy cows, draft cattle, and goats. The program was quasi-experimental where the distribution of livestock to households was staggered to create three full treatment groups (dairy cows, draft cattle, meat goats) of households that received livestock in year one termed “Originals,” and three partial treatment groups of households that would receive subsequent generations of livestock termed “Pass on Gift” or ”POG.” One bull was given to each village that received draft or dairy cattle for reproductive purposes. POG households received training alongside original households at baseline. The community livestock group determined which households were Original and which were POG, although there is no discernable pattern in allocation. It is possible that POG households might change their behavior in anticipation of future livestock receipt. Jodlowski found no evidence of this behavior by looking at changes in expenditure for POG households in Rounds 1 and 2, prior to receipt of any animals.

Two eligible villages with community groups that applied but did not receive animals at any point during the program evaluation were termed “Prospectives.” These villages are geographically separate from the treatment villages and were intended to receive livestock at a later date after the evaluation period. All households in the prospective villages are labeled ”Prospective.” Assuming there are no substantive differences between the treatment and prospective villages at the time of application, the prospective villages can serve as a control group following De Janvry, et. al. (2010) Conditional on similarities between eligible villages, the staggered rollout eliminates the behavioral choice, there are no selection issues between adopters and non-adopters and a difference-in-differences model can be used. Treatment villages include households that did not participate in the farmers groups and did not receive treatment, termed ”Independents.” These households are likely different than households that selected into the program, and therefore are not used as a control group, but are used to provide general information about village trends.

In early 2012, Original households in Kamisenga received one pregnant dairy cow, households in Kaunga received two pregnant draft cattle, and households in Kanyenda received seven pregnant meat goats. The prospective communities were Chembe and Mwanaombe, which did not receive animals or training. The total livestock value transferred to each households was approximately 10,000 Kwacha, which is about 10 times the median asset level of a household. Data were collected in eight survey rounds between January/February 2012 and September/October 2017. Original treatment households were instructed to transfer subsequent generations of animals to POG households. Table 1 shows program attrition. Initially 324 households are surveyed and 291 remain by Round 8, an attrition rate of 10.2 percent. The balanced panel for the first four rounds used 300 households, the first six rounds used 275 households, and the balance panel for all eight rounds has 257 households.

As the assignment of treatment villages was not random, Table 2 presents the baseline characteristics of households during Round 1 to test the viability of the prospective communities as a control group. Note that the independents are not intended to be a control group for any other group, but serve as a source of information about village-level trends. Variable descriptions are included in Appendix A. Treatment households were significantly larger than households in prospective villages at baseline. Original households cultivate more land. Differences in herd size were not significant, not were household assets or annual revenue. Baseline statistics for outcome variables are in Table 3. While the value of total (food and non-food) weekly expenditures were significantly higher in prospective villages on a per capita basis, they were not at a household level. There were no significant differences in household dietary diversity scores, or weekly milk or meat consumption value or frequency.

4.2 Outcome Variables

Nutrition outcomes can be measured in terms of consumption levels, dietary diversity, or households' self-reported food security. I focus on the consumption of meat and milk products, disaggregated by three methods of acquisition: home production, purchases, and gifts. The outcome variable of interest is the log weekly per capita consumption value of milk or meat by acquisition method. Values are deflated to 2012 ZMK using inflation rates provided by the International Monetary Fund (IMF.)

4.3 Replication and Extension

Two prior papers have been published from this data set which consider spillover effects. Jodlowski and Kafle both considered POG households as the recipients of potential spatial spillovers, based on the assumption that any animals received by the POG households were immature and unproductive. Both found increases in the value of milk consumption by POG households in the village that received dairy cows. While Jodlowski and Kafle assumed that POG households did not own productive animals through Round 4, it is unlikely that this is true through Round 8.

To account for this, POG households were reclassified in all specifications that utilized all eight rounds of data. For each round, if the POG household had received an animal from Heifer International during that round or in a previous round, it was labeled "POG_y," otherwise the household was a "POG_n." This designation will allow me to distinguish between social or spatial spillover effects on POG households without animals (POG_n), and treatment effects on POG households with animals (POG_y). Figure 1 shows the share of households that have received animals by round.

I replicated the two papers and extended the authors' analyses through Round 8. A full explanation and results are included in Appendix C. After eight rounds, total expenditures increased by 35% for dairy cow recipients, 39% for draft cattle recipients and 43% for meat goat recipients, and 18% for POG households that received livestock. These effects were driven by increases in both food and non-food expenditures for all recipients. For draft households, the increase in nonfood expenditure is more than three times that of food expenditure, supporting the hypothesis that those households are not shifting wealth increases into consumption.

After Round 8, the value of milk consumption per capita increased by about 80% for dairy cow households and 40% for POG recipient households. This effect is smaller than the effects seen after Round 4 for treatment households, which may be due to aging of animals. Meat consumption per capita increased by 50% for dairy cow households, 100% by meat goat households, and about 60% for POG recipient and non-recipient households. This effect was similar to the effect seen after Round 4. Livestock revenue increased by over 400% for dairy cow households and 95% by draft cattle households, but there were no significant increases for meat goat households. These effects were consistent and persistent from Round 4 to Round 8. Based on the increase in meat consumption by meat goat households, it seems likely that those households chose to consume rather than sell their goats, while the dairy cow households were able to increase both consumption of milk and livestock revenue simultaneously.

5 Empirical Results

If sharing is due to surplus production of meat or milk and there are transaction costs to participating in formal markets, it is likely that proximate households would exhibit increased total consumption due to informal purchases or gifts. If it is information being shared, it is likely that proximate or networked households would increase total consumption due to market purchases or home production. As there is only data on location of purchases for Round 8, it is not possible to identify the two distinct types of purchases. Thus the outcomes of interest are milk consumption from gifts and home production, after controlling for geographic factors correlated with production with the spatially autocorrelated error term. I estimate Spatial and Durbin Error models ($\rho = \theta > 0$) for all disaggregated milk and meat consumption outcomes. These were compared to the fixed effect estimates.

The results of the spillover effect estimation for milk consumption are presented in Tables 4 and 5. Using the fixed effects estimator (Table 4) I find that for original dairy cow recipients, the 92% (accounting for the log transformation of the outcome variable) increase in total consumption can be attributed to increased production and decreased purchases. There is evidence that program designation is significant based on gifting to POG non-recipient in the dairy village. POG_Dairy_n recipients experienced a 16% increase in milk gift consumption value per capita per week. For milk consumption, none of the spatial models in Table 5 provided any information over the base fixed effect model with village fixed effects.

The results of the spillover effects estimation for meat consumption are presented in Tables 6 and 7. Using the fixed effects estimator (Table 6), there are significant effects in total consumption for most treatment and non-treatment groups, driven primarily by purchases. There is evidence that program designation is significant based on gifting to POG non-recipient in the goat village. POG_Goat_n recipients experienced a 28% increase in meat gifts per capita per week. It is uncertain if the increased meat consumption values by Original, POG_y, and POG_n households in the dairy cow village are due to higher prices from increased demand, or if the larger meat consumption values are themselves a function of the higher prices. Banerjee

6 Conclusion

I find evidence of direct treatment effects and indirect effects from program design. The lack of empirical results on spatial spillovers should not necessarily be perceived as a failure, but as an incentive to design programs to more accurately capture spillovers. The identification of spillover effects is difficult both empirically and econometrically. Empirical estimation is hindered by survey design and measurement error. Papers that have been successful in identification of spillovers have incorporated network effects and geographic location into the planning of the program, and used more sophisticated techniques in network mapping, such as photo identification of networked individuals.

The importance of the identification of spillover effects drives the continued search for solutions to the current measurement and specification issues. Both the quantity and type of livestock provided to households is calibrated by the type of village. Thus it is important to quantify spillover effects among possible pathways: through program design, through social networks, or due to spatial proximity. If households share excess milk, meat, or labor along social connections, then development organizations could maximize program effects by selecting villages with large existing social networks. If households share along spatial connections, then development organizations could maximize program effects by selecting villages where houses are more closely located. If there are effects on POG-non recipient households, then development organizations could increase program effects by increasing the number of POG-defined households, even if those households will not receive animals. The identification of spillover effects, analysis of spillover pathways, and subsequent program management could be important tools in addressing nutritional deficits in rural areas.

Table 1: Sample Size and Attrition by Village and Treatment

	Round 1	Round 8	Difference	Attrition Rate
Chembe	31	29	-2	6.5%
Kamisenga	87	79	-8	9.2%
Kanyenda	115	101	-14	12.2%
Kaunga	55	52	-3	5.5%
Mwanaombe	36	30	-6	16.7%
Original	106	96	-10	9.4%
POG	111	101	-10	9.0%
Independent	40	35	-5	12.5%
Prospective	67	59	-8	11.9%
Total	324	291	-33	

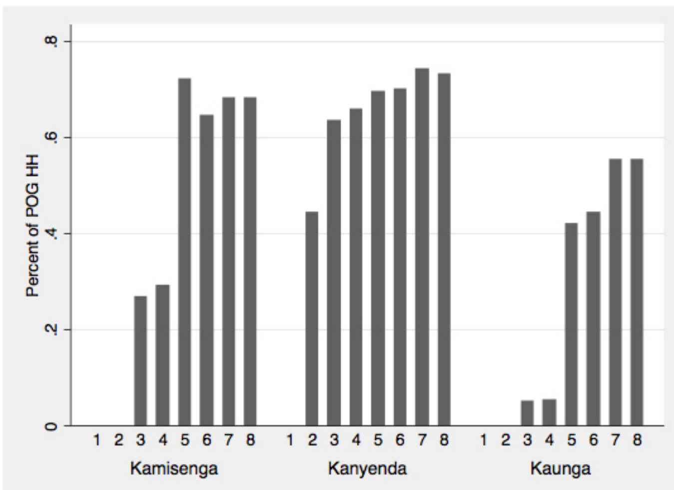

Figure 1: Percentage of POG households that have received animals by Round

Table 2: Baseline characteristics by treatment type

	Original	POG	Independent	Prospective	Orig v. Pros	POG v. Pros
Household Level						
Household size	7.41	6.92	5.97	5.73	-1.67***	-1.19**
	(2.80)	(2.75)	(2.37)	(2.16)		
Adult Equivalents	3.44	3.18	2.84	2.78	-0.66***	-0.40**
	(1.09)	(1.04)	(0.83)	(0.83)		
Dependency ratio	0.46	0.52	0.48	0.45	-0.02	-0.08*
	(0.20)	(0.17)	(0.21)	(0.22)		
Land (HA)	3.10	2.84	0.97	2.00	-1.10*	-0.84*
	(4.94)	(3.15)	(0.92)	(1.41)		
Herdsize (TLU)	1.16	0.74	0.26	1.23	0.07	0.49
	(1.95)	(1.80)	(0.49)	(2.59)		
Assets (2012 ZMK)	8033.92	4360.40	1481.99	5458.87	-2575.05	1098.46
	(10966.19)	(7448.94)	(1288.62)	(7899.00)		
Revenue (2012 ZMK)	8768.41	8612.79	3948.50	11044.78	2276.38	2432.00
	(11357.80)	(11170.14)	(3809.68)	(21257.88)		
Household Head						
Age	50.39	42.61	41.77	44.96	-5.43*	2.34
	(12.66)	(12.22)	(12.92)	(14.70)		
Education Level	2.51	2.52	2.23	2.69	0.18	0.16
	(1.21)	(1.29)	(1.17)	(1.05)		
Gender (1=female,0=male)	0.28	0.25	0.33	0.21	-0.07	-0.04
	(0.45)	(0.44)	(0.47)	(0.41)		
Married (1=yes, 0=no)	0.82	0.87	0.82	0.79	-0.03	-0.08
	(0.39)	(0.33)	(0.38)	(0.41)		
Observations	106	111	40	67	173	178

[1] Standard errors in parentheses
[2] ***Significant at the 1 percent level. **Significant at the 5 percent level.*Significant at the 10 percent level.
[3] Asset value and revenue are valued in 2012 Zambian kwacha. Assets includes the value of livestock, livestock equipment, durables goods, and agricultural tools. Annual revenue is 4x quarterly livestock revenue, 4x quarterly non farm income, annual crop revenue, remittances and other transfers. Herdsize is in tropical livestock units equal to 0.7 for mature cattle, 0.5 for immature cattle, and 0.1 for sheep or goats.

Table 3: Baseline outcomes by treatment type

	Original	POG	Independent	Prospective	Orig v. Pros	POG v. Pros
Total weekly consumption	908.39	852.24	676.45	1032.10	123.70	179.85
	(668.64)	(628.24)	(469.72)	(997.34)		
Total weekly consumption (per capita)	136.96	143.27	131.51	214.30	77.35**	71.03*
	(118.95)	(124.78)	(109.53)	(206.53)		
Food consumption per week	145.89	142.40	104.00	152.71	6.82	10.31
	(100.17)	(104.91)	(55.48)	(95.24)		
Food consumption per week (per capita)	21.47	24.34	19.60	30.86	9.39**	6.52
	(14.06)	(23.17)	(12.73)	(21.50)		
Food secure (1=yes,0=no)	0.37	0.38	0.33	0.37	0.01	-0.01
	(0.48)	(0.49)	(0.47)	(0.49)		
Dietary diversity	5.78	5.68	5.63	5.63	-0.16	-0.06
	(1.94)	(1.61)	(1.41)	(1.92)		
Milk consumption (days per week)	1.28	1.13	0.72	1.72	0.43	0.59
	(2.10)	(2.07)	(1.54)	(2.71)		
Meat consumption (days per week)	1.01	1.22	0.78	1.21	0.20	-0.01
	(0.94)	(1.40)	(0.83)	(1.27)		
Value of weekly milk consumption	4.49	3.23	2.80	3.43	-1.07	0.20
	(7.89)	(6.55)	(5.65)	(6.64)		
Value of weekly meat consumption	48.33	47.73	27.18	54.54	6.22	6.82
	(70.49)	(71.49)	(27.82)	(53.73)		
Observations	106	111	40	67	173	178

[1] Standard errors in parentheses
[2] ***Significant at the 1 percent level. **Significant at the 5 percent level.*Significant at the 10 percent level.
[3] The values of all consumption variables (total, food, milk, meat) are measured in 2012 Zambian kwacha per week and include items purchased, produced, or received as a gift by the household. Food security status is equal to one if the household reported having sufficient food quantity, and either sufficient or insufficient food variety. Dietary diversity is the number of food groups consumed out of 11 possible food groups during the prior 24 hours.

Table 4: Direct treatment effects on household milk consumption per capita

	Total Consumption	Production	Gifts	Purchases
After x dairy	0.653***	0.811***	-0.029	-0.131
After x goat	0.140	0.198***	-0.004	-0.055
After x draft	0.391**	0.414***	-0.016	-0.005
After x POG x dairy_y	0.506***	0.606***	0.029	-0.130
After x POG x goat_y	0.133	0.241***	0.028	-0.138
After x POG x draft_y	0.200	0.135	0.082	-0.018
After x POG x dairy_n	0.157	-0.017	0.150***	0.043
After x POG x goat_n	0.017	0.021	0.008	-0.013
After x POG x draft_n	-0.069	-0.034	0.043	-0.079
N	2056	2056	2056	2056
R^2	0.066	0.113	0.021	0.028
Controls	Y	Y	Y	Y

[1] Outcome variables are log 2012 ZMK values. Controls include household size, positive and negative household shocks, and village fixed effects.
[2] * $p < .10$, ** $p < .05$, *** $p < .01$

Table 5: Spatial analysis of Direct and Indirect treatment effects on household milk consumption per capita

Outcome variable:	Total Consumption	Production	Gifts	Purchases
After x dairy cow	0.602***	0.812***	-0.032	-0.167
After x meat goat	0.033	0.207	0.016	-0.19
After x draft cattle	0.305	0.384	-0.022	-0.053
After x POG x dairy cow_y	0.707***	0.665***	0.037	0.022
After x POG x meat goat_y	0.134	0.195	0.05	-0.112
After x POG x draft cattle_y	0.205	0.201	0.028	-0.031
After x POG x dairy cow_n	0.18	-0.069	0.128*	0.143
After x POG x meat goat_n	0.208	0.074	0.023	0.111
After x POG x draft cattle_n	-0.114	-0.062	0.042	-0.099
W x After dairy cow	-0.152	0.194	-0.105	-0.327
W x After meat goat	0.521	0.153	-0.041	0.433
W x After draft cattle	-0.889	-0.363	0.159	-0.612
W x After POG x dairy cow_y	-0.325	-0.487	0.412	-0.24
W x After POG x meat goat_y	-0.371	-0.421	-0.021	0.052
W x After POG x draft cattle_y	-1.25	-0.852	-0.334	-0.129
W x After POG x dairy cow_n	-0.252	-0.2	0.23	-0.289
W x After POG x meat goat_n	-0.713	-0.366	0.058	-0.413
W x After POG x draft cattle_n	0.084	0.633	0.133	-0.726
ρ	0.315***	0.241**	0.187*	0.176*
Controls	Y	Y	Y	Y

[1] Outcome variables are log 2012 ZMK values. Controls include household size and positive and negative household shocks.
[2] * $p < .10$, ** $p < .05$, *** $p < .01$

Table 6: Direct treatment effects on household meat consumption per capita

	Total Consumption	Production	Gifts	Purchases
After x dairy	0.728***	0.432*	0.027	0.615***
After x goat	0.721***	0.543**	0.084	0.368*
After x draft	0.428*	0.378*	-0.108	0.491**
After x POG x dairy_y	0.534**	0.415*	0.008	0.468**
After x POG x goat_y	0.714***	0.459*	0.080	0.447**
After x POG x draft_y	0.746**	0.354	0.017	0.718***
After x POG x dairy_n	0.572**	0.406*	-0.022	0.517***
After x POG x goat_n	0.801***	0.541*	0.250*	0.320
After x POG x draft_n	0.273	0.353	-0.069	0.317
N	2056	2056	2056	2056
R^2	0.129	0.151	0.021	0.132
Controls	Y	Y	Y	Y

[1] Outcome variables are log 2012 ZMK values. Controls include household size, positive and negative household shocks, and village fixed effects.
[2] * $p < .10$, ** $p < .05$, *** $p < .01$

Table 7: Spatial analysis of Direct and Indirect treatment effects on household meat consumption per capita

Outcome variable:	Total Consumption	Production	Gifts	Purchases
After x dairy cow	0.626**	0.301	-0.053	0.616**
After x meat goat	0.918***	0.828***	0.069	0.461*
After x draft cattle	0.798	1.082***	-0.12	0.475
After x POG x dairy cow_y	1.26***	0.884***	-0.019	1.11***
After x POG x meat goat_y	0.257	-0.012	0.04	0.142
After x POG x draft cattle_y	0.888	0.533	0.113	0.91**
After x POG x dairy cow_n	1.175***	0.892***	-0.015	0.956***
After x POG x meat goat_n	0.651*	0.257	0.341**	0.183
After x POG x draft cattle_n	0.772	0.647*	0.048	0.82*
W x After dairy cow	-1.984	-2.527**	0.03	-1.318
W x After meat goat	-1.761*	-2.415***	0.021	-1.331*
W x After draft cattle	-1.011	-0.656	0.012	-1.642
W x After POG x dairy cow_y	-2.821	-0.512	-0.12	-2.978**
W x After POG x meat goat_y	-0.176	0.916	-0.153	-0.169
W x After POG x draft cattle_y	-0.558	-2.089	-0.179	1.253
W x After POG x dairy cow_n	-3.11*	-0.724	0.013	-2.72*
W x After POG x meat goat_n	-1.923	1.294	0.529	-1.735
W x After POG x draft cattle_n	-1.822	-2.108*	-0.401	0.099
ρ	0.429***	0.517***	-0.207*	0.36***
Controls	Y	Y	Y	Y

[1] Outcome variables are log 2012 ZMK values. Controls include household size and positive and negative household shocks.
[2] * $p < .10$, ** $p < .05$, *** $p < .01$

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Appendix

A Description of Variables

Adjustment to monetary variables:

On January 1st, 2013, the Zambian kwacha was redenominated to address persistent inflation. The old currency unit was divided by 1000 to yield the new unit of kwacha (ZMK). During Rounds 1-4, the survey reported values in the old currency system and thus these values were adjusted to the new system by dividing by 1000 in order to compare to Rounds 5-8. Round 3-8 were deflated using inflation rates provided by the World Bank to represent 2012 values (Round 1 and 2). USD dollar equivalents are provided using purchasing power parity (PPP) conversions provided by the World Bank.

FAO recommends the use of a Household Dietary Diversity Score (HHDDS) which is generated by surveying households on which food groups they consume over a given period and counting the number of food groups which are met. It is recommended to use 24 hour recall and surveying the household over multiple seasons. (Carletto et al., 2017; FAO, 2010; Engle-Stone et al., 2017) Another possibility is a Food Consumption Score (FCS) which is a mean of food items consumed, but does not have contextualized cutoff points or use food groups.(FAO, 2010) Hoddinot and Yohannes (1999) showed that a 1 percent increase in dietary diversity is associated with a 1 percent increase in per capita consumption and 0.7 percent increase in total per capital calorie availability Ruel (2002) added that dietary diversity is not a measure of dietary quality, but is correlated with food security. In this paper, I use a household dietary diversity measure that follows the FAO recommendation, but combines certain items to yield 13 groups instead of 16 groups. The 13 food groups are vegetables, beverages/sweets, cereals, white tuber, yellow/orange tuber, orange/red flesh fruits, other fruits, meat/chicken, eggs, fish legumes/nuts/seeds, milk and milk products, and oils. Consumption frequency is measured as the number of days the household reports consuming specific items from these food groups over a seven day period.

Household expenditures are typically used to capture household wealth and poverty status. The CRLESP project measured total household expenditure, as well as aggregates of expenditures on food and non-food items, and expenditures on specific categories of food groups. The food expenditure aggregate includes food that the household purchases, produces at home, or is gifted by another household.

Expenditure variables:

$foodexp$ is the weekly amount in kwacha the household spent in the prior week on 13 food group items, which are then aggregated to form total weekly food expenditure by the household. $foodexp_{wkpc}$ is the total weekly food expenditures divided by household size.

$nonfoodexp$ is the Kwacha value of household spending on an aggregate of all purchased non-food items. $nonfoodexp_{wkpc}$ is the total weekly nonfood expenditures divided by the household size. The survey asks about purchases during the past 3 months, which is then divided by 12 to determine the weekly non food expenditure for the household. Categories include clothing, kitchen equipment, bedding, furniture, electrical, building, transportation, ceremonial, church offerings,taxes, medicine, school fees and materials, alcohol, tobacco, and other consumable goods.

$totexp$ is is the weekly amount spent by the household on both food and nonfood items, calculated as the aggregate of weekly $foodexp$ and weekly $nonfoodexp$. $totexp_{wkpc}$ is the total expenditure, divided by household size.

All expenditure variables are adjusted to 2012 values and are winsorized at the 99% level to eliminate outliers. Missing nonfood expenditures were imputed using household characteristics and expenditure levels in the prior round.

$Foodshare$ is weekly household food expenditures divided by weekly household total expenditures. $ASFshare$ is weekly household meat and milk expenditures divided by weekly household total expenditures.

Value of Consumption variables:

The value of consumption of each category within milk, meat, oil, sweets/beverages, rice, and maize, is constructed as the aggregate of the total amount reported purchased, gifted, or consumed from home production by the household on a weekly basis. The value of the home produced and gifted amounts is calculated using 2012 ZMK values for comparative purposes. The value of purchased amounts is reported by the households, and then deflated to 2012 ZMK values. The consumption values are then divided by household size to yield weekly consumption per capita values.

There are two survey-based quirks related to consumption variables. The first round of survey collection aggregated meat, chicken, fish, and dried fish into a single category. This was disaggregated in subsequent rounds. Thus any estimates using meat consumption value as a dependent variable should be conservative estimates, as the baseline consumption value is inflated. The survey instrument in the first four rounds asks: total consumption quantity, the distinct percentages from production/gifts/purchases, and the cost of purchases. However, enumerators turned the percentage question into a binary yes/no, and thus it is not possible to separate the consumption quantity into the three categories. Therefore in all rounds, the coding has been to count purchases only if production or gift is not selected. There is an obvious bias here that cannot be remediated.

Livestock variables:

$herdsize$ is the total number of livestock owned by the household converted into tropical livestock units (TLU), a standardization determined by FAO based on livestock size. Number of cattle and goats are reported by the household.

$livstksales$ is the total value of livestock sold during the prior three months by the household $livstkprodsales$ is the total value of livestock products (meat, milk, eggs, manure, or draft labor) sold during the prior three months by the household. $livstkrev$ is the aggregate of the two type of livestock sales, which is then divided by $householdsize$ to yield $livstkrev_{wkpc}$, which is per capita weekly livestock revenue. All variables are adjusted to 2012 values. $livstkrev_wkpc$ is winsorized at the 99 % level.

Household Characteristics:

$Total\,land$ is the total area in hectares that the household planted during the prior three months as the aggregate of the land cultivated by crop

$HH\,Durable\,assets$ are an aggregate of all permanent assets owned by the household. This is winsorized at the 99 % level. TV and $bicycle$ ownership are binary variables equal to 1 if the household reports ownership, and 0 otherwise.

$Education$ level of the household head is a step scale from 0 for no education, to 6 for Tertiary University (> 3 years)

$Gender$ and $Marital\,Status$ are also identified for the head of the household, and are binary variables.

Dependency ratio is the ratio of number of children under 16 to the total *householdsize*.

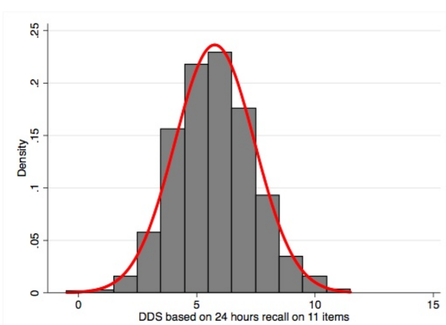
Food Security and Consumption Variables:

foodsecure is a dummy representing 0 if the household reports feeling more insecure than 6 months ago and 1 if the household reports feeling less secure than 6 months ago

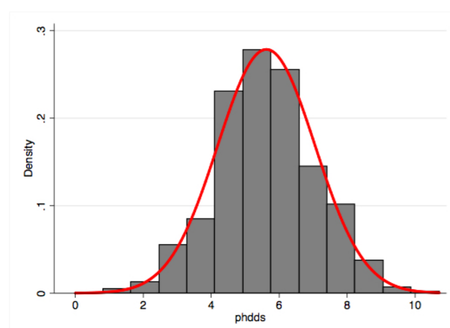
FeelingPoor is a dummy representing 0 if the household reports feeling worse off than 6 months ago and 1 if the household reports the same or better off than 6 months ago.

hdds is a household dietary diversity measure using 24-hour recall respectively. The survey instrument asked households whether they had consumed items within 13 categories during the previous 24 hours, consistent with FAO methodology: Cereals, White tubers and roots, Yellow tubers and roots, Vegetables, Fruits orange or red flesh, Fruit other, Meats, Eggs, Fish and other seafood, Milk and milk products, Legumes nuts seeds, Oils and Fats, and Sweets spices condiments and beverages. There were no households in the sample who answered "No" to all food groups in the 24-hour recall. Because a household may consumer a category weekly but not daily, a probability based dietary recall (HHDDSprob) was developed to address these patterns using data from a seven day recall. The probability was calculated as: $\sum_{i=1}^{13} \frac{n_i}{7}$ where n is the number of times per week food category i was consumed.

As household dietary diversity is technically a count variable, other functional forms might be required. However, the distributions of both the HHDDS and HHDDSprob variables were normal.



(a) HH dietary diversity



(b) Probability weighted HDDS

Figure A.1: Distribution of count variables

The frequency of consumption is reported as the number of days within the past week the household reported serving each of the following categories: *milk*, *meat*, *cereals*, *sweets*/*beverages*, *andoil*.

B Market Price Analysis

Figure B.1: Milk Consumption Value by Category and Median Village Price

Figure B.2: Meat Consumption Value by Category and Median Village Price

Table B.1: Inflation by Round and and Treatment

	Dependent variable			
	Milk Price (nominal)		Meat Price (nominal)	
	(1)	(2)	(3)	(4)
Treated x Kamisenga (dairy cow)		−7.289		4.891*
Treated x Kanyenda (meat goat)		−17.124*		−1.735
Treated x Kaunga (draft cattle)		2.581		−3.914
Kamisenga (dairy cow)	−10.420	−10.420	−9.427***	−9.427***
Kanyenda (meat goat)	−6.971	−6.971	1.265	1.265
Kaunga (draft cattle)	−2.108	−2.108	−2.218	−2.218
Mwanaombe (control)	−13.990	−13.990	−1.003	−1.003
Round 2 x Kamisenga (dairy cow)	6.971	7.532	9.395	6.706
Round 3 x Kamisenga (dairy cow)	5.843	7.665	13.170*	10.581
Round 4 x Kamisenga (dairy cow)	31.609*	34.525*	10.084	6.527
Round 5 x Kamisenga (dairy cow)	6.505	6.505	16.640**	13.306*
Round 6 x Kamisenga (dairy cow)	8.273	10.702	9.001	5.444
Round 7 x Kamisenga (dairy cow)	−13.480	−10.167	15.317**	11.702
Round 8 x Kamisenga (dairy cow)	8.598	13.083	4.480	0.638
Round 2 x Kanyenda (meat goat)	72.956***	78.664***	0.702	1.787
Round 3 x Kanyenda (meat goat)	10.691	24.390	−0.195	1.332
Round 4 x Kanyenda (meat goat)	13.328	25.886	−4.332	−3.049
Round 5 x Kanyenda (meat goat)	11.783	24.877	0.439	2.058
Round 6 x Kanyenda (meat goat)	13.837	29.737	−1.561	0.174
Round 7 x Kanyenda (meat goat)	−11.228	2.091	−2.095	−0.511
Round 8 x Kanyenda (meat goat)	8.294	23.278	0.944	2.679
Round 2 x Kaunga (draft cattle)	0.610	0.179	4.300	5.805
Round 3 x Kaunga (draft cattle)	2.822	1.532	3.860	5.639
Round 4 x Kaunga (draft cattle)	11.955	10.406	−2.625	−0.016
Round 5 x Kaunga (draft cattle)	9.331	7.610	12.533*	15.328**
Round 6 x Kaunga (draft cattle)	5.563	3.686	4.063	6.998
Round 7 x Kaunga (draft cattle)	−5.498	−8.079	2.602	5.048
Round 8 x Kaunga (draft cattle)	7.469	5.592	8.275	10.698
Round 2 x Mwanaombe (control)	8.208	8.208	0.090	0.090
Round 3 x Mwanaombe (control)	9.310	9.310	3.055	3.055
Round 4 x Mwanaombe (control)			−5.264	−5.264
Round 5 x Mwanaombe (control)	11.074	11.074	−0.461	−0.461
Round 6 x Mwanaombe (control)			2.239	2.239
Round 7 x Mwanaombe (control)	−11.283	−11.283	1.574	1.574
Round 8 x Mwanaombe (control)			2.045	2.045
Constant	15.990*	15.990*	19.458***	19.458***
Observations	360	360	693	693
R^2	0.108	0.118	0.140	0.146
Notes	*p<0.1; **p<0.05; ***p<0.01			
	Base levels: Round 1, Chembe; round dummies suppressed			

C Replication of Prior Results

Two prior papers have identified household level treatment effects from the first four rounds of this data set: Jodlowski used a difference-in-difference (DiD) model and found increases in expenditure per capita for all treatment households, increases in probability weighted household dietary diversity for goat and dairy cow households only, and increases in the value of milk consumption for POG households in dairy cow and draft cow villages. (2016) Kafle also used a DiD model and quasi maximum likelihood (MLE) to find similar increases in food and nonfood expenditures and livestock revenues, increases in the consumption of milk, and decreases in the subjective measures of poverty by all treatment households. He also found significant increases in the value and frequency of milk consumption by POG households. (2016) Kafle included independents in his analysis, whereas Jodlowski did not, although they are not intended to be a control or treatment group.

Extension of the methodology used by Jodlowski and Kafle to all eight rounds is instructive because the first four rounds occurred during the initial 18 months of the program, while the final round (round 8) occurred a full 5.5 years after the initial distribution of animals to Original households. The persistence or decline of treatment effects over time can yield a better estimate of the medium-term impact of livestock donation on rural households.

Both papers looked at baseline characteristics of households during round 1 to consider the viability of the prospective communities as a control group. Neither could be reproduced exactly due the processing of the raw data, but Table C.1 is similar to Jodlowski's Table 2, and Kafle's Table 4. Note that the final column represents differences between independent and prospectives, and the independents are not intended to be a control group for any other group. Further variable descriptions are included in the appendix.

Households in treatment villages were significantly larger than households in prospective at baseline. Cultivated land levels differ from Kafle's paper as I used the aggregate of land cultivated per crop, and I believe he used the total number of hectares reported by the household as cultivated. Original households cultivate significantly more land, and have more cattle and more goats. If this is true, then the decision to allocate treatment vs. prospective villages based on application timing, may have been affected by the existing livestock knowledge and experience of villages who applied first, and thus the prospective villages are not a reliable control group for the treatment villages.

A table of outcome variables from round 1 is included as Table 3 in Kafle's paper, and is reproduced as Tables C.2 and C.3 in this paper. A full description of each variable is included in Appendix A. Kafle presents the outcome variable statistics without significance measures, possibly because of the significant differences that abound between prospective households and treatments households.

Table C.1: Summary of Replication and Extension of Expenditure and Revenue Outcome Variables

Model	Outcome Variable	Round	After x Dairy	After x Draft	After x Goat	After x Pog	After x Pog_y	After x Pog_n
J1	Total Expenditure per capita (Log, ZMK/week)	1-4	0.229**	0.262**	0.215**			
J1		1-4	0.185	0.224*	0.212**			
J1		1-8	0.223*	0.250**	0.273***			
J2		1-4	0.271**	0.303**	0.256**	0.068		
J2		1-4	0.119	0.184	0.164*	0.019		
J2		1-8	0.315**	0.341***	0.365***		0.175*	0.130
K1	Total Expenditure	1-4	0.241**	0.277**	0.202*	0.080		
	per capita	1-4	0.226*	0.260**	0.252***	0.065		
	(Log, ZMK/week)	1-8	0.308**	0.329***	0.360***		0.173*	0.117
K1	Food Expenditure	1-4	0.363***	0.208	0.220*	0.152		
	per capita	1-4	0.337***	0.180	0.257**	0.122		
	(Log, ZMK/week)	1-8	0.256*	0.155*	0.327***		0.186*	0.115
K1	Non-food Expenditure	1-4	-0.078	0.413**	0.203	0.010		
	per capita	1-4	0.008	0.331*	0.218*	0.013		
	(Log, ZMK/week)	1-8	0.322**	0.552***	0.382***		0.176	0.151
J1*	Milk Consumption	1-4	20.310***	16.175**	2.618			
	Value by Household	1-4	11.273***	6.046	1.438			
	(ZMK/week)	1-8	6.076***	0.907	-1.415			
K1	Milk Consumption	1-4	4.210***	0.836	1.070	1.152**		
	per capita	1-4	0.817***	0.291*	0.244**	0.215***		
	(Log, ZMK/week)	1-8	0.592***	0.159	0.137		0.322***	0.030
K1	Meat Consumption	1-4	0.478	0.716	0.805	0.878*		
	per capita	1-4	0.290	0.528	0.577***	0.356**		
	(Log, ZMK/week)	1-8	0.404*	0.384	0.745***		0.466***	0.476***
K1	Oil Consumption	1-4	0.456	0.242	0.307	0.286		
	per capita	1-4	0.237**	0.148*	0.153**	0.128**		
	(Log, ZMK/week)	1-8	0.269***	0.111	0.190**		0.056	0.132*
K1	Sweets/Beverages	1-4	0.911**	-0.119	0.278	-0.033		
	Consumption per capita	1-4	0.466***	-0.081	0.284**	0.047		
	(Log, ZMK/week)	1-8	0.480***	0.091	0.359***		0.113	-0.014
K1	Rice Consumption	1-4	0.433	2.298***	1.253*	0.528		
	per capita	1-4	0.030	0.435***	0.269**	0.053		
	(Log, ZMK/week)	1-8	-0.025	0.322***	0.274***		0.025	-0.049
K1	Maize Consumption	1-4	1.119**	0.187	0.044	0.650***		
	per capita	1-4	0.137	0.051	0.039	0.151*		
	(Log, ZMK/week)	1-8	0.007	-0.027	-0.018		0.058	0.094
K1	Livestock Revenue	1-4	7.009***	1.667**	-0.437	-0.478		
	per capita	1-4	1.777***	0.731***	-0.020	-0.174		
	(Log, ZMK/week)	1-8	1.641***	0.666***	0.281		0.200	-0.140

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Model J1: $y_{ilt} = \alpha_0 + \sum_l \beta_l A_t T_{il} + \sum_t \gamma_t A_t + \sum_l \delta_l T_{il} + \mu X_{ilt} + FE_i + \varepsilon_{ilt}$

where $A_t T_{il}$ is an interaction between A_t an indicator for after treatment (0 if $t = 1$, 1 otherwise) and T_{il}, an indicator equal to 1 if household$i$ received species l and 0 if prospective

X_{ilt} are covariates: household size, dependency ratio, and positive and negative household shocks.

For J1*, X_{ilt} also includes log weekly total household expenditure per capita

Model J2: Model J1 where Treatment now includes livestock-specific treatment and POG households

Model K1: Model J2 where X_{ilt} is a covariate vector: gender and marital status of household head, and positive and negative shocks

Table C.2: Summary of Replication and Extension of Frequency Variables

Model	Outcome Variable	Round	After x Dairy	After x Draft	After x Goat	After x Pog	After x Pog_y	After x Pog_n
J1	Probability-Weighted Household Dietary Diversity	1-4	0.633***	-0.130	0.404**			
		1-4	0.633***	-0.130	0.404**			
		1-8	0.212	-0.398*	0.449**			
J2		1-4	0.575**	-0.282	0.356	-0.117		
		1-4	0.575***	-0.187	0.346*	-0.094		
		1-8	0.137	-0.473*	0.374*		0.002	-0.282
J1	Household Dietary Diversity	1-4	0.248	-0.564*	0.303			
		1-4	0.301	-0.426	0.309			
		1-8	0.322	-0.894**	0.547**			
K2	Household Dietary Diversity	1-4	0.200***	0.207***	0.008	0.057		
		1-4	0.179***	0.161***	-0.054	0.008		
		1-8	0.182***	0.121***	-0.017		0.034	0.015
K2	Milk consumption (number of days/week)	1-4	1.570***	0.765***	0.685***	0.478***		
		1-4	1.785***	0.620**	0.711***	0.653***		
		1-8	1.421***	0.477*	0.366*		0.770***	0.032
K2	Meat consumption (number of days/week)	1-4	0.036	-0.026	0.339***	0.019		
		1-4	0.031	-0.002	0.287**	-0.110		
		1-8	0.035	0.010	0.321***		0.131	0.018
K2	Cereal consumption (number of days/week)	1-4	-0.003	0.020	-0.002	-0.000		
		1-4	0.001	0.010	-0.008	-0.003		
		1-8	-0.001	-0.008	-0.010		-0.010*	-0.007
K2	Oil consumption (number of days/week)	1-4	0.034	0.024	-0.030	-0.014		
		1-4	0.048**	0.009	-0.046	-0.028		
		1-8	0.030	0.026	-0.006		0.012	-0.014
K2	Sweets/beverages consumption (number of days/week)	1-4	0.189***	0.150**	0.066	0.031		
		1-4	0.158**	0.096	0.043	-0.046		
		1-8	0.125*	0.134	0.093		0.089	-0.006
K3	Feeling poor (=1 if feel relatively worse and =0 if same or better	1-4	-1.360***	-0.694***	-0.339**	0.153		
		1-4	-0.836***	-0.598***	0.053	0.313**		
		1-8	-0.743***	-0.421**	0.051		0.021	0.414***
K3	Food Secure (=1 if feel secure and =0 if feel otherwise)	1-4	0.594***	0.181	0.068	-0.09		
		1-4	0.612***	0.150	-0.043	-0.190		
		1-8	0.193	0.107	-0.124		-0.217*	-0.528***

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Dark Grey row values are original estimates from Jodlowski/Kafle using rounds 1-4.

Light grey values are Cardell replication using round 1-4 data, and white row values are using round 1-8 data

Model J1: $y_{ilt} = \alpha_0 + \sum_l \beta_l A_t T_{il} + \sum_t \gamma_t A_t + \sum_l \delta_l T_{il} + \mu X_{ilt} + FE_i + \varepsilon_{ilt}$

where $A_t T_{il}$ is an interaction between A_t an indicator for after treatment (0 if t = 1, 1 otherwise) and T_{il}, an indicator equal to 1 if household$i$ received species l and 0 if prospective

X_{ilt} are covariates: log weekly total expenditure per capita, household size, dependency ratio, and positive and negative household shocks.

Model J2: Model J1 where Treatment now includes POG households

Model K2: $E(y_{ilt} \mid x_{ilt}, \bar{x_{il}}) = exp(\sum_l \beta_l A_t T_{il} + \sum_t \gamma_t A_t + \sum_l \delta_l T_{il} + \gamma POG_{it} + \lambda Indp_{it} + \pi X + \theta \bar{X})$

X is a covariate vector: household size, number of children 5 or under, age, hh head gender, marital status, number of sheep, number of pigs, and positive and negative shocks

Model K3: $P(y_{ilt} \mid x_{ilt}, \bar{x_{il}}) = \Phi(\sum_{l=1}^{3} \beta_l A_t T_{il} + \sum_{t=2}^{4} \gamma_t A_t + \sum_{l=1}^{3} \delta_l T_{il} + \gamma POG_{it} + \lambda Indp_{it} + \pi X + \theta \bar{X})$

X is a covariate vector: household size, number of children 5 or under, age, hh head gender, marital status, number of sheep, number of pigs, and positive and negative shocks

Table C.3: Baseline characteristics by treatment

	Original	POG	Independent	Prospective	Orig v.Pros	POG v.Pros	Indp v.Pros
Household size	7.406	6.919	5.975	5.731	-1.674***	-1.188**	-0.244
	(2.801)	(2.754)	(2.370)	(2.157)			
Number of kids under 5	1.179	1.270	1.125	1.015	-0.164	-0.255	-0.110
	(1.003)	(0.943)	(1.042)	(0.913)			
Number of kids 6-16	2.396	2.450	2.025	1.776	-0.620**	-0.674**	-0.249
	(1.631)	(1.741)	(1.441)	(1.391)			
Dependency ratio	0.462	0.521	0.483	0.446	-0.016	-0.075*	-0.037
	(0.204)	(0.174)	(0.212)	(0.217)			
Household Head Characteristics							
Education Level	2.509	2.523	2.225	2.687	0.177	0.164	0.462*
	(1.205)	(1.285)	(1.165)	(1.047)			
Gender (1=Female,0=Male)	0.283	0.252	0.325	0.209	-0.074	-0.043	-0.116
	(0.453)	(0.436)	(0.474)	(0.410)			
Marital Status (1=Yes, 0=No)	0.821	0.874	0.825	0.791	-0.030	-0.083	-0.0340
	(0.385)	(0.333)	(0.385)	(0.410)			
Household Assets							
HH durable assets 2012 ZMK	2071.2	1759.3	749.8	1302.5	-768.7	-456.8	552.7**
	(3982.0)	(3885.4)	(630.0)	(1241.4)			
HH durable assets 2012 USD	828.7	703.9	300.0	521.2	-307.6	-182.8	221.2**
	(1593.3)	(1554.6)	(252.1)	(496.7)			
Total Land	3.098	2.843	0.969	2.002	-1.096*	-0.841*	1.034***
	(4.939)	(3.145)	(0.925)	(1.409)			
HH herdsize in TLU	1.377	0.741	0.262	1.233	-0.145	0.491	0.971**
	(1.893)	(1.797)	(0.489)	(2.595)			
Number of cattle	1.208	0.550	0.0250	0.776	-0.431	0.227	0.751**
	(2.211)	(2.177)	(0.158)	(2.058)			
Number of goats	2.500	1.505	0.225	1.224	-1.276*	-0.281	0.999**
	(4.870)	(3.272)	(0.920)	(2.315)			
TV ownership (1=Yes, 0=No)	0.472	0.387	0.100	0.388	-0.084	0.001	0.288***
	(0.502)	(0.489)	(0.304)	(0.491)			
Bicycle ownership (1=Yes,0=No)	0.840	0.820	0.700	0.866	0.026	0.046	0.166
	(0.369)	(0.386)	(0.464)	(0.344)			
Observations	106	111	40	67			

Point estimates are mean; Standard deviations are in parentheses; the last three columns contain the difference between group means and their significance

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table C.4: Replication Outcome Variables at Baseline by Treatment Type

	Original	POG	Independent	Prospective	Orig v. Pros	POG v. Pros	Indp v. Pros
Weekly expenditure per cap 2012 ZMK	31.17	33.90	28.39	45.04	13.87**	11.14*	16.65***
	(19.10)	(28.16)	(18.35)	(30.89)			
Weekly expenditure per cap 2012 USD	12.47	13.56	11.36	18.02	5.551**	4.458*	6.663***
	(7.641)	(11.27)	(7.342)	(12.36)			
Food share as % of expenditure	0.546	0.560	0.619	0.543	-0.003	-0.018	-0.076*
	(0.167)	(0.188)	(0.178)	(0.169)			
ASF share as % of expenditure	0.139	0.142	0.177	0.157	0.018	0.0153	-0.020
	(0.121)	(0.118)	(0.157)	(0.119)			
Weekly Livestock revenue per cap 2012 ZMK	2.809	3.932	1.126	8.378	5.569	4.446	7.252*
	(8.365)	(10.86)	(2.530)	(26.49)			
DDS based on 24hr recall on 13 items	5.783	5.685	5.625	5.627	-0.156	-0.058	0.002
	(1.937)	(1.612)	(1.409)	(1.921)			
Days milk served/week	1.283	1.126	0.725	1.716	0.433	0.590	0.991*
	(2.097)	(2.068)	(1.536)	(2.707)			
Days meat served/week	1.009	1.216	0.775	1.209	0.200	-0.007	0.434*
	(0.941)	(1.404)	(0.832)	(1.274)			
Feeling poor (1=Yes,0=No)	0.632	0.730	0.850	0.866	0.234***	0.136*	0.016
	(0.485)	(0.446)	(0.362)	(0.344)			
Food Secure (1=Yes,0=No)	0.368	0.378	0.325	0.373	0.005	-0.005	0.048
	(0.485)	(0.487)	(0.474)	(0.487)			
Observations	106	111	40	67			

Point estimates are mean; Standard deviations are in parentheses; the last three columns contain the difference between group means and their significance

2012 USD PPP values are using World Bank conversion factor

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

C.1 Replication and Extension of Jodlowski, et.al.

Jodlowski uses a DiD model looking at the trajectories by treatment arm, defined as the type of animal received: goat, dairy cow, draft animal. This strategy does not require randomness in allocation of treatment, but does rely on the assumption that there are no time trends correlated with both selection into treatment and the outcome variables. She defends this assumption based on the lack of significant differences between village baseline characteristics. (LC Note: discuss this?) All specifications include fixed effects and a set of control variables. Standard errors are clustered at the household level, with robust standard errors.

$$y_{ilt} = \alpha_0 + \sum_{l=1}^{3} \beta_l A_t T_{il} + \sum_{t=2}^{4} \gamma_t A_t + \sum_{l=1}^{3} \delta_l T_{il} + \mu' X_{ilt} + FE_i + \varepsilon_{ilt} \tag{9}$$

y_{ilt} is outcome for household i, in species-specific (dairy, draft, goat) treatment group l, in round t

The outcome variables are log weekly expenditure per capita (lnexpendwkpc), total household weekly milk consumption (MilkvalTot), livestock asset value as a proxy for livestock expenditure (Livstkassetval), dietary diversity (hdds), and probability-weighted dietary diversity (phdds). The probability was calculated as: $\sum_{i=1}^{13} \frac{n_i}{7}$ where n is the number of times per week food category i was consumed.

X_{ilt} are time-varying household characteristics including log weekly total expenditure per capita, household size, dependency ratio, and positive and negative household shocks. Dependency ratio is the ratio of total members of the household under 16 to the total number of household members. Household shocks are self-reported and are binary variables equal to 1 if the household has experienced a positive (negative) shock in the past six months, and 0 otherwise. Positive shocks include new job, new business, or other sources of income including gifts. Negative shocks include serious illness, loss of a job, crop failure, theft, robbery, or other losses of income.

$A_t T_{il}$ is an interaction between A_t an indicator for after treatment (0 in round 1, 1 otherwise) and T_{il}, an indicator equal to 1 if household i received species l. Thus β_l is the treatment effect by livestock type.

Replication Results

The results are presented in Table 4. The **odd-numbered columns** are replications of Jodlowski's specification for round 1-4, and the **even-numbered columns** are the same models using all eight rounds of data. Outcomes are household dietary diversity (Columns 1 and 2), probability-weighted household dietary diversity (Columns 3 and 4), log weekly household expenditure per capita (Columns 5 and 6), and total value of milk consumed weekly by the household (Columns 7 and 8.) In all specifications, the control group consists of both prospective and POG households.

Dietary Diversity Outcomes: hdds and phdds

Consistent with Jodlowski, I found significant increases in probability-weighted household dietary diversity (phdds) for households with dairy cows through round 4, although this effect disappeared by round 8. Probability-weighted household dietary diversity (phdds)also increased for goat households and was sustained through round 8. Consistent with Jodlowski's results in rounds 1-4, the impact of draft ownership on both dietary diversity outcomes (hdds and phdds) was negative and significant through round 8. Kafle's model which looks at consumption changes in specific food groups may shed more light on the mechanism driving this decline.

Wealth Outcome: Weekly total expenditure per capita

I was unable to replicate the significant positive impact Jodlowski found on log weekly expenditure per capita (*lntotexpwkpc*) for dairy households, however, I did find significant positive effects for draft and goat households which were sustained through round 8. Consistent with Jodlowski, the Rsquared measure for the model in column (5) is very small.

Nutrition outcome: Value of weekly household milk consumption

Consistent with Jodlowski, I found significant increases in the value of milk consumption for dairy cow households, which were sustained through round 8. The point estimates were very different however. I was unable to replicate the significant effect she found for draft cattle households..

Spillover Effects on POG Households

The results from the regressions which differentiate between prospective and POG households are presented in Table 5. Outcomes are probability-weighted household dietary diversity (*phdds*) in Columns 1 and 2, log weekly household expenditure per capita (*lntotexpwkpc*) in Columns 3 and 4, and livestock asset value in 2012 ZMK (*livstkassetval*) in Columns 5 and 6, which is the variable I thnk Jodlowski renamed ”Livestock expenditure.” Note that livestock asset value was not measured in rounds 2, 3, or 8.

Consistent with Jodlowski I did not find any significant impacts on probability-weighted dietary diversity (*phdds*) or log weekly expenditure per capita (*lntotexpwkpc*) for POG households in rounds 1-4, although there were weakly significant increases in the expenditure variable for POG households through round 8. I was unable to replicate Jodlowski's insignificant impact on livestock assets for POG households through round 4, which leads me to believe the variable is different somehow.

The significance of results for dairy, draft, and goat households in Table 5 compared to Table 4 supports the separation of POG households from prospective households, which will be utilized by Kafle in his replication of Jodlowski's work.

Table C.5: Panel regression on HDDS, Prob DDS and ln per capita expenditure

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	hdds	hdds	phdds	phdds	lntotexp_wkpc	lntotexp_wkpc	Milk_val_TOT	Milk_val_TOT
after_dairy	0.301	0.322	0.633***	0.212	0.185	0.223*	11.27***	6.076***
	(0.309)	(0.293)	(0.184)	(0.190)	(0.114)	(0.125)	(2.157)	(1.794)
after_draft	-0.426	-0.894**	-0.130	-0.398*	0.224*	0.250**	6.046	0.907
	(0.350)	(0.380)	(0.259)	(0.239)	(0.116)	(0.111)	(3.679)	(2.559)
after_goat	0.309	0.547**	0.404**	0.449**	0.212**	0.273***	1.438	-1.415
	(0.266)	(0.261)	(0.184)	(0.180)	(0.0857)	(0.0930)	(1.730)	(1.415)
lntotexp_wkpc	0.658***	0.698***	1.093***	1.091***			7.480***	6.552***
	(0.121)	(0.0806)	(0.0983)	(0.0641)			(1.236)	(0.896)
dratio	-1.141**	-0.387	0.227	0.0191			-4.066	2.362
	(0.521)	(0.288)	(0.468)	(0.201)			(4.439)	(2.423)
hhsize	0.126***	0.0906***	0.211***	0.158***			0.940**	0.760***
	(0.0469)	(0.0262)	(0.0342)	(0.0200)			(0.452)	(0.237)

Standard errors in parentheses

* $p < .10$, ** $p < .05$, *** $p < .01$

Table C.6: Panel regression on Probability DDS, ln per capita expenditure for POG households

	(1)	(2)	(3)	(4)	(5)	(6)
	phdds	phdds	lntotexp_wkpc	lntotexp_wkpc	livstk_asset_val	livstk_asset_val
1.rd	0	0	0	0	0	0
	(.)	(.)	(.)	(.)	(.)	(.)
2.rd	-0.234	-0.136	-0.0971	-0.232***		
	(0.160)	(0.153)	(0.0654)	(0.0694)		
3.rd	0.497***	0.621***	0.0152	-0.146**		
	(0.160)	(0.149)	(0.0611)	(0.0647)		
4.rd	0.206	0.309*	0.126*	-0.0262	76.70	42.68
	(0.176)	(0.167)	(0.0656)	(0.0693)	(235.9)	(178.3)
after_dairy	0.575***	0.137	0.119	0.315**	-220.1	-486.2
	(0.207)	(0.210)	(0.110)	(0.130)	(418.4)	(425.6)
after_draft	-0.187	-0.473*	0.184	0.341***	-17.72	-219.4
	(0.273)	(0.254)	(0.112)	(0.116)	(221.6)	(247.7)
after_goat	0.346*	0.374*	0.164*	0.365***	-927.0***	-1208.7***
	(0.206)	(0.200)	(0.0909)	(0.0992)	(343.6)	(376.7)
after_pog	-0.0948		0.0190		352.0*	
	(0.172)		(0.0755)		(185.0)	
lntotexp_wkpc	1.093***	1.092***			426.1***	326.6***
	(0.0982)	(0.0642)			(160.9)	(92.85)
dratio	0.221	0.0534	-0.0694		-323.7	-131.9
	(0.470)	(0.203)	(0.152)		(606.7)	(215.8)
hhsize	0.211***	0.158***	-0.132***		63.94	59.86**
	(0.0344)	(0.0197)	(0.0115)		(41.75)	(25.98)
pshockh_k	0.100	0.149**	0.0313	0.0694**	-307.0	-42.56
	(0.0986)	(0.0704)	(0.0415)	(0.0313)	(253.5)	(100.9)
nshockh_k	0.0623	-0.0158	0.0228	0.0263	-187.8	24.82
	(0.103)	(0.0665)	(0.0421)	(0.0295)	(208.1)	(75.22)
5.rd		0.944***		-0.211***		-121.7
		(0.145)		(0.0706)		(168.1)
6.rd		1.122***		-0.0968		-17.25
		(0.153)		(0.0690)		(178.4)
7.rd		0.365**		0.372***		-49.11
		(0.153)		(0.0684)		(216.4)
8.rd		-0.0791		0.351***		
		(0.149)		(0.0685)		

C.2 Replication and Extension of Kafle, et. al.

Kafle begin with a replication of Jodlowski's model. His difference-in-differences (DiD) model distinguishes between original, prospective, POG, and independent households, and he also analyzes specific food groups as outcome variables. For the count variables of houshold dietary diversity (*hdds*) and probability-weighted household dietary diversity *phdds*, he uses MLE to estimate a poisson regression combined with the Chamberlin-Mundlak approach. In addition, Kafle estimated the impact of the program on binary subjective poverty measures using a pooled probit model.

1. Difference-in-Difference Model

$$y_{it} = \alpha_0 + \sum_{t=2}^{4} \beta_t Round_t + \sum_{t=2}^{4} \delta_t Original_{it} + \sum_{t=2}^{4} \gamma_t POG_{it} + \sum_{t=2}^{4} \lambda_t Indp_{it} + \Pi X + c_i + \varepsilon_{it} \tag{10}$$

y_{it} is the continuous outcome variable for household i in round t, either log weekly expenditures per capita (total, food, or nonfood) or log livestock weekly revenue per capita (in 2012 ZMK)

$Round_t$ is a dummy for rounds 2,3,4

$Original_{it}, POG_{it}, andIndp_{it}$ are interaction terms between treatment category (Original, POG, Independent) and the $Round_t$ dummy (2-8)

c_i are household level fixed effects, X are control variables including gender and marital status of household head, and the same positive and negative shock indicators used by Jodlowski

Thus δ_t is the treatment effect comparing Original households with Prospective households and γ_t is the combined program and spillover effect on POG households. λ_t is a spatial spillover effect on ineligible independent households compared to Prospective households

Standard errors are clustered at the household level, with robust standard errors.

Replication Results

The results from estimation of the DiD model for original and POG households are included in Table 6, now with independent households and covariates supressed for brevity. The odd-numbered columns in Table 6 are replications of Kafle/Jodlowski's specification for round 1-4, and the even-numbered columns are the same models using all eight rounds of data. Outcomes are log total household weekly expenditure per capita ($totexp$) in Columns 1 and 2, log household weekly food expenditure per capita ($foodexp$) in Columns 3 and 4, log household weekly non food expenditure per capita ($nonfoodexp$) in Columns 5 and 6, and log household weekly livestock revenue per capita ($livstkrev$) in Columns 7 and 8. In all specifications, the control group consists of prospective households. Kafle replicated Jodlowski's specification in separating by livestock type, shown in Table 7, using the same outcome variables and column definitions. Kafle also separated expenditures by consumption group, presented in Table 8.

Expenditure outcomes: per capita weekly food and nonfood expenditure, per capita weekly food expenditure, per capita weekly non food expenditure

Consistent with Kafle, I find significant positive impacts on per capita weekly total expenditures and food expenditures for Original households in the first four rounds (Columns 1 and 3), and for non-food expenditures in round 3 (Column 5), shown in Table 6. These impacts persist throughout all eight rounds for original households (Columns 2,4,6). Consistent with Kafle, I find a significant positive impact on food expenditure for POG households in round 4, which is slightly higher for recipient POG households (POG_y) than non-recipient POG households (POG_n) as shown in Column 4 in Table 6. In rounds 7 and 8, I find significant positive impacts for both types of POG households on total expenditures, food expenditures, and nonfood expenditures, as shown in Columns 2,4, and 6 in Table 6.

In Table 7, Kafle replicates Jodlowski's methodology where "After" represents all rounds after the baseline. He finds positive significant effects on total expenditures and food expenditures for all livestock types of original households, and significant positive effects on nonfood expenditures for draft households through round 4. I am able to replicate all those findings (Columns 1,3,and 5), as well as significant positive impacts on nonfood expenditures for goat and dairy households. Through round 8, positive impacts are seen for all original households in all categories, except for food expenditures for dairy households. Kafle found no impacts on POG households through round 4, however I found positive significant impacts on total expenditure and food expenditures for POG recipient households (POG_y), but not for the non-recipient households (POG_n).

Expenditure outcomes by Category: Rice, Meat, Milk, Oil, Oth(Sweets), Maize Expenditures

In Table 8, Kafle estimates the log value of food expenditures by category in 2012 ZMK per capita per week. The odd-columns are for rounds 1-4, and the even-columns are through round 8. Consistent with Kafle I find significant increases in rice expenditures for draft households (Column 1), sustained through round 8 (Column 2), although of a much smaller magnitude. I also find significant increases in rice expenditures for goat households (Columns 1 and 2). I found significant increases in meat expenditures for draft, goat, and POG households, sustained through round 8 (Columns 3 and 4), while Kafle did not find any increases except for POG households. I found significant increases in milk expenditures for all original and POG households (Columns 5 and 6), whereas Kafle only found increases for dairy and POG households. I found significant increases in oil expenditures for all original and POG households (Columns 7 and 8), whereas Kafle did not. I found significant increases in other expenditures (sweets/beverages) for dairy and goat households (Columns 9 and 10), whereas Kafle only found a significant positive effect for dairy households. I was unable to replicate the significant impact that Kafle found on Maize consumption for Dairy households through round 4 (Column 11.)

Revenue outcomes

Consistent with Kafle, I find significant positive impacts on per capita weekly livestock revenue (*livstkrev*) for dairy and goat households in the first four rounds (Column 7 in Table 6), and this effect persists through round eight (Column 8). The impact on livestock revenue for POG recipient households is weakly significant in rounds 5 and 7 (Column 8).

In Kafle's extension of Jodlowski's model in Table 7, he found positive significant impacts on livestock revenue for dairy cow and draft cattle households through round 4 (Column 7). I was able to replicate those results, although the coefficients were much smaller than Kafle. These effects persisted throughout round 8 (Column 8.) Consistent with Kafle, there were no significant impacts on POG households (Columns 7 and 8).

Table C.7: DiD Estimation including POG and extended to Rd8 (Kafle Table 5)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	totexp	totexp	foodexp	foodexp	nonfoodexp	nonfoodexp	livstkrev	livstkrev
orig_r2	0.245**	0.214**	0.269**	0.239**	0.158	0.153	0.692***	0.693***
	(0.101)	(0.105)	(0.114)	(0.119)	(0.125)	(0.131)	(0.201)	(0.205)
orig_r3	0.295***	0.327***	0.321***	0.336***	0.253**	0.296**	0.786***	0.825***
	(0.097)	(0.100)	(0.115)	(0.122)	(0.119)	(0.125)	(0.209)	(0.215)
orig_r4	0.279***	0.258**	0.351***	0.339***	0.115	0.122	0.527**	0.574**
	(0.106)	(0.115)	(0.111)	(0.117)	(0.142)	(0.155)	(0.225)	(0.234)
orig_r5		0.385***		0.334**		0.367***		1.082***
		(0.113)		(0.136)		(0.136)		(0.298)
orig_r6		0.318***		0.259**		0.400***		0.848***
		(0.122)		(0.126)		(0.149)		(0.271)
orig_r7		0.580***		0.397***		0.748***		0.848***
		(0.121)		(0.139)		(0.151)		(0.275)
orig_r8		0.408***		0.244*		0.672***		0.577**
		(0.127)		(0.139)		(0.156)		(0.286)
pog_r2	0.014		0.095		-0.041		-0.205	
	(0.109)		(0.127)		(0.122)		(0.173)	
pog_r3	0.076		0.101		0.113		-0.065	
	(0.100)		(0.121)		(0.122)		(0.197)	
pog_r4	0.198*		0.348***		-0.031		-0.248	
	(0.116)		(0.124)		(0.148)		(0.210)	
pog_y_r2		-0.133		-0.048		-0.221		-0.455*
		(0.194)		(0.207)		(0.210)		(0.270)
pog_y_r3		0.024		0.013		0.056		-0.325
		(0.140)		(0.153)		(0.182)		(0.254)
pog_y_r4		0.242		0.402**		0.037		-0.365
		(0.159)		(0.163)		(0.189)		(0.251)
pog_y_r5		0.095		0.132		0.058		0.609*
		(0.132)		(0.147)		(0.156)		(0.322)
pog_y_r6		0.167		0.175		0.197		0.184
		(0.123)		(0.131)		(0.152)		(0.274)
pog_y_r7		0.341***		0.343***		0.378**		0.538*
		(0.120)		(0.130)		(0.158)		(0.316)
pog_y_r8		0.363**		0.278*		0.519***		0.212
		(0.140)		(0.148)		(0.175)		(0.324)
pog_n_r2		0.056		0.107		0.040		-0.278
		(0.118)		(0.140)		(0.129)		(0.176)
pog_n_r3		0.130		0.087		0.231*		-0.006
		(0.109)		(0.135)		(0.134)		(0.213)
pog_n_r4		0.151		0.259*		-0.047		-0.196
		(0.135)		(0.144)		(0.176)		(0.242)
pog_n_r5		-0.038		0.097		-0.191		-0.059
		(0.129)		(0.152)		(0.164)		(0.295)
pog_n_r6		0.145		0.188		0.120		-0.053
		(0.153)		(0.159)		(0.200)		(0.263)
pog_n_r7		0.404**		0.471***		0.350*		0.194

Table C.8: DiD Estimation including POG and extended to RD8 (Kafle Table 6)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	totexp	totexp	foodexp	foodexp	nonfoodexp	nonfoodexp	livstkrev	livstkrev
After x dairy	0.252^{**}	0.299^{**}	0.376^{***}	0.247^{*}	0.003	0.317^{**}	1.760^{***}	1.634^{***}
	(0.126)	(0.135)	(0.132)	(0.146)	(0.162)	(0.159)	(0.203)	(0.249)
After x draft	0.298^{**}	0.362^{***}	0.257^{**}	0.225^{*}	0.331^{*}	0.547^{***}	0.731^{***}	0.668^{***}
	(0.121)	(0.112)	(0.130)	(0.119)	(0.175)	(0.180)	(0.192)	(0.195)
After x goat	0.276^{***}	0.389^{***}	0.299^{***}	0.378^{***}	0.218^{*}	0.380^{***}	-0.020	0.279
	(0.099)	(0.103)	(0.114)	(0.115)	(0.125)	(0.124)	(0.199)	(0.221)
After x POG	0.096		0.181^{*}		0.014		-0.174	
	(0.090)		(0.106)		(0.106)		(0.166)	
After x pog_y		0.188^{*}		0.222^{**}		0.173		0.197
		(0.099)		(0.110)		(0.118)		(0.220)
After x pog_n		0.157		0.184		0.151		-0.136
		(0.095)		(0.115)		(0.110)		(0.183)
After x indp	0.180	0.166	0.138	0.136	0.260^{*}	0.267	0.178	0.110
	(0.120)	(0.129)	(0.128)	(0.136)	(0.153)	(0.181)	(0.172)	(0.200)
N	1197	2053	1197	2053	1197	2053	1197	2053
R^2	0.033	0.190	0.053	0.123	0.063	0.185	0.130	0.083

Standard errors in parentheses

Supressed covariates are dummies for round, household head gender, marital status, positive shock, and negative shocks

* $p < .10$, ** $p < .05$, *** $p < .01$

Table C.9: Did Estimation of Consumption Expenditure by Category Results, extended to Rd8 (Kafle Table 7)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Rice	Rice	Meat	Meat	Milk	Milk	Oil	Oil	Oth	Oth	Maize	Maize
After dairy	0.039	-0.028	0.297	0.326	0.822***	0.585***	0.235**	0.265***	0.467***	0.471***	0.145	0.009
	(0.168)	(0.174)	(0.244)	(0.258)	(0.136)	(0.132)	(0.093)	(0.093)	(0.128)	(0.148)	(0.140)	(0.140)
After draft	0.439***	0.318***	0.500**	0.532**	0.290*	0.149	0.148*	0.108	-0.081	0.081	0.051	-0.027
	(0.132)	(0.120)	(0.222)	(0.249)	(0.170)	(0.158)	(0.086)	(0.068)	(0.145)	(0.144)	(0.097)	(0.085)
After goat	0.272**	0.272***	0.742***	0.877***	0.243**	0.128	0.153**	0.187**	0.284**	0.353***	0.039	-0.018
	(0.112)	(0.102)	(0.208)	(0.224)	(0.097)	(0.094)	(0.073)	(0.078)	(0.118)	(0.124)	(0.089)	(0.090)
After POG	0.059		0.524***		0.215***		0.128*		0.044		0.149*	
	(0.122)		(0.177)		(0.076)		(0.065)		(0.102)		(0.084)	
After POG_y		0.019		0.556***		0.313***		0.053		0.106		0.058
		(0.120)		(0.186)		(0.087)		(0.075)		(0.115)		(0.083)
After POG_n		-0.044		0.613***		0.023		0.130*		-0.023		0.092
		(0.127)		(0.194)		(0.085)		(0.076)		(0.119)		(0.082)
After indp	0.131	0.028	0.352	0.472*	0.062	-0.014	0.185**	0.107	0.068	0.009	0.105	0.040
	(0.142)	(0.140)	(0.241)	(0.272)	(0.115)	(0.103)	(0.086)	(0.088)	(0.150)	(0.159)	(0.124)	(0.120)
N	1197	2053	1197	2053	1197	2053	1197	2053	1197	2053	1197	2053
R^2	0.024	0.021	0.236	0.152	0.079	0.040	0.025	0.255	0.061	0.111	0.022	0.142

Standard errors in parentheses

* $p < .10$, ** $p < .05$, *** $p < .01$

Dependent variables are log of food expenditures in Kwacha per capita per week

Covariates suppressed include round, HH head gender, marital status, positive/negative shocks

2. Correlated Random Effects Model (Poisson)

Kafle lists the following equation as his "Equation 2"

$$E(y_{it} \mid x_{it}, \bar{x_i}) = exp(\sum_{t=2}^{4} \beta_t Round_t + \sum_{t=2}^{4} \delta_t Original_{it} + \sum_{t=2}^{4} \gamma_t POG_{it} + \sum_{t=2}^{4} \lambda_t Indp_{it} + \pi X + \theta \bar{X}) \tag{11}$$

Here, y_{it} are the count outcome variables, including household dietary diversity and consumption frequency of specific food groups, for household i in round t. Consumption frequency is measured as the number of days the food item is consumed in the past week. The covariate vector X includes household size, number of children 5 or under, age, gender, marital status of household head, number of sheep, number of pigs, and dummy variables for the same positive and negative shock as used in equations (1) and (2). $\bar{X}$ is the time-invariant mean of the control variables. Estimation of the pooled poisson model yields coefficients which can be interpreted as semi-elasticities: δ_t) is the percent increase in the outcome variable for the treatment group (Original) compared to the control group (Prospectives)

However, the table of results (Kafle Table 8), reproduced below as Table 9, indicates that he actually followed Jodlowski's specification, with the new assumption on the distribution of y_{it} and the inclusion of independents:

$$E(y_{ilt} \mid x_{ilt}, \bar{x_{il}}) = exp(\sum_{l=1}^{3} \beta_l A_t T_{il} + \sum_{t=2}^{4} \gamma_t A_t + \sum_{l=1}^{3} \delta_l T_{il} + \gamma POG_{it} + \lambda Indp_{it} + \pi X + \theta \bar{X}) \tag{12}$$

Replication Results

The results of Kafle's extension of Jodlowski's model are presented in Table 9. Odd columns represent estimation through round 4, while even columns represent estimation through round 8. The outcome variables are Household dietary diversity based on 24 hour recall of 13 food groups (*hdds* in Columns 1 and 2, number of days last week milk was consumed by the household (*milkdays*) in Columns 3 and 4, number of days last week meat was consumed (*meatdays*) in Columns 5 and 6, number of days last week cereal was consumed by the household (*milkdays*) in Columns 7 and 8, number of days last week oil was consumed (*meatdays*) in Columns 9 and 10, and number of days last week sweets or beverages were consumed by the household (*milkdays*) in Columns 11 and 12.

Consistent with Kafle, I find positive significant impacts on dietary diversity for original dairy and goat recipient households (Column 1). These effects are persistent through round 8 (Column 2). No effects on dietary diversity are found for POG households in Columns 1 or 2. Consistent with Kafle, I find positive impacts on the number of milk days consumed for all original households and POG households. (Columns 3 and 4) As expected, only POG households that received livestock saw positive impacts on the frequency of milk consumption. (Column 4) Consistent with Kafle, I found a positive impact on meat consumption by meat goat households, and this effect persisted through round 8. (Columns 5 and 6) Consistent with Kafle, I found a positive impact on the frequency of beverage consumption by dairy households, and this effect persisted through round 8. (Columns 11 and 12)

Table C.10: Estimation of Consumption Frequency with extension to Rd 8 (Kafle Table 8)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	hdds	hdds	milk_days	milk_days	meat_days	meat_days	cereal_days	cereal_days	oil_days	oil_days	bev_days	bev_days
After x dairy	0.179***	0.182***	1.785***	1.421***	0.031	0.035	0.001	-0.001	0.048**	0.030	0.158**	0.125*
	(0.035)	(0.029)	(0.201)	(0.218)	(0.147)	(0.096)	(0.010)	(0.005)	(0.021)	(0.020)	(0.072)	(0.067)
After x draft	0.161***	0.121***	0.620**	0.477*	-0.002	0.010	0.010	-0.008	0.009	0.026	0.096	0.134
	(0.047)	(0.033)	(0.287)	(0.247)	(0.175)	(0.133)	(0.006)	(0.008)	(0.033)	(0.020)	(0.088)	(0.083)
After x goat	-0.054	-0.017	0.711***	0.366*	0.287**	0.321***	-0.008	-0.010	-0.046	-0.006	0.043	0.093
	(0.041)	(0.031)	(0.221)	(0.204)	(0.115)	(0.097)	(0.011)	(0.006)	(0.033)	(0.024)	(0.073)	(0.066)
After x pog	0.008		0.653***		-0.110		-0.003		-0.028		-0.046	
	(0.033)		(0.170)		(0.099)		(0.008)		(0.023)		(0.057)	
After x pog_y		0.034		0.770***		0.131		-0.010*		0.012		0.089
		(0.027)		(0.198)		(0.084)		(0.006)		(0.018)		(0.060)
After x pog_n		0.015		0.032		0.018		-0.007		-0.014		-0.006
		(0.028)		(0.176)		(0.089)		(0.005)		(0.023)		(0.060)
After x indp	-0.103**	-0.115***	0.081	-0.311	-0.311*	-0.263**	-0.009	-0.010	-0.028	-0.036	-0.024	-0.078
	(0.045)	(0.034)	(0.369)	(0.324)	(0.165)	(0.113)	(0.013)	(0.008)	(0.035)	(0.033)	(0.083)	(0.073)
N	1178	2035	1179	2034	1179	2035	1179	2035	1179	2035	1179	2035

Standard errors in parentheses

Supressed covariates include HH head gender, marital status, education, hhsize, number of kids under 5, number of sheep, pigs, chickens, and positive/negative shocks

* $p < .10$, ** $p < .05$, *** $p < .01$

3. Correlated Random Effects Model (Probit)

$$P(y_{it} \mid x_{it}, \bar{x_i}) = \Phi(\sum_{t=2}^{4} \beta_t Round_t + \sum_{t=2}^{4} \delta_t Original_{it} + \sum_{t=2}^{4} \gamma_t POG_{it} + \sum_{t=2}^{4} \lambda_t Indp_{it} + \pi X + \theta \bar{X}) \tag{13}$$

Here $y_i t$ represent the binary outcome variables which are subjective measures of poverty and food security status. This model assumes that the unobserved effect c_i is normally distributed and correlated with the control variables X_{it}, which are the same set as in Equation (3). The interpretation of the coefficient of δ_t is the predicted probability of treatment (original) households reporting the outcome of interest compared to the control group (prospectives.)

Similarly to the poisson estimation, the table of results (Kafle Table 9, reproduced below as Table 10, indicates that he actually followed Jodlowski's specification, with the new assumption on the distribution of y_{it} and the inclusion of independents:

$$P(y_{ilt} \mid x_{ilt}, \bar{x_{il}}) = \Phi(\sum_{l=1}^{3} \beta_l A_t T_{il} + \sum_{t=2}^{4} \gamma_t A_t + \sum_{l=1}^{3} \delta_l T_{il} + \gamma POG_{it} + \lambda Indp_{it} + \pi X + \theta \bar{X}) \tag{14}$$

Replication Results

The results of Kafle's extension of Jodlowski's model are presented in Table 10. Odd columns are through round 4 and even columns are through round 8. The outcome variables are food security ($food\_secure$) in Columns 1 and 2, which is a binary variable equal to 1 if the household feels more food secure than six months ago, and 0 if not, and feeling poor (*needy*) in Columns 3 and 4, which is a binary variable equal to 1 if the household feels relatively worse than six month earlier, and 0 if the household feels the same or better.

Consistent with Kafle, I find positive significant impacts on food security for dairy households (Column 1), that are not persistent through round 8 (Column 2). I also find significant negative impacts on POG household food security through round 8 (Column 2). Consistent with Kafle, I find a decrease in the probability of dairy and draft households feeling poor compared to prospectives through both round 4 and round 8 (Columns 3 and 4). I am unable to replicate his results for goat or POG households. I find that the probability of POG households feeling poor increased through both rounds 4 and 8, attributable to POG households that had not yet received animals. (Columns 3 and 4)

Table C.11: Kafle Alternative Poisson Model Results extended: Table 9

	(1) food_secure	(2) food_secure	(3) needy	(4) needy
After x dairy	0.612***	0.193	-0.836***	-0.743***
	(0.202)	(0.149)	(0.198)	(0.165)
After x draft	0.150	0.107	-0.598***	-0.421**
	(0.233)	(0.172)	(0.227)	(0.190)
After x goat	-0.043	-0.124	0.053	0.051
	(0.173)	(0.129)	(0.174)	(0.140)
After x POG	-0.190		0.313**	
	(0.148)		(0.150)	
After x POG_y		-0.217*		0.021
		(0.125)		(0.139)
After x POG_n		-0.528***		0.414***
		(0.136)		(0.144)
After x indp	-0.453**	-0.605***	0.370*	0.543***
	(0.213)	(0.159)	(0.212)	(0.169)
N	1180	2039	1180	2039

Standard errors in parentheses

* $p < .10$, ** $p < .05$, *** $p < .01$

Supressed covariates include HH head gender, marital status, education, hhsize, number of kids under 5, number of sheep, pigs, chickens, and positive/negative shocks