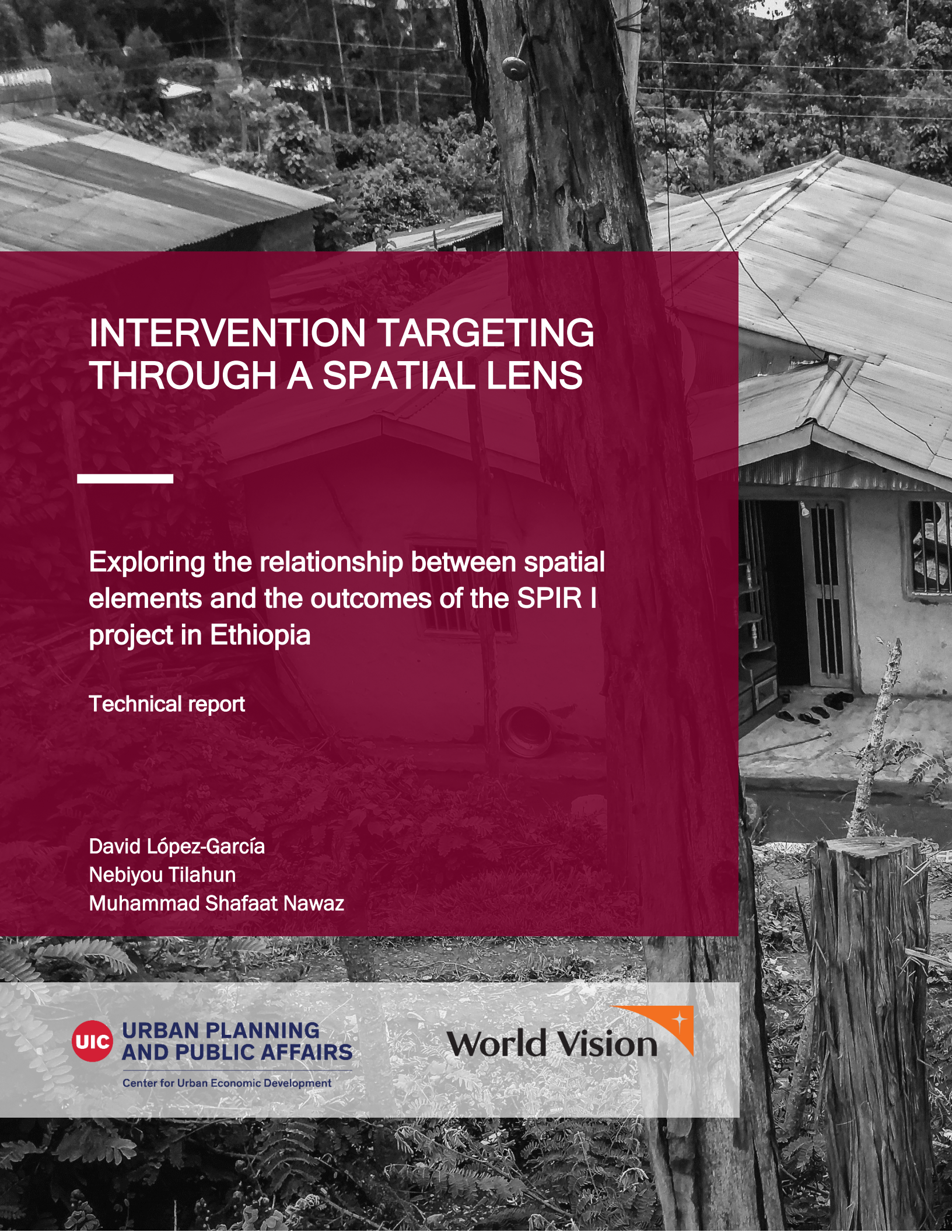

INTERVENTION TARGETING THROUGH A SPATIAL LENS

Exploring the relationship between spatial elements and the outcomes of the SPIR I project in Ethiopia

Technical report

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Abstract

Understanding the role of space in development interventions is essential, as there is reason to believe spatial attributes may influence program outcomes. This study assesses the extent to which proximity and/or access to spatial features such as markets, concentrations of economic activity, access to governmental services, and critical infrastructure such as roads, hospitals, or water play a role in the success of programs' targeting. By analyzing the case of World Vision's Strengthen PSNP4 Institutions and Resilience (SPIR I) program in Ethiopia, we evaluate the relationship between spatial variables broadly and the positive effects of the programs' treatments. The project is guided by the following research questions: Do treatments still effectively influence SPIR I program outcomes when spatial variables are controlled for? How did the SPIR I program treatment interventions interact with the spatial characteristics of the intervention regions to affect outcomes? What are the implications of these findings for targeting in development interventions? Using secondary data from an experiment designed by the International Food Policy Research Institute (IFPRI) titled "Impact evaluation of the Strengthen PSNP4 Institutions and Resilience (SPIR I)", we estimate three separate linear mixed effects models, one for each outcome variable of interest: women empowerment, nutrition, and livelihoods. The models include a random effect to account for unobserved heterogeneity between Kebele groups (spatial units composed of contiguous Kebeles) in which the treated households are nested. In addition, each model accounts for treatments, household and spatial covariates, and interactions between treatments and spatial variables. The study's main finding is that spatial context can affect program outcomes in both unobservable and observable ways. First, for all three outcomes of interest, we find that unmeasured place-based factors help explain variation in outcomes even after controlling for observed spatial covariates. Second, observed spatial covariates affect some outcomes. For example, we find that the effectiveness of livelihood interventions varied with a household's distance to market. On the other hand, treatment effects on women's empowerment and nutrition were not sensitive to the spatial variables we examined.

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1. Introduction

Effective targeting in development interventions is critical to increasing the relevance and efficacy of programs (Grosh et al., 2022; Saqalli et al., 2011). Ineffective targeting can result in misalignments with the local needs, leading to unsustainable outcomes after the program ends. Placement and eligibility of programs are often driven solely by social and economic factors (Coady et al., 2004; Saqalli et al., 2011; Tumusiime & Matotay, 2014). However, research suggests that the spatial characteristics of a place can have an influence, too. A few studies have assessed the relationship between targeting and spatial factors, with many of them addressing topic-specific interventions such as health (Meyer-Rath et al., 2018), livelihoods (Jakobsen, 2013), and food insecurity (Mathenge et al., 2020).

Understanding the role of space in development interventions is essential, as there is reason to believe spatial attributes influence program outcomes. For example, a study about targeting resource-poor smallholder farmers for improving agribusiness showed that distance to the market is a critical determinant of their involvement in agribusiness (Mathenge et al., 2020). Another study found that farmers' adaptive capacities to the changing rural environments were significantly associated with their spatial neighbors' decisions (Lim et al., 2021). Spatial endowments can either hinder or enhance the effectiveness of policy interventions, like those aimed at reducing food insecurity (Mathenge et al., 2023). Such studies argue for the critical value of exploring development interventions with a spatial lens to ensure optimal targeting within a specific local context for better outcomes.

Against this backdrop, this study seeks to examine the relationship between spatial elements and outcome variables of World Vision's completed Strengthen PSNP4 Institutions and Resilience (SPIR I) program in Ethiopia (Alderman et al., 2021). Specifically, we assess the extent to which proximity and/or access to spatial features such as markets, concentrations of economic activity, access to governmental services, and critical infrastructure such as roads, hospitals, or water play a role in the success of programs' targeting. We aim to evaluate the relationship between spatial variables broadly and the positive effects of the programs' treatments on outcome variables, thus enhancing the understanding of the role of space in mediating the effects of development interventions.

The study proposes a multilevel analysis of three outcomes of interest: a) women's empowerment, b) women's nutrition, and c) households' livelihoods.

The project was guided by the following overarching research question:

- How do the effects of SPIR I treatments on program outcomes vary depending on spatial attributes?

This question was answered through the following sub-questions:

- How do treatments influence SPIR I program outcomes when spatial variables are controlled for?
- How did the SPIR I treatments interact with spatial variables to affect program outcomes?
- What are the implications of these findings for existing literature and for targeting in development interventions?

These questions are designed to critically examine whether outcomes of interest are affected by spatial factors related to the SPIR I program. Our approach controls for both observed spatial variables and unobserved spatial factors at larger geographic units within which households are located.

The study's main findings are as follows: first, unobserved spatial factors help explain some of the outcome variation for all three outcomes of interest. This means that households in certain kebele groups (a grouping of contiguous kebeles) do better or worse as a group due to unobserved factors. This remains true even when we control for spatial covariates in the models. Second, the effect of treatments is robust to the inclusion of spatial variables in the women's empowerment and nutrition models. The effects of the treatment arms, as compared to those of the control treatment group, remain stable. In the nutrition model, while parameter estimates remain stable, the statistical significance of one treatment arm weakens when measures of spatial variables are introduced. No spatial variables are significant in the women's empowerment model, and except for access to piped water, all spatial factors are not statistically significant in the nutrition model. In the livelihood model, the treatment arms with enhanced livelihood interventions are significant without interactions. After introducing spatial interactions, we show that distance to markets modifies how treatments work – in this case, livelihood interventions are more effective in areas that are farther away from markets. This effect is hidden when no spatial interaction is modeled. In sum, spatial factors influence outcomes, but not uniformly across domains. While distance to markets and infrastructure access did not significantly affect women's empowerment or nutrition outcomes, they were important in shaping livelihoods, particularly when interacting with treatment types. We conclude that development interventions never occur in a vacuum – where a household is located in relation to spatial factors can matter for program outcomes.

This report is organized as follows. Section 2 presents an overview of existing literature about the relationship between targeting development interventions and the spatial characteristics of where implementation occurs. Section 3 describes the study's methodology and the process through which the team of researchers developed the indicators needed for the study. Section 4 presents the main results of the spatial econometric analysis. Section 5 concludes this report and develops the recommendations for future targeting efforts.

2. Review of relevant literature

We derived two main takeaways from our literature review. First, the interaction between targeting in development interventions and spatial factors remains understudied. Second, the initial characteristics or endowments of target populations prior to development interventions play a critical role in a program's success (Lim et al., 2021; Mathenge et al., 2020, 2023; Oumer & de Neergaard, 2011; Saqalli et al., 2011; Tumusiime & Matotay, 2014). Several studies have looked at targeting development interventions through a spatial lens. Nevertheless, these studies are not focused on evaluating the relationship between targeting and the effectiveness of programs. Some studies have been focused on inequalities in the spatial distribution of development aid (Briggs, 2018), the efficacy of strategies (Bigman & Fofack, 2000) and the effectiveness of targeting methods (Coady et al., 2004; Grosh et al., 2022) at different spatial scales, and the spatial determinants of participation in development programs (Mathenge et al., 2020). Scholars have also proposed spatial analysis for welfare-maximizing targeting (Garbero et al., 2023), identified hotspots to guide targeting towards specific territories (Angaw et al., 2021), and developed spatial models to optimize resource allocation in selecting target populations (Meyer-Rath et al., 2018).

A few studies do focus on targeting and the effectiveness of programs, but their methodologies are seldom based on geospatial analysis. Tumusiime & Matotay (2014) conducted a qualitative study about the effectiveness of agricultural assistance programs in Tanzania and found that farmers with prior access to suitable land are more likely to respond positively to intervention programs than those lacking such access. In a study of rural development interventions in Nigeria, Saqalli et al (2011) employed agent-based modeling and found that the success of such interventions is closely tied to the presence of prior agroecological, social, and economic capacities within communities. In a study of asset distribution in Buthan, Jakobsen (2013) employed asset mapping and found that spatial inequalities in the distribution of human, agricultural, locational, financial, and physical capital can influence policy interventions' effectiveness in developing adaption strategies. A study by Lim et al (2021) about the uptake of agriculture adaptation strategies in Africa and Asia estimated spatial effects and found that neighboring farmers significantly influence the selection of adaption choices.

2.1. Determinants of success or failure in development interventions.

Our literature review allowed us to identify five different analytical categories of determinants of success or failure of targeting in development interventions: (1) access to infrastructure, (2) proximity to economic agglomerations, (3) the natural environment attributes, (4) relational resources, and (5) household assets. The first two categories of the typology are eminently spatial, while the last three categories are pre-existing endowments that target populations have prior to development interventions.

The category *access to infrastructure* involves the physical distance and/or accessibility of target populations to an array of productive and reproductive infrastructure that supports and complements the implementation of development interventions. For instance, the literature has identified that distance to the closest paved road, road density, as well as distance to the nearest water source, hospital, or veterinary facility, all play a role in the outcomes of development interventions (Benson et al., 2005; Jakobsen, 2013; Kurz et al., 2023; Mathenge et al., 2020, 2023; Okwi et al., 2007).

The category *proximity to economic agglomerations* relates to the physical distance between target populations and nodes of economic activity. For example, there is ample agreement in the literature

about the influence of distance or travel time to food markets (Benson et al., 2005; Jakobsen, 2013; Kruseman et al., 2006; Mathenge et al., 2020, 2023; Okwi et al., 2007; Oumer & de Neergaard, 2011). Studies have also highlighted the role of distance and travel time to towns, municipalities, and cities (Okwi et al., 2007), to district centers (Jakobsen, 2013), and population density (Benson et al., 2005; Kruseman et al., 2006; Okwi et al., 2007).

The category of *relational resources* comprises an array of resources and support that target populations receive from their communities. Scholars have looked at participation in cooperatives (Kruseman et al., 2006) and farming associations (Lim et al., 2021; Mathenge et al., 2020). Access to various sources of credit (Jakobsen, 2013; Kruseman et al., 2006; Lim et al., 2021; Mathenge et al., 2020, 2023), weather information (Lim et al., 2021), hybrid seeds (Mathenge et al., 2020; Oumer & de Neergaard, 2011) as well as modern agriculture technologies and agricultural extension services (Mathenge et al., 2023). Other relevant relational resources include participation in irrigation systems (Haile et al., 2022; Kruseman et al., 2006), government and NGO intervention (Lim et al., 2021; Mathenge et al., 2020; Oumer & de Neergaard, 2011), and availability of a pool of labor (Lim et al., 2021).

The category *natural environment attributes* include aspects related to the natural environment of the places where implementation takes place that can influence the programs' outcomes. Here, existing literature highlights several characteristics of soil such as its fertility, degradation, elevation, and steepness (Benson et al., 2005; Kruseman et al., 2006; Mathenge et al., 2020; Okwi et al., 2007; Oumer & de Neergaard, 2011; Saqalli et al., 2011; Tittonell et al., 2005; Tumusiime & Matotay, 2014). There is ample attention to the role of water such as rainfall characteristics (Benson et al., 2005; Haile et al., 2022; Kruseman et al., 2006; Mathenge et al., 2020; Okwi et al., 2007; Saqalli et al., 2011), presence of flooding (Benson et al., 2005; Haile et al., 2022) and drought (Haile et al., 2022), and overall access to sources of water (Palmer-Jones & Sen, 2006; Saqalli et al., 2011). There is also discussion about the prevalence of pests and diseases in the program outcomes (Kurz et al., 2023; Mathenge et al., 2020, 2023).

The category of *household assets* involves a series of pre-existing resources that target populations have at their disposal before development interventions. For example, studies have looked at several kinds of capital, such as human capital, production and non-production-related assets, heads of livestock owned, land ownership and tenure, and farm size (Jakobsen, 2013; Lim et al., 2021; Mathenge et al., 2020, 2023; Oumer & de Neergaard, 2011; Saqalli et al., 2011; Tumusiime & Matotay, 2014). Other household assets include farming experience, agricultural training and skills, experience dealing with a climate crisis, having a bank account, and availability of family labor (Lim et al., 2021; Mathenge et al., 2020, 2023). There is also attention to monetary funds from an array of sources, such as receiving public transfers, remittances, income from non-agricultural employment, income from renting land or machinery, and family savings (Haile et al., 2022; Jakobsen, 2013; Lim et al., 2021; Mathenge et al., 2020, 2023; Oumer & de Neergaard, 2011).

The last category is *other control variables*, which includes a series of variables identified by the literature that might be playing a role in the outcomes of development interventions but are outside the above five categories. We will consider these as control variables, and include gender and sex ratio, dependency ratio, female-headed households, age of household head, household size, and presence of armed conflict (Benson et al., 2005; Haile et al., 2022; Lim et al., 2021; Mathenge et al., 2020).

Our proposed typology will inform the specification of the spatial econometric models developed in this study. As mentioned above, we are interested in exploring the influence of spatial factors on three outcomes of interest: a) women's empowerment through poultry ownership, b) women's nutrition, and c) households' livelihoods. In general, the models assess how spatial variables from the categories (1) access to infrastructure, (2) proximity to economic agglomerations, and (3) relational resources interact with the SPIR I treatments to influence the outcome variables while controlling for variables from categories (4) natural environment attributes, (5) household assets, and (6) other control variables.

2.2. Intervention outcomes: women's empowerment, women's nutrition, and livelihoods

Understanding the impacts of livelihood and nutrition interventions on women's empowerment, nutritional outcomes, and household livelihoods requires engaging with a diverse body of literature. The fields of development economics, rural sociology, and agricultural policy have emphasized the importance of asset accumulation, behavior change communication, and the spatial context of interventions as key factors shaping program success.

2.2.1 Women's empowerment. Direct asset transfer programs have significantly enhanced women's control over productive resources, a key dimension of women's empowerment. Theories of empowerment stress that access to and control over productive assets can alter women's bargaining positions within households and communities (Agarwal, 1997). Through a multi-country study of "graduation" programs, Banerjee et al. (2015) demonstrated that direct asset transfers, like livestock or poultry, and training can substantially improve women's control over productive assets, income, and psychosocial status. Nevertheless, researchers also highlight the role of context-specific dynamics, such as local social norms, community-based support structures, and collective institutions, in shaping the success of empowerment interventions (Agarwal, 1997; Meinzen-Dick et al., 2011).

There is also literature emphasizing the role of knowledge and behavior change in shifting gender dynamics (Meinzen-Dick et al., 2011) and suggesting the integration of multi-sectoral approaches (Hashemi & Rosenberg, 2006). However, research has also highlighted the limitations of informational or behavioral interventions when not paired with material support. Recent critiques argue that "soft" interventions like information and training without economic levers may struggle to transform women's control over tangible resources substantially (Kabeer, 1999). Theories of "catch-up effects" argue that empowerment through asset accumulation is particularly potent for households at the very bottom of asset distributions, wherein the poorest or most asset-deprived households benefit most from targeted interventions (Banerjee et al., 2015; Hashemi & de Montesquiou, 2024). Regarding spatial elements, conventional theories do emphasize market access as a precondition for rural empowerment (Rao & Qaim, 2011).

2.2.2. Women's nutrition. There is agreement that nutrition-sensitive programming, particularly behavior change communication and direct nutrition interventions, can lead to measurable improvements in women´s diet (Meinzen-Dick et al., 2011; van den Bold et al., 2013). According to van den Bold et al. (2013), women's empowerment is an important pathway to better nutrition outcomes, but empowerment alone does not guarantee improvements in dietary diversity or nutrition unless accompanied by access to resources and knowledge. The role of small livestock, particularly poultry, has been frequently highlighted as a promising strategy to enhance dietary diversity. Poultry ownership offers direct access to nutrient-dense animal-source foods, particularly for women, while also serving as a relatively accessible entry point into asset accumulation (Meinzen-Dick et al., 2011).

2.2.3 Livelihoods. Prior research has found that cash and asset transfers coupled with capacity-building can successfully enhance household assets and productive capacities (Berhane et al., 2014; de Montesquiou et al., 2014). Wiggins and Proctor (2001) argue that location profoundly shapes livelihood opportunities, noting that rural areas distant from economic centers face unique constraints that require tailored development strategies. This resonates with more recent critiques advocating for spatially differentiated programming, recognizing that remoteness can exacerbate vulnerabilities that require targeted compensatory strategies (Beegle et al., 2018). Beegle et al. (2018) call for a deeper understanding of how spatial heterogeneity affects social safety net outcomes, arguing that uniform program designs may fail to reach the most marginalized if they do not account for remoteness, infrastructure deficits, or variations in service quality.

3. Methods and data

This study uses secondary data from an experiment designed by the International Food Policy Research Institute (IFPRI) titled "Impact Evaluation of the Strengthen PSNP4 Institutions and Resilience (SPIR I)." The IFPRI conducted an experimental, quantitative impact evaluation designed to measure the causal impact of the SPIR I project in Ethiopia. The research uses the proprietary SPIR I dataset and publicly available geospatial datasets from the United Nations Office for the Coordination of Humanitarian Affairs and Open Street Maps to explore the relationship between spatial elements and three outcomes of interest of the SPIR I intervention: a) women's empowerment through poultry ownership, b) women's nutrition, and c) households' livelihoods. In what follows, we explain the sample size, the treatment arms, the sample distribution, our general approach to econometric modeling, and the spatial variables, outcome variables, and control variables that we calculated for this study.

3.1 Sample size

The proprietary SPIR I dataset includes data on 3,912 households. There are 126 households in the dataset with missing home location coordinates. This means that this study is based on a sample of 3,786 households for which coordinates information is available.

3.2 Treatment arms

All the households in the sample were beneficiaries of the Productive Safety Net Programme (PNSP4). A subset of households received combinations of SPIR livelihoods (L) and nutrition (N) activities and enhanced livelihood (L*) and nutrition (N*) activities.

Summary of Intervention arms:

- **Intervention L:** SPIR livelihood activities: starting Village Economic and Social Associations (VESAs), financial literacy training, agriculture and livestock value chain development, home gardening and forage production.
- **Intervention L*:** SPIR livelihoods activities plus (i) social analysis and action (SAA) to improve women's access to markets, (ii) aspirations promotion activities in randomly selected kebeles (subdistricts), and (iii) targeted poultry or cash livelihood transfers.
- **Intervention N:** SPIR nutrition activities: Nutrition Behavior Change Communication (BCC); WASH activities.
- **Intervention N*:** SPIR nutrition activities plus (i) Timed and Targeted Counseling (TTC) (more intensive nutrition BCC), (ii) Community-based Participatory Nutrition Promotion (CPNP), (iii) male engagement in BCC, and (iv) Interpersonal Therapy in Groups (IPT-G) interventions for women screened for depression (provided after the midline survey), all supported by a Community Health Facilitator (CHF).

The treatment arms in the clustered randomized controlled trial (RCT) conducted by Alderman et al. (2021) are integrated combinations of L, L*, N, and N*, as follows:

- The households assigned to Treatment 1 (T1) were given both enhanced livelihood and enhanced nutrition benefits (L* + N*). There were 949 such households in the sample.
- The households assigned to treatment 2 (T2) were given enhanced livelihood benefits and basic SPIR nutrition activities (L* + N). There were 970 such households in the sample.
- Households assigned to treatment 3 (T3) were given basic SPIR livelihoods activities and enhanced nutrition benefits (L + N*). There were 945 such households in such sample.
- The remaining 922 households from the sample were not given SPIR benefits, becoming the control group (C: PNSP4 only).

The sample is fairly distributed across control group C and the three treatment arms, T1, T2, and T3 (Table 1).

Table 1. Treatment arms in the sample

T1: L* + N*	T2: L* + N	T3: L + N*	C: PNSP4 only
949	970	945	922

The * indicates the kinds of enhanced benefits given to households.

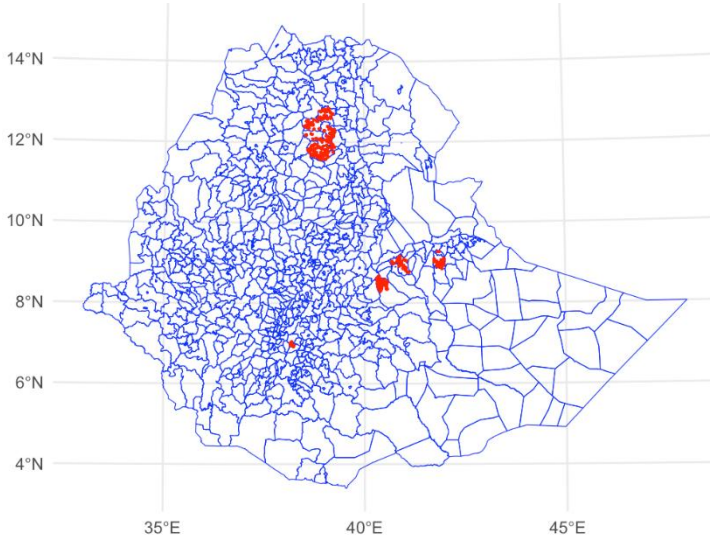
3.3 Sample distribution

Ethiopia is administratively divided into regions, zones, woredas, and kebeles. There are 12 regions in the country. The SPIR I dataset includes a sample of households from two Ethiopian regions, Amhara and Oromia. There are 2,156 sample households from the Amhara region and 1,630 from the Oromia region. The sample includes households from 13 Woredas, seven in the Amhara region and six in the Oromia region. At the Woreda level, the distribution of households varies from minimum 38 households in Kurfachelle Woreda of the Oromia region to the highest number of 753 households from Daro Lebu Woreda of the Oromia Region (Table 1). On average, there are 291 households in the sample from each Woreda.

Table 1. Households in Woredas

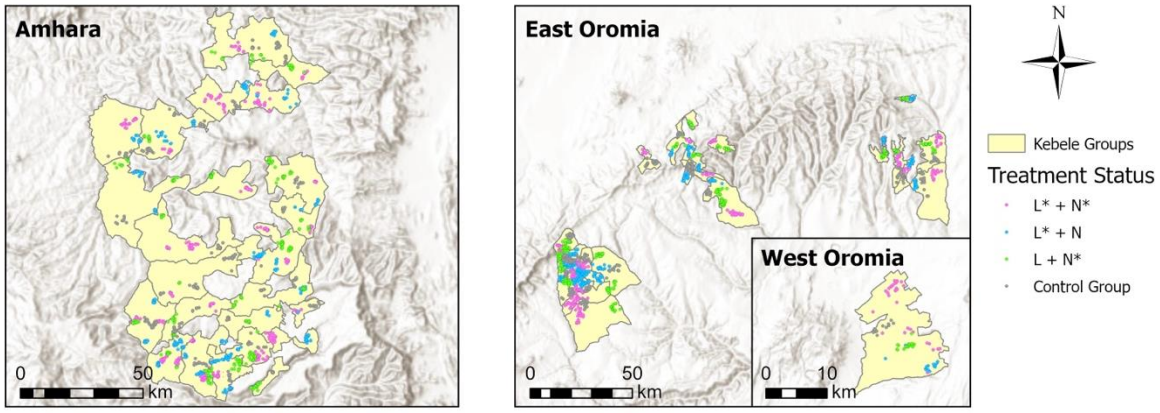
No.	Region	Woreda	Households
1.	Amhara	Bugna	94
2.	Amhara	Dahena	306
3.	Amhara	Gaz Gibla	147
4.	Amhara	Lasta	317
5.	Amhara	Meket	695
6.	Amhara	Sekota	301
7.	Amhara	Wadla	296
8.	Oromia	Chiro	234
9.	Oromia	Daro Lebu	753
10.	Oromia	Gemechis	223
11.	Oromia	Grawa	295
12.	Oromia	Kurfachelle	38
13.	Oromia	Siraro	87

Map 1. Spatial distribution of households in the sample



Households were surveyed in 188 Kebeles, with an average of 20 households from each Kebele. The minimum number of households for any kebele is 6, while the maximum is 23. A table with the number of households surveyed in each Kebele can be found in Annex 1 of this document. Map 1 shows the spatial distribution of households in the dataset. The blue lines represent Woreda boundaries, while the red dots represent households in the sample.

Map 2: Spatial distribution of surveyed households by treatment status



Map 2 shows the spatial distribution of households in the sample by treatment status. In SPIR I, treatments were randomly assigned to Kebeles and all households within a Kebele received the same treatment. Kebeles are nested in Woredas which are larger administrative units. The 188 Kebeles in this study are contained in 13 Woredas. For the analysis here, we group Kebeles into 47 intermediate sized geographic units based on contiguity that we call *Kebele groups.* These geographies on average contain 4 Kebeles that are proximate to one another and include households that received different treatment arms. As compared to Woredas, each Kebele group is small enough that the Kebeles it contains share underlying similarities on account of being neighbors. The details of how the Kebele groups are created is described in Annex 2.

3.4 Approach to econometric modeling

The analysis involved a panel dataset with measurements on outcomes of interest pre- and post-treatment at the household level. We estimated three models each focusing on one outcome of interest: women's empowerment, nutrition, and livelihoods. Each model was specified as a **linear mixed effects model with a random intercept at the kebele-group level.** Because households in the same kebele-group share geography, infrastructure, and social context, we expect their outcomes to be correlated. The random intercept for each kebele-group captures this correlation and any spatial heterogeneity not explained by observed covariates. Although we include several spatial variables in our model such as distance to markets and access to infrastructure, these are not exhaustive, and the random effects absorb the remaining spatial effects. Ignoring this clustering would understate standard errors. The fixed effects in the model allow us to estimate average treatment impacts on the change in outcome and its associations with measured spatial variables and initial endowment for each household. We also include interaction terms between treatments and spatial covariates to estimate how treatment effects vary with measured spatial variables.

We used the following general model setup, which was applied separately to the three outcomes of interest, which we represent here as O.

$$\Delta O_{ij} = \beta_0 + \beta_k T_{k,ij} + \beta_3 H_{ij} + \beta_4 S_{ij} + \gamma_k (T_{k,ij}.S_{ij}) + O_{i0} + \upsilon_j + \epsilon_{ij}$$

Where *i* and *j* index the household and kebele group respectively, and:

- ΔO: difference in outcome of interest for household *i* in kebele group *j*. The dependent variable is specified as the difference between endline and baseline measures for the outcome.
- T_k: treatment *k,* with *k* indexing treatments 1, 2, 3 or 4 (4 considered the control group)
- H: characteristics of household
- S: spatial variables such as proximity to markets, access to critical infrastructure, hospitals, schools, etc. for the household. Some variables such as kebele household density, kebele road density, and access to piped water are measured at the kebele level but will vary across households in kebele groups.
- $T_k.S$ interaction between treatment and spatial variables
- O_{i0}: is the outcome variable, for household i, as measured at baseline. The variable is intended to capture differences based on initial endowments/positions of households.
- $\beta_0, \beta_k, \beta_3, \beta_4, \gamma_k$: parameters to be estimated
- υ_j: is a random effect at the Kebele group level assumed to be Normally distributed with mean 0 and variance σ^2.
- ϵ_{ij}: error term

We specified three models, one for each outcome variable of interest. The first model focuses on women's empowerment and assesses the effect of treatments and spatial variables on change in women's poultry ownership from baseline to endline. The second model assesses effects on women's nutrition as measured by changes in diet diversity index from baseline to endline. The third model assesses the effects on households' livelihoods as measured by changes in a household's wealth index from baseline to endline. Our econometric approach examines how spatial variables (access to infrastructure and proximity to economic agglomerations) influence treatment outcomes while accounting for the spatial variables, household endowments, and other relevant control variables identified in the literature.

3.5 Spatial variables

We calculated and used data on 9 spatial variables from open-access sources and the geolocation of households surveyed in the *SPIR I dataset.* Our goal was to produce an array of variables identified in the literature review under the categories of *access to infrastructure* and *proximity to economic agglomerations*. Table 3 lists the spatial variables used in the regression models. More spatial variables

were calculated but not used in the final models because of missing values, collinearity, and insignificance.

Table 2. Spatial variables used in the final models.

Variable	Alias	Unit	Source
Distance to health post office	hpo	Meters	Proprietary data from World Vision: kebele survey_clean_coordinates
Distance to paved road	prd	Meters	
Distance to market	mkt	Meters	
Distance to RUSACCO office	rus	Meters	
Distance to DA office	dao	Meters	
Distance to Kebele office	kbo	Meters	
Access to public piped water	apw	Binary yes and no	Variable b09 in SPIR_endline_kebele_survey
Density of primary roads	dpr	Km road length / sq km	OSM streets
Kebele household density	khd	Households / sq km	Ethiopia subnational population statistics

Data for distance to health post (hpo), distance to paved road (prd), distance to market (mkt), distance to Rural Savings and Credit Cooperative, RUSACCO (rus), distance to DA office (dao), distance to Kebele office (kbo), and access to public pipped water (apw) were created using data available in the SPIR I dataset. This dataset offered the geographic coordinates for infrastructure like markets, RUSCACCO, Kebele office, and such. Using these locations, and the locations of each household, the projected coordinate systems allowed for calculation of geographic distances. The variable distance to primary road (dpr) was created using OSM street data. The data for the variables Kebele household density (khd) and Kebele road density (krd) were created at the Kebele level and assigned the same value to each household in the survey sharing a Kebele. The road length was calculated in ArcGIS Pro using Open Street Maps (OSM) data.

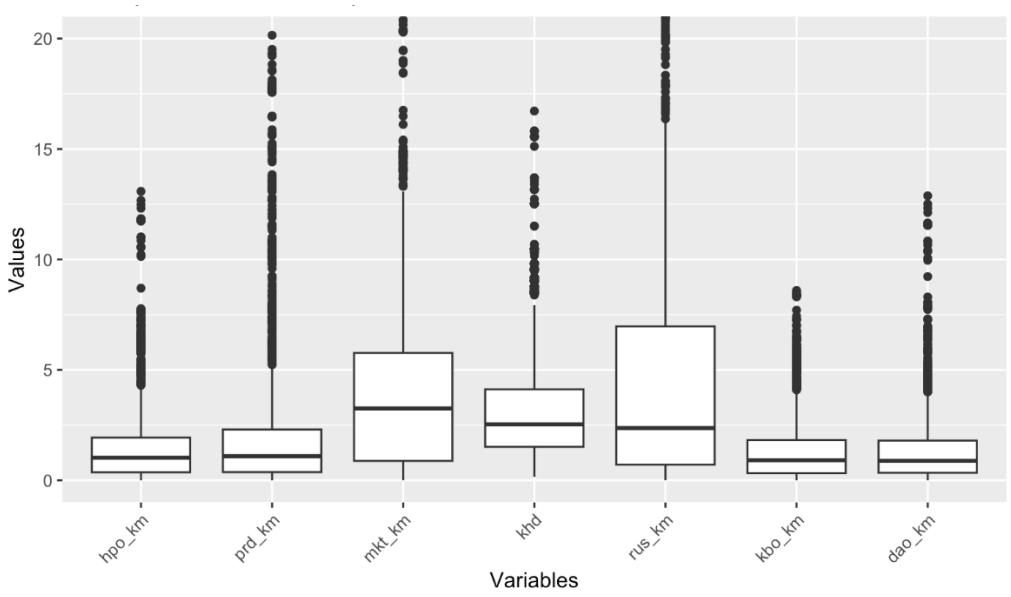
Table 3 presents the summary statistics of the spatial variables. Figure 1 presents a graph showing the distribution of the spatial variables and their outliers. Maps 3 through 9 show the spatial distribution of the spatial variables developed for the study.

Table 3. Summary statistics of spatial variables.

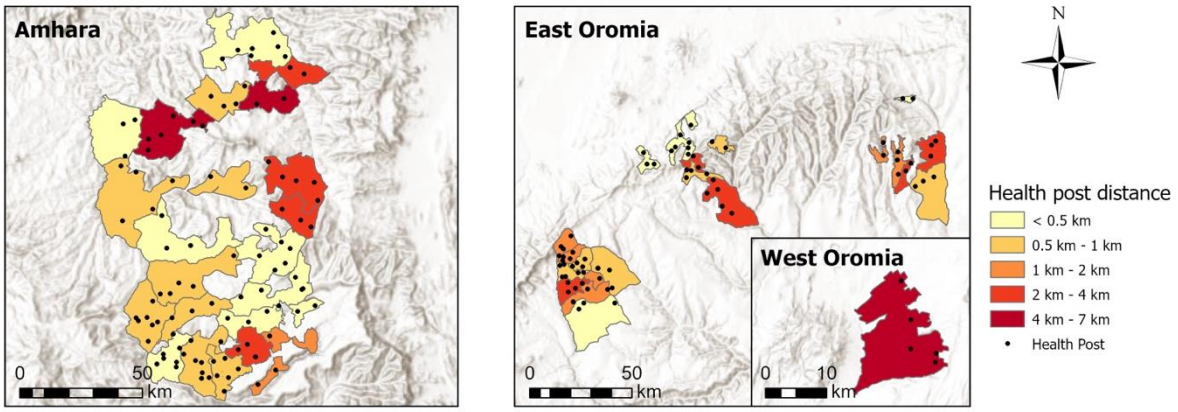
Alias	Min	Q1	Median	Mean	Q3	Max	SD	Var	N
hpo	3.03	364.24	1023.09	1431.33	1935.41	13082.27	1546.75	2392444	3786
prd	2.15	371.33	1094.71	2038.23	2302.27	20149.97	3013.71	9082453	3786
mkt	6.49	878.87	3254.81	3984.82	5766.01	21620.52	3665.46	13435631	3786
rus	7.31	709.64	2365.84	4348.99	6970.07	29021.65	5046.63	25468507	3786
dao	4.2	341.79	882.03	1303.84	1800.52	12882.32	1447.23	2094484	3786
kbo	4	324.95	908.59	1227.03	1774.63	7705.22	1161.57	1349254	3786
dpr	0	0	0	0.0067	0.00005	0.29	0.019	0.00038	3786
khd	1.54	15.16	25.35	43.9	41.19	3908.89	116.98	13683.21	3707

Alias	No	Yes	NA
apw	2292	1478	16

Figure 1. Box-whisker plot of spatial variables

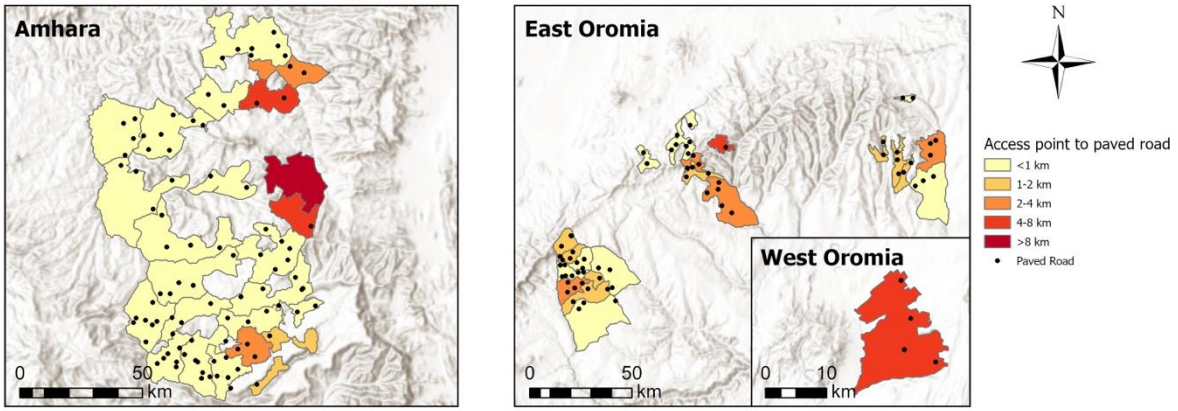


Map 3: Average Kebele group level household distance from health post office (hpo)



Distance to Health Post Office (hpo) was measured from each household using the geographic coordinates available in IFPRI datasets, and the distance for areal average of each household from the nearest health post is shown in Map 3. The maps reveal distinct spatial patterns in access to health services across. Regional disparities in access are evident. The Amhara region shows better access in some areas and kebele groups with further distance from health post offices in others. Oromia exhibits a wide range of accessibility, highlighting the challenges of serving large, diverse regions. While some locations are very close to health services, the median value of 1023.09 meters indicates that half of the observations are located over a kilometer away from a health post. This underscores the challenges in providing equitable access to healthcare. Furthermore, the presence of households at distances of 9km or more from a health post highlights the stark differences in accessibility and the urgent need for targeted interventions to improve healthcare access in remote and underserved areas.

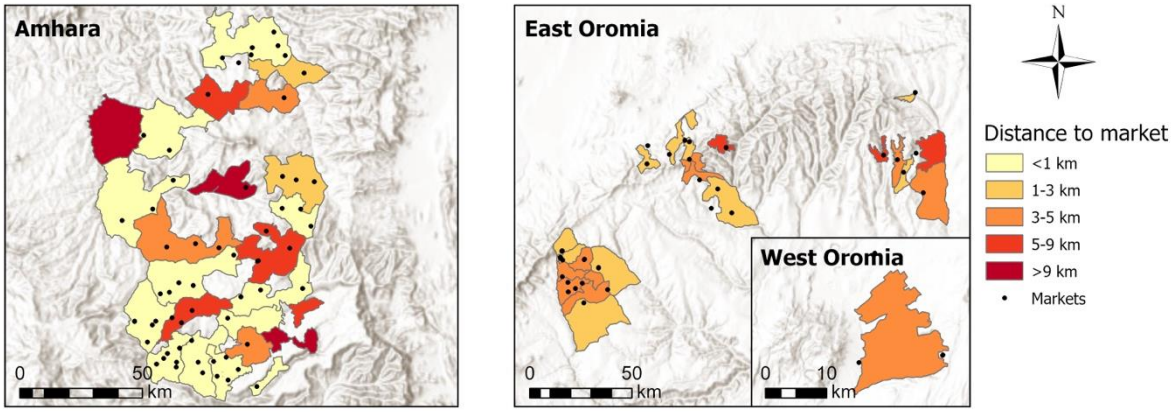
Map 4: Average Kebele group level household distance from paved road (prd)



Distance to Paved Road (prd) was also measured in metric system using the geographic coordinates available in IFPRI datasets, as shown for areal average of each household in Map 4. This map shows that many households have immediate access to paved roads within a few kilometers. However, access to paved roads is far from immediate for many others. The descriptive statistics show a maximum value

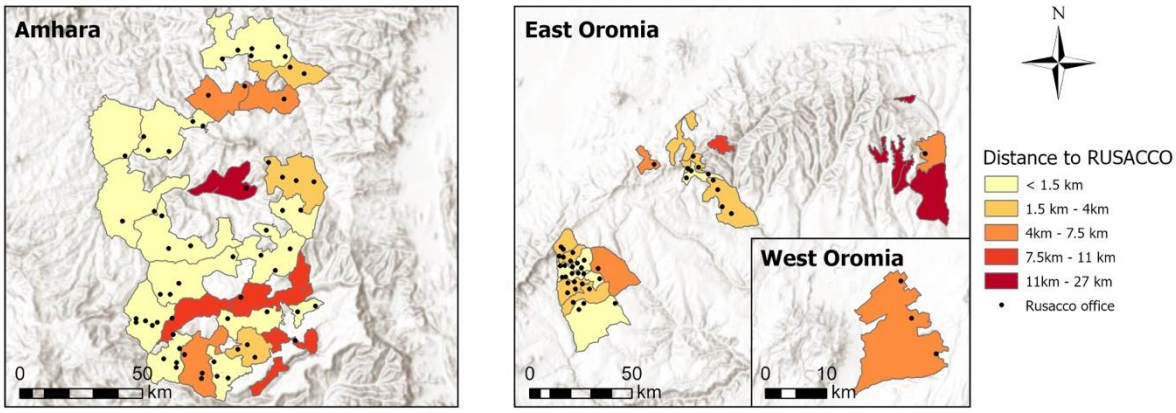
of 20149.97 meters and a high standard deviation of 3013.71 meters, further underscoring the disparities in road access.

Map 5: Average Kebele group level household distance from market (mkt)



Distance to Market (mkt) was also measured in metric system using the geographic coordinates available in IFPRI datasets, as shown for areal average of each household in Map 5. The map suggests that some households are located very close to markets, with a minimum distance of 6.49 meters. However, the median distance of 3254.81 meters indicates that half of the observations are located over 3 kilometers away from the nearest market. Further distances underscore the challenges faced by households, with some being over 21 kilometers away from the closest market.

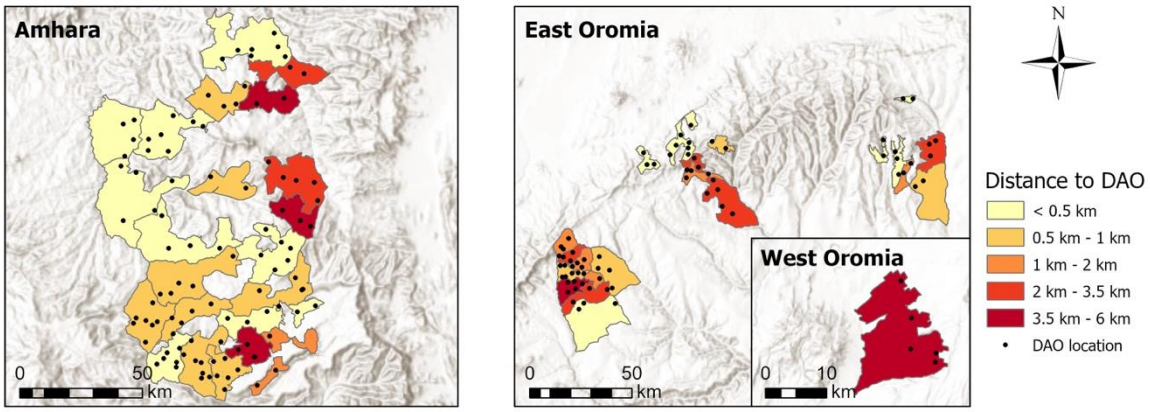
Map 6: Average Kebele group level household distance from RUSACCO Office (rus)



Distance to rural saving cooperatives office (rus) was also measured in metric system using the geographic coordinates available in IFPRI datasets, as shown for areal average of each household in Map 6. The map illustrates that some locations are very close to these offices, with a minimum distance of just 7.31 meters. The median distance of 2365.84 meters indicates that half of the households are

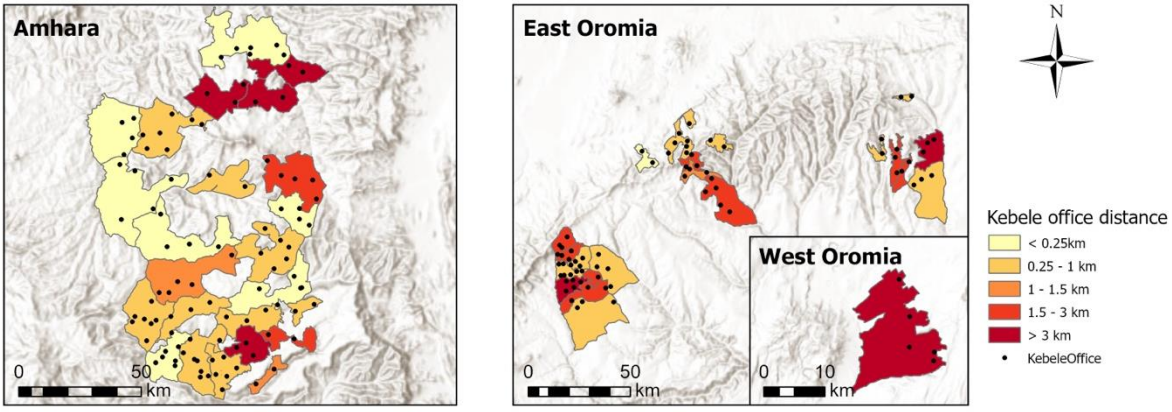
located more than 2 kilometers away. Further households emphasize the significant accessibility gaps, with some located more than 29 kilometers away from a RUSACCO office.

Map 7: Average Kebele group level household distance from DA office (dao)



Distance to the Development Agriculture Office (dao) was also measured in metric system using the geographic coordinates available in IFPRI datasets, as shown for areal average of each household in Map 7. The map suggests that some areas are very close to a DA office, with a minimum distance of just 4.2 meters. However, the median distance of 882.03 meters suggests that half of the observations are located less than a kilometer away. The farther locations further demonstrate the accessibility challenge, with some households being over 12 kilometers away from a DA office.

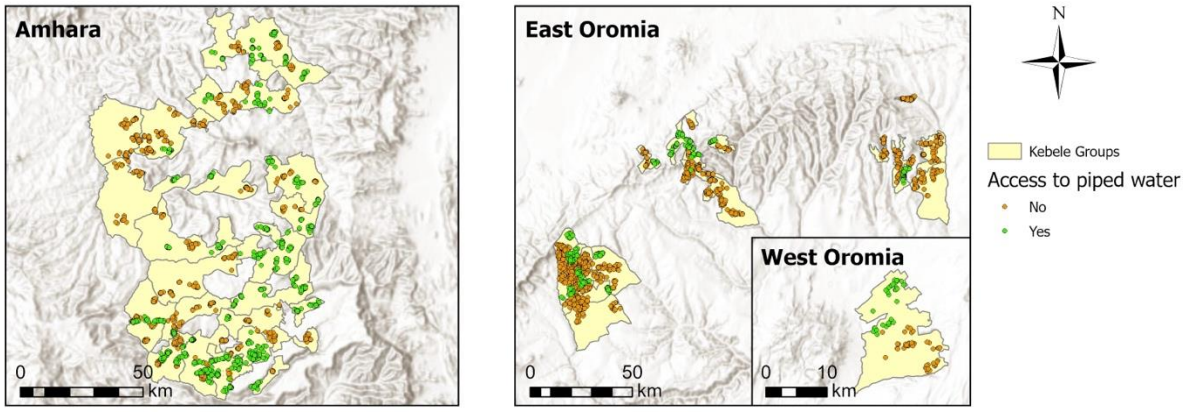
Map 8: Average Kebele group level household distance from Kebele office (kbo)



Distance to Kebele Office (kbo) was also measured in metric system using the geographic coordinates available in IFPRI datasets, as shown for areal average of each household in Map 8. The map shows that some households are located very close to Kebele offices, with a minimum distance of just 4

meters. However, the median distance of 908.59 meters indicates that half of the observations are situated less than a kilometer away. The farther households illustrate the uneven distribution of administrative services, with some households being over 7 kilometers away from the nearest Kebele office.

Map 9. Households' access to public pipped water shown on Kebele group boundaries



Data for households' access to piped water (apw) is mapped in Map 9. Data on access to piped water was collected the Kebele level. This data was spatially joined with the household data to find that 2,292 households did not have access to public piped water, while 1,478 did, while data was missing for 16 households. As clearly visible, there is a clustering of orange dots together, which represent the households that do not have access to piped water. Conversely, the green dots are also clustered representing houses with access to piped water. This shows a clear difference between the areas that have better public services than others.

3.6 Outcome variables.

The selection of the three outcome variables, female empowerment, nutrition, and livelihood,for this study was influenced by several key factors, including the literature review, results from the SPIR I study, the study design, and consultation with World Vision staff.

For household-level outcomes, changes in overall household wealth were selected to capture how household economic status changed in response to the treatments. The study had collected data on ownership of different asset classes that could be categorized as durable goods, production assets, and livestock both before treatment and at endline. We combined these data to form a wealth index at the household level and examined how it was affected by the treatments and different spatial variables.

For female empowerment, we considered both female personal income and female poultry ownership as potential measures that could indicate the treatment effects. Drawing from SPIR I's results, which

showed strong treatment effects on poultry ownership, we prioritized that variable to examine how treatment impacts might depend on spatial variables.

For nutrition, we considered both changes in child nutrition and changes in maternal nutrition as potential outcome variables. We eventually selected maternal nutrition due to its representativeness of the household nutrition as a whole.

3.6.1 Women's empowerment model: Difference in ownership of poultry.

We used ownership of poultry (opl) to develop the outcome variable in the Women's empowerment model. The variable is calculated as the difference between the number of poultry at the endline (opl_e) and the number of poultry owned at the baseline (opl_b). This difference is referred to as opl_diff. The formula is as follows:

Women's empowerment outcome = Endline ownership of poultry - Baseline ownership of poultry

$$opl\_diff = opl\_e - opl\_b$$

The following table shows the summary statistics of the outcome variable difference in poultry ownership (opl_diff). The table indicates that the average number of poultry owned increased from 1.68 at baseline to 3.19 at the endline. This outcome variable was derived from data on households for which the number of poultry was recorded at both the baseline and endline. However, some households experienced a decrease in the number of poultry owned during this period. Notably, the minimum value of -37 suggests that at least one household owned 37 fewer poultry at the endline compared to the baseline. The mean 1.52 of the outcome variable, however, suggests that most households owned more poultry heads at the endline on average.

	Sample size	min	Q1	median	mean	Q3	Max	NA's
opl_b	3069	0	0	0	1.68	3	40	474
opl_e	3678	0	1	2	3.19	5	28	-
opl_diff	2507	-37	0	1	1.52	3	28	474

3.6.2 Nutrition model: Difference in Women's Dietary Diversity.

We used Minium Dietary Diversity for women (mdd) as the outcome variable in the Nutrition-related model. Data for mdd was created at baseline and endline using the following ten food group categories[1].

No.	mdd food groups	Number of women reported yes	
		Baseline	Endline
1	Grains, roots, and tubers	2765	3576
2	Pulses	1407	2080
3	Nuts and seeds	251	886
4	Dairy	241	470
5	Meat, poultry, and fish	31	171
6	Eggs	61	168
7	Dark leafy greens and vegetables	257	258
8	Other Vitamin A-rich fruits and vegetables	611	357
9	Other vegetables	519	2083
10	Other fruits	96	164

The outcome variable for women's nutrition is calculated as the difference between the food diversity consumed at the endline and baseline surveys. This difference is referred to as mdd_diff (i.e., the difference between endline MDD mdd_e and baseline MDD mdd_b). The formula is:

Women's nutrition outcome = Endline food diversity - Baseline food diversity

$$mdd\_diff = mdd\_e - mdd\_b$$

The data shows the difference in food diversity between the baseline and endline surveys. On average, women's food diversity increased slightly (mean of mdd_diff = 0.6). However, the spread of the difference is wide, with values ranging from a decrease of 5 to an increase of 8 in the food groups consumed. The variability suggests that while some women saw an improvement in food diversity, others experienced a decline. The median increase in food diversity was 1, indicating that more women experienced a modest improvement rather than a significant decline or increase.

The following table shows the summary statistics of the outcome variable Difference in Minimum Dietary Diversity for Women (mdd_diff):

Alias	Sample size	Min	Q1	Median	Mean	Q3	Max	SD	Var
mdd_e	3660	1	2	3	2.79	3	10	1.22	1.48
mdd_b	2856	1	1	2	2.18	3	7	1.1	1.2
mdd_diff	2765	-5	0	1	0.6	1	8	1.53	2.33

[1] The selection of food groups for the mdd-w is based on the methodology proposed by the International Dietary Data expansion Project (link). The mdd-w is a dichotomous indicator based on 10 food groups. Women who have consumed at least five of the 10 possible food groups in the last 24 hours are classified as having minimally adequate diet diversity.

3.6.3 Livelihoods model: Difference in Wealth Index.[2]

To produce an outcome variable for the livelihoods model we created a wealth index for the SPIR I data. While SPIR I included number of units owned for different types of durable goods, production assets and livestock, it did not include price data, and therefore it was not possible to construct a monetized value of all assets for households. To produce a wealth index, we thus rely on data from SPIR II where both price and quantity of goods owned were reported. Using this data, we produced a monetized value of all assets (W) and also compute two non-price-based indices to approximate W, one using a standardized min-max index based on reported counts of assets and another that relies on principal component analysis on the same data. Both sets of indices were compared against W at the household level as described in Appendix 5 and the min-max based index was selected as the better option. This index is a weighted sum of indices produced separately for durable goods, production assets and livestock. The weights for combining the indices were derived from SPIR II and used with SPIR I data to compute an overall wealth index at baseline and endline for each household.

To produce the Min-Max index, we first normalize the quantity of each asset owned by households to a range of 0 to 1. A value of 0 corresponds to the minimum reported quantity for that asset across all households and a value of 1 corresponds to the maximum. If x_{ij} is the quantity of asset j for household i, the normalized measure for that asset is:

$$s_{ij} = \frac{x_{ij} - min\ (x_i)}{max\ (x_i) - min(x_j)}$$

We then compute an asset class index for durable goods (S_1), production assets (S_2), and livestock (S_3) by taking the average of s_{ij} for assets in that asset class. Finally, these three indices are combined into a weighted overall wealth index for each household i as follows:

$$S_i = \sum_{k=1}^{3} w_k s_{ik}$$

Since the asset category indices are based on quantity of units owned, combining them without weights would give equal importance to assets that are significantly different in value. The weights w_k are selected to reflect the contribution of durable goods, production assets, and livestock to overall wealth. We derive these weights based on the proportion of total monetized value from each asset group. In SPIR II, durable goods, production assets, and livestock make up 17.8%, 8.5%, and 73.7% of total monetized value across all households. Further modification was needed to apply the index to SPIR I data since data on production assets (accounting for 8.5% of the index) was sparse. This proportion

[2] A step-by-step guide about the calculation of the Wealth Index is provided in Annex 6 of this report.

was reassigned the two other categories, and the final index was based 20% on durable goods and 80% on livestock.

The following table presents the descriptive statistics of the wealth index at the baseline (wtd_b), the wealth index at the endline (wtd_e), and the outcome variable difference in wealth index (wtd_diff):

	Sample size	min	1st qu.	median	mean	3rd qu.	Max	NA's
wtd_b	3065	0	2.000	4.444	5.078	7.259	40.028	721
wtd_e	3596	0	3.155	6.288	7.457	10.352	42.186	190
wtd_diff	2919	-22.643	-0.880	1.859	2.383	5.331	38.048	867

The outcome variable for the livelihoods model is calculated as the difference between the wealth index at the endline (wtd_e) and the wealth index at the baseline (wtd_b). This difference is referred to as wtd_diff. The formula is:

*Livelihoods outcome = 100 * (Endline wealth index – Baseline wealth index)*

$$wtd\_diff = 100 * (wtd\_e - wtd\_b)$$

3.7 Control variables

We produced a series of control variables in four analytical categories: natural environment, household assets, relational resources, and other control variables. A complete list of the control variables developed for this study can be found in Annex 3. Despite trying many control variables, our final models included only five variables in two analytical categories. Control variables were selected for their relevance in the existing literature and their performance in the regression models. We used the presence of flooding (pof), a variable pertaining to the dimension of the natural environment. Variables in the household assets category include female personal savings (fps), ownership of livestock head (olv), non-farm income (nfi), and having farming experience (hfe). Table 4 presents a description of the control variable used in the models.

Table 4. Selected control variables for the models

Category	Variable	Alias	Unit	Type	Source
Natural environment	Presence of flooding	pof	Binary 0 and 1	Nominal	Endline Male Module L
Household assets	Female personal savings	fps	Bir (Ethiopia's currency)	Ratio	Midline Female & Endline Male Module F
	Ownership of livestock head	olv	Number of livestock	Ratio	Endline Female Module C, Baseline Male Module A
	Non-farm Income	nfi	Binary 0 and 1	Nominal	Endline Male Module E, Baseline Female Module I
	Having farming experience	hfe	Binary 0 and 1	Nominal	Baseline Male Module A

We also control for the outcome variable at the baseline. For instance, in the women's empowerment model, where the outcome variable is the difference between ownership of poultry at the endline and the baseline, we control for ownership of poultry at the baseline. In the nutrition model, where the outcome variable is the difference in women's minimum diet diversity index, we control for women's minimum diet diversity index at the baseline. In the livelihoods model, where the outcome variable is the difference in the wealth index between the baseline and the endline, we control for the wealth index at the baseline.

A complete list of the outcome, spatial, and control variables developed for this study can be found in Annex 3 of this report. Tables with the descriptive statistics of the variables in the dataset can be found in Annex 4. A detailed explanation of how each variable was calculated can be found in Annex 5.

4. Model results

4.1 Women's empowerment model

Table 5 presents the output for the women's empowerment model. The dependent variable in this model is the difference in women's ownership of poultry between the endline and baseline.

Table 5. Model results for Women's Empowerment.

	Without spatial variables		With spatial variables	
	Estimate (std. error)		Estimate (std. error))	
(Intercept)	**2.320 (0.312)**	***	**2.571 (0.367)**	***
Treatment 1	**0.688 (0.230)**	**	**0.657 (0.233)**	**
Treatment 2	**0.912 (0.233)**	***	**0.868 (0.237)**	***
Treatment 3	**0.515 (0.233)**	*	**0.527 (0.237)**	*
Poultry owned at the baseline (n)	**-0.894** (0.028)	***	**-0.894** (0.028)	***
Having farming experience	0.000 (0.247)		-0.031 (0.249)	
Ownership of livestock at the baseline	**0.042 (0.024)**	.	**0.042 (0.025)**	.
Access to public pipped water			-0.215 (0.197)	
Distance to RUSACCO office			-0.024 (0.023)	
Distance to Kebele office			0.060 (0.105)	
Distance to DA office			-0.025 (0.100)	
Distance to paved road			-0.025 (0.045)	
Distance to market			0.007 (0.029)	
Kebele household density			-0.001 (0.001)	
Random effects (SD)				
Kebele group	0.927		0.935	
Residual	3.341		3.343	
Num.Obs.	1985		1985	
Goodness of fit (Nakagawa variance-based R^2)				
Marginal R^2 (fixed only)	0.342		0.342	
Conditional R^2 (full model)	0.389		0.390	

. p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

Table 5 presents two models: one excluding spatial variables and another incorporating them. In both models, there is a slight improvement in the goodness of fit due to the inclusion of random effects, but most of the explained variance is captured by the covariates. The comparison between the two models enables an assessment of how including spatial variables influences the estimated effects of the treatment and control variables. The model testing for interactions between the treatments and the spatial variables does not provide a better fit for the data than the model without interactions and, therefore, is not reported here. All treatment variables are statistically significant in the model without spatial variables, while the only statistically significant control variable is baseline poultry ownership. The inclusion of spatial variables does not substantially alter the results. All statistically significant variables in the initial model remain significant in the model with spatial variables. None of the spatial variables themselves are statistically significant. The only notable change is that baseline livestock ownership becomes statistically significant at the 90% level after including spatial variables.

We found that relative to women in treatment 4, those who were in treatments 1, 2, and 3 improved poultry ownership, all other things equal. As explained earlier, households assigned to T1 received enhanced livelihood and nutrition benefits. Households assigned to T2 received enhanced livelihood benefits combined with basic nutrition activities, and those assigned to T3 received enhanced nutrition combined with basic livelihood activities. Households assigned to T4 were the control group and received basic livelihoods and nutrition activities only with no enhanced benefits. Gains in poultry were smaller for those who owned poultry at baseline on average, with each additional poultry unit at baseline lowering the expected gain by 0.9. Owning livestock at baseline was weakly associated with a small positive gain in poultry by the endline.

As noted above, the spatial variables we controlled were unimportant in explaining poultry ownership changes. We also tested the interactions between the treatments and the spatial variables, but they were not significant, and therefore, we do not report them in the final model. Further, looking at the random effects and error variance, kebele group to kebele group variations in outcomes are small and only account for a small part of the variance that the model does not capture (~7%). Most unexplained variance in poultry ownership changes (~93%) occurs at the individual level.

Implications for the literature. Our findings contribute several insights to the existing literature on women's empowerment. First, the women's empowerment model shows that treatments involving enhanced livelihood benefits (T1 and T2) significantly increased women's poultry ownership, with T1 (enhanced livelihood and nutrition) and T2 (enhanced livelihood and basic nutrition) yielding gains. These results reinforce arguments that material interventions can directly enhance women's control over productive assets (Agarwal, 1997; Kabeer, 1999). Interestingly, the smaller but still positive effect of the enhanced nutrition and basic livelihood arm (T3) suggests that behavior change interventions alone may also have an impact.

Second, the lack of significant effects for spatial covariates (e.g., distance to roads, markets) suggests that livestock-based empowerment pathways may be resilient even in remote areas. This observation adds nuance to conventional theories emphasizing market access as a precondition for rural empowerment (Mathenge et al., 2020; Rao & Qaim, 2011).

Third, we observe that providing enhanced livelihood benefits, combined with basic nutrition (T2) yields empowerment gains comparable to, or even slightly exceeding, those achieved through enhanced

combined livelihood and nutrition interventions (T1). This finding refines prior understandings by suggesting that, while integrated multi-sectoral approaches are often recommended (Hashemi & Rosenberg, 2006), enhanced livelihood-focused interventions may be sufficiently potent in driving women's asset accumulation in resource-constrained contexts.

Fourth, we observe that nutrition-focused interventions without enhanced asset transfers (T3) positively but modestly affect women's empowerment. While this finding aligns with literature emphasizing the role of knowledge and behavior change in shifting gender dynamics (Kabeer, 1999; Meinzen-Dick et al., 2011), it also highlights the limitations of informational or behavioral interventions when not paired with material support. The modest effects found here echo concerns raised in recent critiques that "soft" interventions without economic levers may struggle to transform women's control over tangible resources substantially (Kabeer, 1999).

Fifth, our results show a significant negative association between baseline poultry ownership and subsequent gains, implying that households starting with fewer or no assets benefit most from asset transfers. This adds empirical weight to theories emphasizing the need to target interventions toward the asset-poorest groups, as seen in the "graduation" model literature (Banerjee et al., 2015; Hashemi & de Montesquiou, 2024). Our findings suggest that empowerment through asset accumulation is possible and particularly potent for households at the very bottom of asset distributions, reinforcing the idea that early-stage asset deficits are a key constraint on women's empowerment trajectories.

Finally, contrary to some previous findings (Mathenge et al., 2020; Okwi et al., 2007; Palmer-Jones & Sen, 2006; Rao & Qaim, 2011), we do not find significant effects of spatial factors such as proximity to markets, roads, or service centers on women's empowerment through poultry ownership. This suggests that spatial infrastructure constraints may not pose a major barrier to empowerment in the case of low-transaction-cost assets like poultry. This finding invites a more asset-specific reading of how spatial and infrastructural factors interact with empowerment processes and suggests that small livestock interventions may offer particular advantages in remote or infrastructure-poor settings.

4.2 Nutrition model

Table 6 presents the output for the model on nutrition.[3] The dependent variable in this model is the difference in women's minimum dietary diversity index between the endline and baseline.

We present two models: one excluding spatial variables and another incorporating them. A third model, which tested interactions between the treatment and spatial variables, did not provide a better fit to the data and is therefore not reported here. Introducing spatial variables results in only two notable changes to the model estimates. First, the effect of T1 loses statistical significance at the 95% confidence level. Second, the effect of T3 remains statistically significant after including spatial variables. It is also important to note that introducing spatial variables does not substantially alter the estimators' magnitude for the statistically significant variables.

[3] A step-by-step- guide of the specification of the Nutrition model is provided in Annex 7 of this document.

Table 6. Output for Women's Nutrition Diversity models

	Model without spatial variables Estimate (std. error)		Model with spatial variables Estimate (std. error)	
(Intercept)	**2.137** (0.108)	***	**2.233** (0.115)	***
Treatment 1	**0.138** (0.066)	*	0.120 (0.067)	.
Treatment 2	-0.072 (0.069)		-0.075 (0.070)	
Treatment 3	**0.153** (0.067)	*	**0.147** (0.068)	*
Minimum dietary diversity index (baseline)	**-0.897** (0.021)	***	**-0.898** (0.021)	***
Non-farming income (baseline)	0.197 (0.112)	.	0.181 (0.112)	
Ownership of poultry (baseline)	0.055 (0.048)		0.059 (0.048)	
Ownership of poultry (endline)	**0.193** (0.049)	***	**0.198** (0.049)	***
Access to piped water	**0.197** (0.057)	***	**0.185** (0.058)	**
Ownership of livestock (baseline)	-0.038 (0.059)		-0.029 (0.059)	
Ownership of livestock (endline)	**0.182** (0.060)	**	**0.190** (0.060)	**
Distance to health post office (km)			0.002 (0.018)	
Distance to paved road (km)			-0.015 (0.014)	
Distance to markets (km)			-0.013 (0.008)	
Density or primary roads			-2.112 (1.915)	
Random effects (SD)				
Kebele group	0.173		0.159	
Residual	1.277		1.284	
Num Obs.	2695		2695	
Nakagawa variance-based R^2				
Marginal R^2 (fixed only)	0.403		0.404	
Conditional R^2 (full model)	0.474		0.470	

. p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

Overall, the results show that those receiving T1 (L*+N*)—enhanced livelihood and enhanced nutrition benefits—and T3 (L+N*)—basic livelihood and enhanced nutrition benefits—show higher diet diversity gains as compared to the reference group. However, once we control for the spatial variables, the effect of T1 becomes only weakly significant, and that for T3 continues to show a gain in diet diversity more than the reference group.

Also, baseline diet diversity is negatively associated with gains in diet diversity. There are several possible explanations for this finding. One is that this may reflect a simple regression to the mean.

However, it could also reflect a ceiling effect. Less room for improvement exists among those with a high baseline. It is also possible that individuals with lower diet diversity might be more responsive. Women with lower baseline diet diversity should be prioritized for nutrition messaging or counseling. They could be more motivated or responsive to the interventions because they start from a position of greater need. Access to piped water, poultry ownership at endline, or livestock ownership at endline are associated with higher gains in diet diversity.

None of the spatial variables we controlled for or their interaction with treatments were found to be important in explaining the change in women's diet diversity. Similar to the female empowerment model, we find that kebele group to kebele group variation in outcomes is small. The variance across kebele groups accounts for about 12% of the error variance while the majority of unexplained variance (~88%) occurs at the household/individual level.

Implications for the literature. The findings from the nutrition model contribute new evidence to the research linking development interventions to women's dietary diversity. First, the fact that T1 (enhanced livelihoods and nutrition) and T3 (basic livelihood and enhanced nutrition) had positive and statistically significant impacts on women's minimum dietary diversity supports existing arguments that nutrition-sensitive programming, particularly behavior change communication and direct nutrition interventions, can lead to measurable improvements in women's diets (van den Bold et al., 2013). This reinforces the importance of incorporating nutrition-specific components alongside broader livelihood support. However, the lack of significant impact for Treatment 2 (enhanced livelihoods and basic nutrition) suggests that livelihood interventions alone — even when they boost asset ownership or incomes — do not necessarily translate into better dietary diversity. This finding echoes critiques cautioning that asset-based interventions must be explicitly nutrition-sensitive to impact dietary outcomes (Meinzen-Dick et al., 2011).

Second, the negative association between baseline dietary diversity and improvements at endline (-0.898) suggests that women with already relatively diverse diets had limited scope for further improvement. This "ceiling effect" is consistent with studies finding that the greatest gains from development interventions often occur among the most disadvantaged segments of target populations (Banerjee et al., 2015; Hashemi & de Montesquiou, 2024; van den Bold et al., 2013).

Third, ownership of poultry and livestock at endline is a strong positive predictor of dietary diversity improvements. These results strengthen the evidence that small livestock ownership is an important pathway to improving women's diets, especially through access to nutrient-rich animal-source foods (Meinzen-Dick et al., 2011; van den Bold et al., 2013).

Fourth, the positive and significant relationship between access to piped water and women's dietary diversity highlights the importance of basic infrastructure in supporting better nutrition outcomes. Improved water access can influence food preparation, hygiene, and consumption of fresh foods, supporting the broader literature linking WASH (Water, Sanitation, and Hygiene) improvements (Mahmud & Mbuya, 2015; van Cooten et al., 2019) to better nutrition (Meinzen-Dick et al., 2011; van den Bold et al., 2013).

Finally, the limited role of spatial variables (e.g., distance to health posts, roads, and markets) in explaining changes in dietary diversity suggests that local service access alone was not a major driver of improvements. This somewhat contrasts with parts of the existing literature that posit better physical

access to markets and health services as critical for dietary improvements (van den Bold et al., 2013), and it indicates that behavioral and intra-household factors might play a more decisive role in this context.

4.3. Livelihoods

Table 7 presents the output of the model for the livelihood model. This model's dependent variable is the wealth index difference between the endline and baseline.

We report results from three models: one without spatial variables, a second incorporating spatial variables, and a third including interactions between the treatment variables and distance to market. The marginal R^2 of the models improves modestly as spatial variables and interactions are added, from 0.168 without spatial variables, to 0.186 when spatial variables are added, and to 0.191 when interactions are added. As spatial variables are added, the gap between the conditional and marginal R^2 values decreases, indicating the random effects account for a smaller but still important share of the variance. A likelihood ratio test between model 3 (with interactions) and model 2 (with spatial variables) indicates that the model with interactions is preferred. Partitioning the error variance between Kebele groups to Kebele groups random effects and noise at the household level, random effects account for only 8% of this variance. As with the prior two models, most unexplained variance in wealth gains (~92%) occurs at the household level.

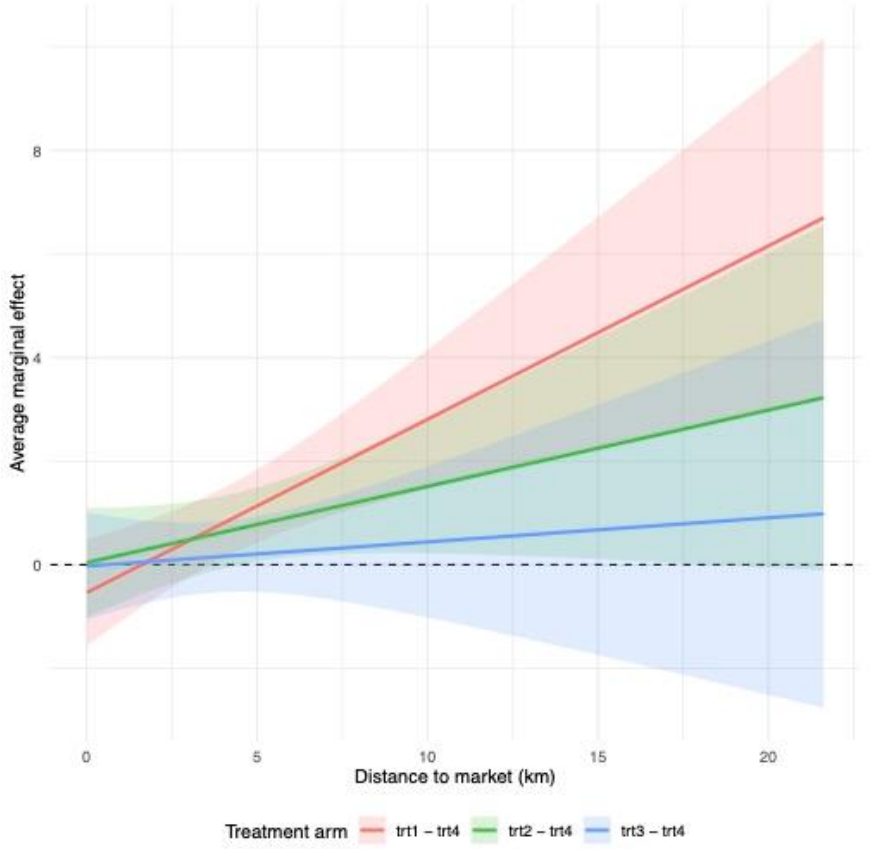
T1 and T2 are statistically significant in the model without spatial variables, whereas T3 is not. Including spatial variables in Model 2 does not affect the significance of the treatment estimates; however, access to public piped water and distance to Kebele offices and markets emerge as statistically significant predictors. In contrast, the model incorporating interactions between treatments and distance to markets yields notable changes. Most saliently, in the third specification, we see that households in more remote areas (away from markets) show higher wealth gains than those in the control group. For example, a household 10 km away from a market would be expected to gain 2.54 points on the wealth index under Treatment 1, 1.24 points under treatment 2, 0.17 points under Treatment 3 and experience a decline of 0.27 points under treatment 4, holding all other variables constant. The marginal effect of each treatment (vs. control/T4) on household wealth index across distance to market is shown in Figure 2. For a household at 10 kms, these marginal effects for Treatments 1, 2 and 3 are 2.81, 1.51 and 0.44 respectively. One possible explanation for this finding is that remote households gain more from enhanced livelihood support because the availability of land and the environment away from markets may be more conducive to taking advantage of such support and expanding livestock or poultry assets. As noted earlier, poultry and livestock ownership account for 80% of the wealth index.

Table 7. Output for Livelihoods model

	Model without spatial variables		Model with spatial variables		Model with spatial variables & interactions	
	Estimate (std. error)		Estimate (std. error)		Estimate (std. error)	
(Intercept)	**4.611 (0.330)**	***	**4.129 (0.395)**	***	**4.698 (0.449)**	***
Treatment 1	**0.746 (0.285)**	**	**0.795 (0.287**	**	-0.539 (0.433)	
Treatment 2	**0.860 (0.293)**	**	**0.665 (0.296)**	*	0.041 (0.446)	
Treatment 3	0.240 (0.288)		0.230 (0.289)		-0.026 (0.437)	
Wealth Index (baseline)	**-0.523 (0.022)**	***	**-0.537 (0.022)**	***	**-0.538 (0.022)**	***
Access to public piped water			**-0.897 (0.242)**	***	**-0.886 (0.242)**	***
Distance to Kebele office			**0.375 (0.135)**	**	**0.404 (0.138)**	**
Distance to market			**0.095 (0.034)**	**	-0.027 (0.061)	
Distance to RUSACCO office			0.030 (0.031)		0.018 (0.031)	
Distance to DA office			-0.072 (0.133)		-0.107 (0.137)	
Distance to paved road			-0.013 (0.057)		-0.022 (0.057)	
Treatment 1 : Distance to market					**0.335 (0.082)**	***
Treatment 2 : Distance to market					**0.147 (0.079)**	.
Treatment 3 : Distance to market					0.047 (0.087)	
Random effects (SD)						
Kbg	1.589		1.480		1.477	
Residual	5.090		5.059		5.045	
Number of observations	2901		2901		2901	
Nakagawa variance-based R^2						
Marginal R^2 (fixed only)	0.168		0.186		0.191	
Conditional R^2 (full model)	0.241		0.250		0.255	

. p < 0.1, * p < 0.05, ** p < 0.01, *** p < 0.001

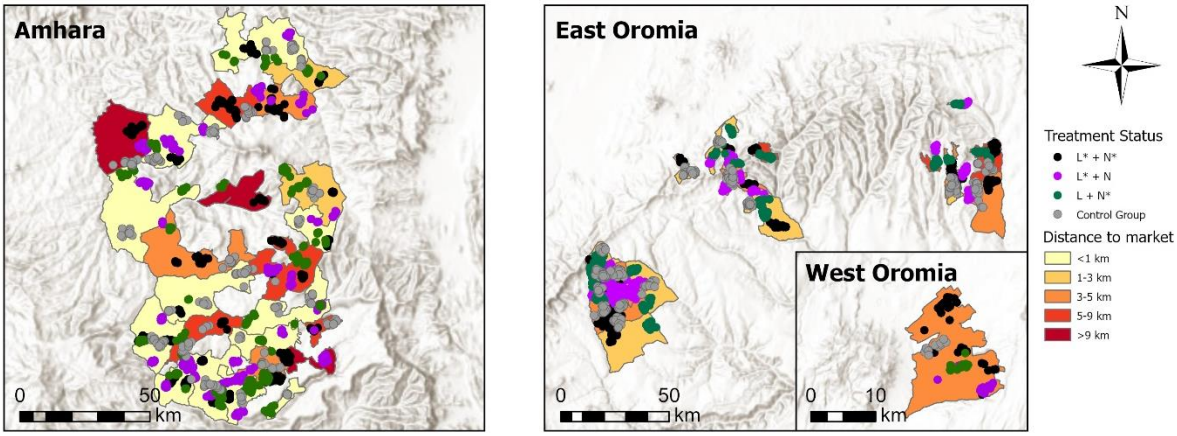
Figure 2. Marginal effect of each treatment (vs. control/T4) on household wealth index across distance to market.



Even though T1 and T2 have the same enhanced livelihood interventions, and their difference is in the nutrition arm, our model cannot explain why the interaction estimates for these treatments with distance are different. In the model without interactions, these estimates are positive, significant, and close in magnitude. It is possible that the stronger distance-based gains for T1 are due to spillover benefits from the more intensive and expansive engagement that occurs in the enhanced nutrition component of T1.

Turning to the remaining variables, households farther from Kebele offices tended to do better in terms of wealth gain, regardless of treatment arm. Further, those who have access to piped water had lower gains in the wealth index as compared to those without access to piped water. The negative sign for access to piped water is counterintuitive – one would typically expect access to infrastructure like piped water to support, not hinder, livelihood improvement. However, this finding can be understood in the context of the case study and the literature on rural development. In some contexts, piped water infrastructure is prioritized in more marginalized and vulnerable areas, where other livelihood options are more limited. In these cases, piped water is not necessarily a proxy for advantage. In other contexts, piped water is often installed first in densely populated areas. The wealth index used in the model, which is weighted heavily toward livestock and production assets, may not reflect the primary livelihood strategy of places with access to piped water.

Map 10. Treatment arms and distance to markets



Map 10 shows the spatial relationship between treatment arms and distance to markets. The light grey colored households in the map are the ones that received treatment 1 and were located closer to the markets. However, the households shown with teal color points in the map were the ones that received the same treatment arm 1 but gained more on the livelihood index because of their increased distance from the markets. As can be seen in the map, there seems to be a clustering of households that received a similar treatment arm and were located at a similar distance from the markets. This is because the study was designed to have closely located households to receive similar treatments, as the treatments were assigned on the Kebele level. Therefore, it would be worthwhile to investigate the households colored teal in this map to further investigate the causes of their better performance on the livelihood index in comparison to the others.

Implications for the literature. The results of the livelihoods model provide insights into how enhanced livelihood and nutrition interventions interact with local spatial factors to influence household livelihood outcomes. First, the finding that Treatment 1 (enhanced livelihood and nutrition) and Treatment 2 (enhanced livelihood and basic nutrition) both had positive impacts on livelihood outcomes in the models without spatial interactions reinforces prior evidence that integrated productive safety net programs can successfully support livelihood improvements (Berhane et al., 2014; de Montesquiou et al., 2014).

However, the importance of spatial interactions suggests that program impacts are spatially contingent. In particular, the significant positive interaction between Treatment 1 and distance to market indicates that households located farther from markets benefited more from the enhanced livelihood and nutrition package. This challenges conventional assumptions that proximity to markets is always beneficial for rural livelihoods (Wiggins & Proctor, 2001). It suggests that targeted program support can compensate for structural disadvantages for households or that rural households may be more advantageously positioned to take advantage of some interventions, boosting livelihoods despite poor market access.

Second, the negative association between baseline wealth and livelihood gains, while also influenced by regression-to-the-mean, is consistent with theories of "catch-up effects" (Banerjee et al., 2015): poorer households starting from a lower baseline had more room for improvement in livelihood

outcomes. This supports arguments that well-targeted interventions can successfully lift the asset base of the poorest households.

Third, the negative impact of access to piped water on livelihood outcomes is surprising and complicates simple interpretations. This finding would benefit from further exploration and suggests that infrastructure improvements alone are insufficient for livelihood success.

Fourth, the positive relationship between distance to the Kebele office and livelihood outcomes indicates that households further away may experience fewer administrative constraints or perhaps more autonomy in livelihood choices. This again underscores the complex role of spatial factors and the calls for context-specific analyses (Beegle et al., 2018).

Finally, the lack of significant effect for Treatment 3 (basic nutrition and enhanced nutrition) across all specifications confirms what has been suggested in prior studies: while nutrition interventions are critical for health and human capital outcomes, they are unlikely to impact short-term livelihood or asset accumulation metrics directly (Meinzen-Dick et al., 2011; van den Bold et al., 2013). This validates the importance of designing interventions explicitly intended to affect specific outcomes. However, even though stand-alone effects of nutrition interventions on livelihoods may not be strong, our models suggest that there may be some spillover from the enhanced nutrition arm that positively affected program participants in T1.

5. Conclusions: Spatial factors and implications for targeting in development interventions

The study's main finding is that spatial context is important in explaining program outcomes for SPIR I. We demonstrate that Kebele-group to Kebele-group variation persists even after incorporating spatial covariates across all three outcomes, indicating that households in some locations collectively do better or worse regardless of the treatment they received. Further, treatment impacts for enhanced livelihood depend on distance to market, with households that are farther from markets showing higher improvements due to the livelihood intervention treatment. However, this impact is not observed in female poultry ownership and nutrition diversity. In these two cases, spatial variables do not appear to influence treatment effects. In any case, the change in the estimators of treatment effects after accounting for spatial covariates indicates that location should not be ignored. If spatial factors are not properly accounted for, the treatment effects can be over- or underestimated. There is the risk that what looks like an impact of the intervention may partly reflect the advantages or disadvantages of place. Controlling spatial variables helps with separating program effects from locational effects and understanding how one depends on the other.

After adding spatial variables to the women's empowerment model, treatment effects remain stable and statistically significant, but the spatial variables themselves are not significant. This means that the effects of T1, T2, and T3 are robust to spatial controls, suggesting that treatments directly affect poultry ownership regardless of location. The lack of significance for spatial variables implies that poultry ownership is a relatively spatially independent asset – it can be raised and managed in diverse settings. Given substantial variance remains unexplained at the household level, individual- and household-level factors may help better capture success or failure than spatial covariates. Nevertheless, one can confidently hold that empowerment through small livestock (poultry) can be location resilient; space does not majorly distort treatment effects.

In the nutrition model, adding spatial variables leaves treatment effect estimates mostly unchanged in magnitude. However, T1 becomes statistically less significant after spatial controls, but none of the additional spatial factors were statistically significant. Regardless of the treatment they received, those with access to piped water had larger improvements in diet diversity. Overall, nutrition improvements were resilient irrespective of the spatial context in which they were administered.

As per the livelihoods model, T1 and T2 are significant without interactions. After introducing spatial interactions, we show that distance to markets modifies how treatments appear to work – in this case, livelihood interventions are more effective in more remote areas. This effect is hidden when no interaction is modeled. The main takeaway from the livelihoods model is that the livelihood interventions favored remote contexts that are further away from markets.

Spatial factors influence outcomes, but not uniformly across domains. While distance to markets and infrastructure access did not significantly affect women's empowerment or nutrition outcomes, they were important in shaping livelihood outcomes, particularly when interacting with treatment types. This suggests that interventions aimed at asset accumulation (like poultry ownership) or behavior change (like nutrition counseling) may be less sensitive to spatial context. In contrast, interventions focused on economic strengthening through market participation require more deliberate spatial targeting and adaptation. Thus, blanket assumptions about the impact of remoteness should be avoided. We conclude

that development interventions never occur in a vacuum – where a household is located in relation to spatial factors can matter for program outcomes.

The findings of this study allow us to propose the following implications for targeting in development interventions:

- **Program evaluations must include spatial controls**. Evaluations that ignore space risk over- or under-estimate the effects of treatment arms. Including spatial variables in monitoring and evaluation frameworks helps isolate treatment effects from location advantages or disadvantages.

- **Women's empowerment interventions can be spatially resilient**. Interventions involving small livestock (poultry) and training elements may not require location-based targeting, since their effects are consistent across space. This suggests interventions can be deployed broadly across space without needing to heavily adjust for geographic location.

- **Women's nutrition interventions can be spatially resilient**. The effects of T3 (basic livelihood and enhanced nutrition) on women´s nutrition remained statistically significant after controlling for spatial factors. This also suggests that targeted nutrition counseling and community-based nutrition promotion can be deployed broadly across space without the risk of decreased intervention impact.

- **Livelihoods interventions should be tailored to spatial remoteness**. Livelihoods interventions focused on livestock do not necessarily require access to markets. Livestock-based livelihood interventions work better in remote areas where market access is poor. This means targeting strategies can prioritize more remote households for such interventions.

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Annex 1. Number of households surveyed by Kebele

No.	Region	Woreda	Kebele	Households
1.	Amhara	Bugna	Birkuakua	20
2.	Amhara	Bugna	Debre Roha	22
3.	Amhara	Bugna	Kob	19
4.	Amhara	Bugna	Quaro	15
5.	Amhara	Bugna	Zeblo	18
6.	Amhara	Dahena	A/work	19
7.	Amhara	Dahena	Abam	16
8.	Amhara	Dahena	Arbit	20
9.	Amhara	Dahena	Ayinemariam	22
10.	Amhara	Dahena	Chirguzy	21
11.	Amhara	Dahena	Dura	19
12.	Amhara	Dahena	Gologota	22
13.	Amhara	Dahena	Menshiwa	20
14.	Amhara	Dahena	Seramire	21
15.	Amhara	Dahena	Shimtituku	20
16.	Amhara	Dahena	Siwra	22
17.	Amhara	Dahena	Tigle adinet	21
18.	Amhara	Dahena	Tsamila	22
19.	Amhara	Dahena	Tsirwala	20
20.	Amhara	Dahena	Yekatit dewol	21
21.	Amhara	Gaz Gibla	Arka	19
22.	Amhara	Gaz Gibla	Astequal	22
23.	Amhara	Gaz Gibla	Degola	22
24.	Amhara	Gaz Gibla	Dufqa	22
25.	Amhara	Gaz Gibla	Qewa	21
26.	Amhara	Gaz Gibla	Taba	22
27.	Amhara	Gaz Gibla	Tiqir	19
28.	Amhara	Lasta	Auneyosef	21
29.	Amhara	Lasta	Enjafat	22
30.	Amhara	Lasta	Getermeda	18
31.	Amhara	Lasta	Giraray	21
32.	Amhara	Lasta	Kulmesk	21
33.	Amhara	Lasta	Medagie	22
34.	Amhara	Lasta	Sarzina	22
35.	Amhara	Lasta	Shallo	22
36.	Amhara	Lasta	Sorba	20
37.	Amhara	Lasta	Tadosamba	22
38.	Amhara	Lasta	Tefelamay	20
39.	Amhara	Lasta	Telfetit	22
40.	Amhara	Lasta	Tiraseferie	21
41.	Amhara	Lasta	Wodebiye	21
42.	Amhara	Lasta	yimiriha	22
43.	Amhara	Meket	Agrit	21
44.	Amhara	Meket	Akat	21
45.	Amhara	Meket	Amisa	19
46.	Amhara	Meket	Ansa wuha	22
47.	Amhara	Meket	Arebal	18
48.	Amhara	Meket	Asesa	22
49.	Amhara	Meket	Aydefer	21

50.	Amhara	Meket	Aymat	21
51.	Amhara	Meket	Berekeza	19
52.	Amhara	Meket	Debre Zebit	22
53.	Amhara	Meket	Debre keribe	20
54.	Amhara	Meket	Dibiko	22
55.	Amhara	Meket	Enat Guya	21
56.	Amhara	Meket	Fintire	20
57.	Amhara	Meket	Hana Mekuat	21
58.	Amhara	Meket	Hmusit	9
59.	Amhara	Meket	Jirile	6
60.	Amhara	Meket	Kila	17
61.	Amhara	Meket	Lama Debir	15
62.	Amhara	Meket	Maserit	22
63.	Amhara	Meket	Mebel	18
64.	Amhara	Meket	Mesfina	21
65.	Amhara	Meket	Meskel	20
66.	Amhara	Meket	Serko	22
67.	Amhara	Meket	Timitimat	21
68.	Amhara	Meket	Tiwuha	21
69.	Amhara	Meket	Tsebelat	21
70.	Amhara	Meket	Warkaye	23
71.	Amhara	Meket	Waro	19
72.	Amhara	Meket	Wefchana	20
73.	Amhara	Meket	Woketa	20
74.	Amhara	Meket	Woyra Bere	18
75.	Amhara	Meket	adisge	21
76.	Amhara	Meket	denkena	19
77.	Amhara	Meket	keyafer	10
78.	Amhara	Meket	kolaboya	22
79.	Amhara	Sekota	Akim tsirewa	19
80.	Amhara	Sekota	Bagmila	20
81.	Amhara	Sekota	Bara eyesus	22
82.	Amhara	Sekota	Debre birhan	20
83.	Amhara	Sekota	Etiknu	20
84.	Amhara	Sekota	Jerba	20
85.	Amhara	Sekota	Sawna	18
86.	Amhara	Sekota	Tsata	22
87.	Amhara	Sekota	Tsemera	22
88.	Amhara	Sekota	Zanziba	18
89.	Amhara	Sekota	Zuna	22
90.	Amhara	Sekota	arisherewa	15
91.	Amhara	Sekota	k/astedader	22
92.	Amhara	Sekota	mahbere slasie	19
93.	Amhara	Sekota	mikun	22
94.	Amhara	Wadla	Abidikom	19
95.	Amhara	Wadla	Bete Yohans	21
96.	Amhara	Wadla	Dorera	22
97.	Amhara	Wadla	Gashena	22
98.	Amhara	Wadla	Kon Geter	7
99.	Amhara	Wadla	Kurkur Solela	22
100.	Amhara	Wadla	Lay Talit	22
101.	Amhara	Wadla	Meley	11
102.	Amhara	Wadla	Quana	22
103.	Amhara	Wadla	Semerna	20

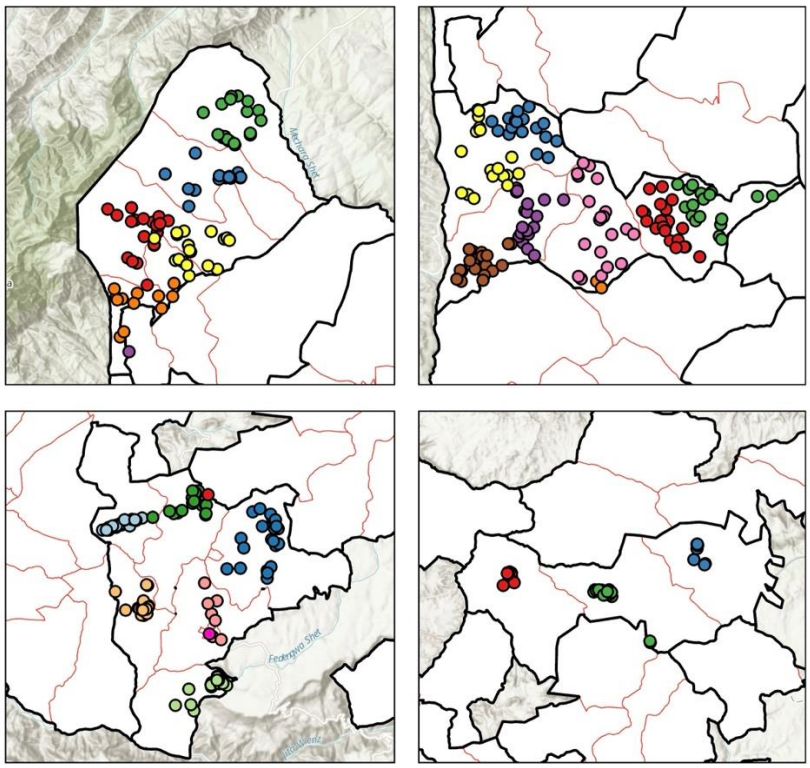
104.	Amhara	Wadla	Washa Michael	21
105.	Amhara	Wadla	Yebeles	22
106.	Amhara	Wadla	Yeneja Kinkina	22
107.	Amhara	Wadla	Yeneja Misigua	21
108.	Amhara	Wadla	Zugora	22
109.	Oromia	Chiro	Ciroo Qallaa	21
110.	Oromia	Chiro	Galma Caffee	21
111.	Oromia	Chiro	Garanigus #1	20
112.	Oromia	Chiro	Garanigus #2	20
113.	Oromia	Chiro	Haalawa Goraa	19
114.	Oromia	Chiro	Madhicho#3	21
115.	Oromia	Chiro	Madhicho#9	21
116.	Oromia	Chiro	Marawaa Rabsuu	17
117.	Oromia	Chiro	Qillisoo	17
118.	Oromia	Chiro	Sheekadam	17
119.	Oromia	Chiro	Teyifee	19
120.	Oromia	Chiro	Waacuu Bosoqaa	21
121.	Oromia	Daro Lebu	Agamtii	22
122.	Oromia	Daro Lebu	B/Hodaa	21
123.	Oromia	Daro Lebu	Bortee	20
124.	Oromia	Daro Lebu	Boyidoo	22
125.	Oromia	Daro Lebu	C/Haraa	20
126.	Oromia	Daro Lebu	D/Robaa	22
127.	Oromia	Daro Lebu	Dhibaa	22
128.	Oromia	Daro Lebu	Fugug	21
129.	Oromia	Daro Lebu	G/Jajju	20
130.	Oromia	Daro Lebu	Gaddoulloo	22
131.	Oromia	Daro Lebu	Galaglee	21
132.	Oromia	Daro Lebu	Gudis	22
133.	Oromia	Daro Lebu	H/Adii	18
134.	Oromia	Daro Lebu	H/Bafanoo	21
135.	Oromia	Daro Lebu	H/Huluqoo	20
136.	Oromia	Daro Lebu	H/Qilee	20
137.	Oromia	Daro Lebu	Hamsiosoo	20
138.	Oromia	Daro Lebu	I/Janataa	22
139.	Oromia	Daro Lebu	Ijaaraa	20
140.	Oromia	Daro Lebu	Jilboo	16
141.	Oromia	Daro Lebu	K/Wacuu	23
142.	Oromia	Daro Lebu	Katora	21
143.	Oromia	Daro Lebu	Kortuu	22
144.	Oromia	Daro Lebu	M/Gudeesaa	23
145.	Oromia	Daro Lebu	Madhisaa	21
146.	Oromia	Daro Lebu	Mardidaa	19
147.	Oromia	Daro Lebu	Miliqaayee	22
148.	Oromia	Daro Lebu	Nannoo	22
149.	Oromia	Daro Lebu	O/Aneeso	22
150.	Oromia	Daro Lebu	O/lakuu	21
151.	Oromia	Daro Lebu	O/lalaba	19
152.	Oromia	Daro Lebu	Qurquraa	21
153.	Oromia	Daro Lebu	Sakina	22
154.	Oromia	Daro Lebu	Satawaa	20
155.	Oromia	Daro Lebu	Sororoo	21
156.	Oromia	Daro Lebu	T/Xuphoo	22
157.	Oromia	Gemechis	Barehemo	20

158.	Oromia	Gemechis	Gigiyyaa	22
159.	Oromia	Gemechis	Gobensaa	17
160.	Oromia	Gemechis	M/DH/D/Sadet	21
161.	Oromia	Gemechis	M/DH/W/Dima	20
162.	Oromia	Gemechis	Odda Dimma	22
163.	Oromia	Gemechis	Qu/Sagariyya	19
164.	Oromia	Gemechis	Ru/Agamti	20
165.	Oromia	Gemechis	W/Deffo	19
166.	Oromia	Gemechis	W/H/Bafanno	21
167.	Oromia	Gemechis	W/H/Dimma	22
168.	Oromia	Grawa	C/W/Jirenya	21
169.	Oromia	Grawa	Caf Janta	22
170.	Oromia	Grawa	Dorobaa 03	21
171.	Oromia	Grawa	Haqa Bas	19
172.	Oromia	Grawa	Ifa Bate	21
173.	Oromia	Grawa	Karahorda	22
174.	Oromia	Grawa	Kufakas	20
175.	Oromia	Grawa	M/J/Balina	22
176.	Oromia	Grawa	Magartuu	22
177.	Oromia	Grawa	Mojo Laga Odaa	22
178.	Oromia	Grawa	Mojo Tasmo	22
179.	Oromia	Grawa	Rasa Nagaya	21
180.	Oromia	Grawa	Tokumajalala	21
181.	Oromia	Grawa	Tutajanata	19
182.	Oromia	Kurfachelle	Hula Janata	21
183.	Oromia	Kurfachelle	Rasa Janata	17
184.	Oromia	Siraro	Honogo Bonkicha	16
185.	Oromia	Siraro	Shelo Abore	20
186.	Oromia	Siraro	Shelo Belela	14
187.	Oromia	Siraro	Shelo Ilancho	15
188.	Oromia	Siraro	Shesha Goyke	22

Annex 2. Creation of the Kebele Groups

Kebeles are grouped into 47 intermediate sized geographic units based on contiguity that we call Kebele groups. These geographies on average contain 4 Kebeles that are proximate to one another and include households that received different treatment arms. As compared to Woredas, each Kebele-group is small enough that the kebeles it contains share underlying similarities on account of being neighbors. Each household in our analysis is spatially allocated to the kebele group it falls in.

The spatial data on the Kebele boundaries was obtained from open source HDE data: 'Humanitarian Data Exchange' (https://data.humdata.org/dataset/cod-ab-eth). When households are visualized on these boundaries, there was some data mismatch, mostly on the edges of these boundaries. Some households had coordinates that belonged to a different Kebele than the one listed in the IFPRI dataset. The image below illustrates the case of four different Kebele groups (black boundaries). The first three groups consist of 4, 4, and 6 Kebeles (red boundaries), respectively, which have been merged to form one Kebele group each. However, within each of the first three groups, households that are spatially within the same Keble boundary may have different Kebele entries in the IFPRI data (colors are based on IFPRI Kebeles). As can be seen, this was a issue affected some households in the first three cases. The fourth group, which consists of three Kebeles, does not have this issue; the households share the same entries as their Kebele boundaries.



Annex 3. List of variables produced for the study

No.	Variable	Alias	Unit or categories (if any)	Type	Var in dataset	Module
1.	Treatment status	trt	T1: L* + N* (1) T2: L* + N (2) T3: L + N* (3) C: PNSP4 only (4)	Nominal	treatment	SPIR_endline_child_anthro
2.	Distance from health post office	hpo	Meters	Ratio	kebele survey_clean_coordinates	
3.	Distance from paved road	prd	Meters	Ratio	kebele survey_clean_coordinates	
4.	Distance from any road	ard	Meters	Ratio	OSM Streets	
5.	Distance from main (primary) road	mrd	Meters	Ratio		
6.	Distance from main secondary road	srd	Meters	Ratio		
7.	Distance from main tertiary road	trd	Meters	Ratio		
8.	Distance from market	mkt	Meters	Ratio	kebele survey_clean_coordinates	
9.	Distance from RUSACCO office	rus	Meters	Ratio		
10.	Distance from DA office	dao	Meters	Ratio		
11.	Distance from Kebele office	kbo	Meters	Ratio		
12.	Kebele households density	khd	Households per sq km	Ratio		
13.	Kebele road density	krd	Km road length per sq km	Ratio	OSM Streets	
14.	Density of primary roads	dpr	Km road length per sq km	Ratio		
15.	Density of secondary roads	dsr	Km road length per sq km	Ratio		
16.	Density of tertiary roads	dtr	Km road length per sq km	Ratio		
17.	Access to public piped water	apw	Binary 0 and 1	Nominal	b09	SPIR_endline_kebele_survey
18.	Presence of flooding	pof	Binary 0 and 1	Nominal	l2_011_m_2	endline_male_module_L
19.	Presence of drought	pod	Binary 0 and 1	Nominal	l2_011_m_1	endline_male_module_L
20.	Presence of erosion	poe	Binary 0 and 1	Nominal	l2_011_m_3	endline_male_module_L
21.	Kebele number of agricultural cooperatives	kac	Number of agricultural cooperatives	Ratio	b14	SPIR_endline_kebele_survey
22.	Kebele number of rural savings and credit cooperatives	ksc	Number of rural savings and credit cooperatives	Ratio	b15	SPIR_endline_kebele_survey
23.	Kebele number of village savings and loan associations	kla	Number of village savings and loan associations	Ratio	b16	SPIR_endline_kebele_survey
24.	Kebele presence of farmer training center	kft	Binary 0 and 1	Nominal	b17	SPIR_endline_kebele_survey
25.	Presence of credit sources	pcs	Number of loans	Ratio	loan_count_drop	endline_female_module_F
26.	Presence of NGOs	pon	Binary 0 and 1	Nominal	e1_05_m_10_1, and e1_05_m_10_2	endline_male_module_E
27.	Availability of fertilizers	aof	Binary 0 and 1	Nominal	d10	SPIR_endline_kebele_survey
28.	Level of education	loe	Those with no education were categorized as 0, grades 1-6 as 2, and 7-22 as 3.	Ordinal	b1_06_hh_10	spir_midline_household_module_b
29.	Gained any format of education	edu	Binary 0 and 1	Nominal	b1_06_hh_10	spir_midline_household_module_b

30.	Ownership of agricultural land	oal	Binary 0 and 1	Nominal	Endline:c1_00_m Baseline:mcp1_c101_01_mm	endline_male_module_C baseline_male_module_C
31.	Ownership of livestock head	olv	Number of livestock	Ratio	Endline: sum of c0_01_1, c0_01_2, and c0_01_5, c0_01_6; Baseline: sum of mbp1_b101_01_mm to mbp1_b101_11_mm	endline_female_module_C baseline_male_module_A
32.	Ownership of poultry	opl	Number	Ratio	Endline: c0_01_3, c0_01_4, Baseline: mbp1_b101_16_mm mbp1_b101_17_mm	endline_female_module_C baseline_male_module_A
33.	Expense on furniture	eof	Bir	Ratio	Endline: h1_01_m_9 Baseline: mhp1_h101_10_mm	endline_male_module_H; baseline_male_module_H
34.	Construction material of house roof	cmr	Thatched roof (1) Corrugated metal roof (2) Mud/sand/stone, etc. (3) Plastic sheeting (4)	Nominal	a1_10_ff	baseline_female_module_A
35.	Construction material of house floor	cmf	Earth (1) Cow dung or cow dung mixed with soil (2) Concrete/stone/cement (3) Tile/bricks (4) Other (6)	Nominal	a1_11_ff	baseline_female_module_A
36.	Construction material of house toilet	cmt	Pit latrine/traditional pit toilet (1) Ventilated improved pit latrine (VIP) (2) Flush toilet (3) Communal (shared w other hh) latrine (4) No facility/bush/field (5) Other (6)	Nominal	map2_a201_ff	baseline_female_module_A
37.	Ownership of a bank account	oba	Binary 0 and 1	Nominal	Endline: f3_13; Baseline: mfp3_f313_ff	endline_female_module_F; baseline_female_module_F
38.	Non-farm Income	nfi	Binary 0 and 1	Nominal	Endline: e1_01_m; Baseline: mip1_i10a_13_ff	endline_male_module_E; baseline_female_module_I
39.	Production related assets	pra	Number of different assets	Ratio	sum of variables a1_03_m_1 through a1_03_m_11	endline_male_module_A
40.	Non-production related assets	npa	Number of different assets	Ratio	Endline: sum of variables a2_03_m_8; a2_03_m_9; a2_03_m_12; a2_03_m_15 Baseline: sum of variables mbp1_b10a_1_ff; mbp1_b10a_2_ff; mbp1_b10a_3_ff; mbp1_b10a_4_ff; and mbp1_b10a_5_ff	endline_male_module_A; baseline_female_module_B
41.	Having farming experience	hfe	Binary 0 and 1	Nominal	c3a_fil_mm, and mmcp2a_filt_mm	baseline_male_module_A

42.	Having family savings	hfs	Bir	Ratio	g3_18_m from both endline, and midline	endline_male_module_G; SPIR_midline_male_module_G
43.	Attending training sessions	ats	Attended no training (0) Animal rearing (1) Food production (2) Both animal rearing and food production (3)	Nominal	m1_09_m_1, m1_09_m_2, m1_09_m_3, m1_09_m_4, m1_09_m_5, m1_09_m_6	SPIR_midline_male_module_M
44.	Female personal savings	fps	Bir	Ratio	f3_25 for both midline and endline	endline_male_module_F; SPIR_midline_female_module_F
45.	Death of a family member	dfm	Binary 0 and 1	Nominal	l2_011_m_7	endline_male_module_L
46.	Presence of violence in Kebele	pvk	Binary 0 and 1	Nominal	g01	SPIR_endline_kebele_survey
47.	Female perception about physical violence	fpv	Unjustified in any case '0', justified in one scenario '1', justified in two scenarios '2', justified in three scenarios '3', and justified in four scenarios '4'.	Ordinal	Endline: Occurrences of '1' in these variables in endline: i5_07_a; i5_07_b; i5_07_c; i5_07_d; Baseline: Occurrences of '1' in i5_07a_ff i5_07b_ff i5_07c_ff i5_07d_ff	endline_female_module_I; baseline_female_module_I
48.	Female perception about freedom to travel alone	fft	No freedom of mobility at all '0', Unconditional freedom of mobility in one case '1', unconditional freedom of mobility in two cases '2', unconditional freedom of mobility in all three cases '3', and only conditional freedom of mobility in all three cases '4'.	Ordinal	Endline: Occurrences of '1' in i5_08_a i5_08_b i5_08_c; Baseline: Occurrences of '1' in i5_8a_ff i5_8b_ff i5_8c_ff	endline_female_module_I; baseline_female_module_I
49.	Female report input in decision regarding spending of income from livelihood sources	frs	No say in spending '0', say in spending on one kind of income '1', say in spending on two types of income '2', and say in spending on all three types of income '3'.	Ordinal	Both endline and midline i1_09_1 i1_09_2 i1_09_3	endline_female_module_I; SPIR_midline_female_module_I
50.	Male report support in gender equitable roles	mrs	No support at all '0', support in one type of household task '1', support in two types of household tasks '2', and support in three types of household tasks '3'.	Ordinal	j2_12 j2_13 j2_14 in both endline and midline	endline_male_module_J; SPIR_midline_male_module_J
51.	Female mental health score	fmh	N/A	Ratio	l3_03_1 to l3_03_9 at both midline and endline	endline_female_module_L; SPIR_Midline_female_module_L
52.	Female undertakes work in last 12 months	fuw	Binary 0 and 1	Nominal	d2_01 and d2_02 at both endline and midline	Endline: endline_female_module_D; Midline: SPIR_midline_female_module_D

53.	Female belongs to micro credit finance institutions	fbc	Binary 0 and 1	Nominal	Endline: f3_09; Baseline: mfp3_f309_ff	Endline: endline_female_module_F; Baseline: baseline_female_module_F
54.	Received a specific food or milk as treatment for severe malnutrition (6-23 months)	rfm	Binary 0 and 1	Nominal	Endline: j4_13; Midline: j4_13_bic	Endline: endline_female_module_J; Midline: SPIR_midline_female_module_J
55.	Household's Number of food types consumed	nft	Number from 0 to 31	Ratio	Endline: sum of select ones from h2_01_1 to h2_01_39; Baseline: sum of select ones from hp2_h201_01_ff to hp2_h201_60_ff	Endline: endline_female_module_H; Baseline: baseline_female_module_H
56.	Child sex at birth	csb	Binary 1 for male and 2 for female	Nominal	ch_sex at endline and at midline	Endline: SPIR_endline_child_anthro; Midline: SPIR_midline_anthro
57.	Child age in months	cam	Number	Ratio	ch_agem at both endline and midline	Endline: SPIR_endline_child_anthro; Midline: SPIR_midline_anthro
58.	Child Height-for-age z-score (HAZ)	haz	z-score	Ratio	ch_haz at both endline and midline	Endline: SPIR_endline_child_anthro; Midline: SPIR_midline_anthro
59.	Child Weight-for-height z-score (WHZ)	whz	z-score	Ratio	ch_whz at both endline and midline	Endline: SPIR_endline_child_anthro; Midline: SPIR_midline_anthro
60.	Child Weight-for-age z-score (WAZ)	waz	z-score	Ratio	ch_waz at both endline and midline	Endline: SPIR_endline_child_anthro; Midline: SPIR_midline_anthro
61.	Child Mid-upper-arm circumference (MUAC)	mac	z-score	Ratio	average of j8_13b, j8_13ba, at both endline and midline	Endline: SPIR_endline_child_anthro; Midline: SPIR_midline_anthro
62.	Child food diversity	cfd	0 to 8	Ratio	j3b_03_1 to j3b_03_18	endline_female_module_J
63.	Female personal income	fpi	Bir	Ratio	Ednline: c0_05d_1 to c0_05d_6, c1_04_1, c1_04_2, c1_04_3, and c1_04_4. Baseline: mcp1_c1_04_1_ff, mcp1_c1_04_2_ff, mcp1_c1_04_3_ff, mcp1_c1_04_4_ff, mcp1_c1_04_5_ff, mcp1_c1_04_6_ff	endline_female_module_C; baseline_female_module_C
64.	Poultry or cash benefit	pcb	Binary 0 and 1	Nominal	m1_13	SPIR_midline_female_module_M

65.	Minimum diet diversity for women	mdd	1 to 10	Ordinal	Endline: h1_01_1, h1_01_3, h1_01_11, h1_01_12, h1_01_13, h1_01_8a, h1_01_8b, h1_01_10, h1_01_9, h1_01_4, h1_01_2, h1_01_6, h1_01_5, h1_01_7. Baseline: hp1_h101_ff, hp1_h203_ff, hp1_h211_ff, hp1_h212_ff, hp1_h213_ff, hp1_h208_ff, hp1_h210_ff, hp1_h209_ff, hp1_h204_ff, hp1_h102_ff, hp1_h206_ff, hp1_h205_ff, hp1_h207_ff	Endline: endline_female_module_H.dta; Baseline: baseline_female_module_H.dta
66.	Minimum diet women	mdw	Binary 0 and 1	Nominal		

Annex 4. Summary statistics of variables produced for the study

Summary statistics of ratio variables:

Alias	Min	Q1	Median	Mean	Q3	Max	SD	Var	N
hpo	3.03	364.24	1023.09	1431.33	1935.41	13082.27	1546.75	2392444	3786
prd	2.15	371.33	1094.71	2038.23	2302.27	20149.97	3013.71	9082453	3786
mkt	6.49	878.87	3254.81	3984.82	5766.01	21620.52	3665.46	13435631	3786
rus	7.31	709.64	2365.84	4348.99	6970.07	29021.65	5046.63	25468507	3786
dao	4.2	341.79	882.03	1303.84	1800.52	12882.32	1447.23	2094484	3786
kbo	4	324.95	908.59	1227.03	1774.63	7705.22	1161.57	1349254	3786
khd	1.54	15.16	25.35	43.9	41.19	3908.89	116.98	13683.21	3707
krd	0.01	0.1	0.23	0.4	0.38	14.63	0.95	0.91	3786
dpr	0	0	0	0.0067	0.00005	0.29	0.019	0.00038	3786
dsr	0	0.000089	0.0207	0.0215	0.0245	0.068	0.018	0.00035	3786
dtr	0	0.0273	0.043	0.052	0.0713	0.322	0.034	0.00116	3786
kac	0	0	1	1.06	1	33	2.43	5.96	3770
ksc	0	0	1	0.75	1	14	1.20	1.44	3770
kla	0	0	1	9.35	19	48	11.98	143.58	3770
pcs	0	1	1	1.55	1	5	0.47	0.22	670
olv_b	0	1	2	2.86	4	47	3.22	10.43	3072
olv_e	0	1	2	2.95	4	27	2.96	8.78	3677
opl_b	0	0	0	1.49	2	40	2.60	6.78	3069
opl_e	0	0	2	2.50	4	28	3.26	10.67	3678
eof_b	0	0	0	26.01	0	5000	181.20	32834.39	3044
eof_e	0	0	0	58.26	0	6000	310.62	96489.99	3704
pra	0	4	6	6.46	9	111	4.38	19.24	3778
npa_b	0	0	0	0.42	0	50	1.85	3.44	3073
npa_e	0	0	1	0.82	1	19	1.27	1.63	3744
hfs_m	0	0	0	160.58	0	80000	1719.03	2955080	2872
hfs_e	0	0	0	138.97	0	30000	1151.16	1325180	3580
fps_m	0	100	200	463.82	441	16300	993.88	987807.6	2087
fps_e	0	160	400	948.60	1000	30000	1843.82	3399700	797
fmh_e	0	0	1	2.28	4	9	2.54	6.45	3777
fmh_m	0	0	2	2.49	4	9	2.7	7.38	3773
nft_e	1	6	8	7.91	10	19	3.02	9.10	3749
nft_b	0	5	7	6.65	8	15	2.60	6.75	3058
cam_e	0	16.2	32.7	33.2	49	75.7	20.7	426	3779
cam_m	0	13	23	25.3	36	696	21.6	466	3661
haz_e	-6	-2.87	-1.82	-1.59	-0.58	5.82	2.02	4.08	2865
haz_m	-5.98	-2.6	-1.7	-1.54	-0.59	5.83	1.63	2.67	3513
waz_e	-4.98	-2.18	-1.23	-1.14	-0.34	4.93	1.62	2.62	2926
waz_m	-4.85	-1.97	-1.19	-1.19	-0.43	4.91	1.25	1.55	3538
whz_e	-4.97	-1.23	-0.44	-0.424	0.37	4.95	1.33	1.76	2903
whz_m	-4.75	-1.2	-0.48	-0.483	0.24	4.59	1.2	1.44	3521
mac_e	0	13.2	14	14	14.8	29.1	1.46	2.14	3229
mac_m	0	12.9	13.7	13.7	14.6	99	3.51	12.4	3406

cfd_e	1	1	2	1.92	3	7	0.94	0.88	1050
cfd_b	1	1	2	1.84	2	6	0.84	0.85	2865
fpi_e	0	0	120	4075	3446	1500000	35154	1235855000	2508
fpi_b	0	0	0	113	15	13700	491	241547	3786
mdd_e	1	2	3	2.79	3	10	1.22	1.48	3660
mdd_b	1	1	2	2.18	3	7	1.1	1.2	2856

Summary statistics of nominal variables:

Var	0	1	NA
apw	2292	1478	16
pof	1149	1300	1337
pod	1373	1076	1337
poe	1126	1322	1338
kft	556	3214	16
ngo	9	2	2775
aof	963	2807	16
edu	1620	1278	888
oal_b	417	2656	713
oal_e	453	3320	13
oba_b	2931	127	728
oba_e	3495	182	109
nfi_b	2929	129	728
nfi_e	2325	123	1338
hfe	409	2648	729
dfm	2387	62	1337
pvk	3582	188	16
fuw_e	3372	409	5
fuw_m	3413	366	7
fbc_e	2770	894	122
fbc_b	2891	167	728
rfm_e	27	37	3722
rfm_m	62	127	3597
pcb	2678	793	315
mdw_e	3368	292	126
mdw_b	2753	103	930

Annex 5. Notes on the calculation of variables

Outcome variables

Women's empowerment model: We calculated theindicator *Difference in ownership of poultry* with the following variables from the SPIR I survey:

Variable	Endline variables	Baseline variables
Ownership of poultry	mbp1_b101_16_mm, mbp1_b101_17_mm	c0_01_3, c0_01_4

Nutrition model: We used Minium Dietary Diversity for women (mdd) as the outcome variable in the Nutrition-related model. Data for mdd was created at baseline and endline using ten food group categories using the following variables[4].

No.	mdd food groups	Baseline variables	Endline variables
1	Grains, roots, and tubers	hp1_h101_ff, hp1_h203_ff	h1_01_1, h1_01_3
2	Pulses	hp1_h211_ff	h1_01_11
3	Nuts and seeds	hp1_h212_ff	h1_01_12
4	Dairy	hp1_h213_ff	h1_01_13
5	Meat, poultry, and fish	hp1_h208_ff, hp1_h210_ff	h1_01_8a, h1_01_8b, h1_01_10
6	Eggs	hp1_h209_ff	h1_01_9
7	Dark leafy greens and vegetables	hp1_h204_ff	h1_01_4
8	Other Vitamin A-rich fruits and vegetables	hp1_h102_ff, hp1_h206_ff	h1_01_2, h1_01_6
9	Other vegetables	hp1_h205_ff	h1_01_5
10	Other fruits	hp1_h207_ff	h1_01_7

Livelihoods model: We used a Household Wealth Index as the outcome variable for the livelihoods model. A detailed explanation of how the index was calculated is available in Annex 6 of this document.

Spatial variables

Six spatial Variables are created using data available in Kebele survey (prd, rus, kbo, dao, hpo, mkt). The geographic location for some Kebeles is, however, missing. But it does not cause missing information for the household data because nearest distance function is used to calculate the distance

[4] The selection of food groups for the mdd-w is based on the methodology proposed by the International Dietary Data expansion Project (link). The mdd-w is a dichotomous indicator based on 10 food groups. Women who have consumed at least five of the 10 possible food groups in the last 24 hours are classified as having minimally adequate diet diversity.

from each household. If information is missing for any Kebele, the distance for the households in that Kebele is calculated from the nearest available. In this sense, the spatial data is created for all 3786 households for each variable. However, missing geographic location for some Kebele's is affecting the values of these spatial variables, generating outliers. Here is the detail of the information available for the spatial variables in Kebele data.

- Data for nearest paved road is available for 169 Kebeles out of the total of 187.
- Data for RUSACCO office location is available for 107 Kebeles out of the total of 187.
- Data for Kebele office location is available for 180 Kebeles out of the total of 187. However, each kebele has its kebele office within the kebele boundary. Therefore, we used geographic centroid as the kebele office location for those Kebeles as following: 1. Wefchana 38.7431113°E 11.7642553°N; 2. Gaddoulloo 40.3879888°E 8.3795877°N; 3. Cafz Janta 41.8190243°E 8.8962784°N; 4. Bagmila 38.8890830°E 12.5831753°N; 5. Marawaa Rabsuu; 6. 40.6873190°E 8.9854123°N; 7. Etiknu 39.0832482°E 12.8553343°N; 8. Jilboo 40.3452442°E 8.6425227°N; 9. Aydefer 38.9883112°E 11.8750855°N.
- Data for DA office location is available for 181 Kebeles out of the total of 187.
- Data for Health post location is available for 178 Kebeles out of the total of 187.

Kebele household density (khd). The data for Kebele household density (khd) variable was created at Kebele level and assigned with same value to each household sharing a Kebele. This variable was created as a ratio of number of households in each Kebele at the baseline to the area of that Kebele in kilometer square. The summary statistics for Kebele household density shows that data is widely spread with huge variance. It implies that the study kebeles range from very low populated to extremely populated kebeles.

Kebele road density (krd). The data for Kebele road density (krd) variable was created at Kebele level and assigned with same value to each household sharing a Kebele. This variable was created as a ratio of total roads length in kilometers in a Kebele to the area of that Kebele in kilometer square. The road length was calculated in ArcGIS Pro using Open Street Maps (OSM) data. The summary statistics for Kebele road density shows that most Kebeles have low road density while there are a few outliers with very high road density. It implies that there is a significant variation between road infrastructure at Kebele level.

Access to public pipped water (apw). The data for access to public piped water (apw) was available in the variable b09 of module SPIR_endline_kebele_survey dataset as a binary variable. We used this data from the Kebele level and joined it with the household data to find that 2,292 households did not have access to public piped water while 1,478 did, and data was missing for 16 households.

Indicators for natural environment attributes

Presence of flooding (pof). The data for presence of flooding (pof) was created from the variable l2_011_m_2 in endline dataset's module "endline_male_module_L". This variable collected binary data from the respondent on the experience of too much rain or flooding during 2019 and 2020 which were the years of implementation of the intervention arms. In this way, this variable is a suitable control for our study. The summary statistics of this variable show that 1,149 households did not experience too

much rain or flooding while 1,300 households did. The data was, however, missing for 1,337 households.

Presence of drought (pod). The data for presence of drought (pod) was created from the variable l2_011_m_1 in endline dataset's module "endline_male_module_L". This variable collected binary data from the respondent on the experience of drought during 2019 and 2020 which were the years of implementation of the intervention arms. In this way, this variable is a suitable control for our study. The summary statistics of this variable show that 1,373 households did not experience drought while 1,076 households did. The data was, however, missing for 1,337 households.

Presence of erosion (poe). The data for presence of erosion (poe) was created from the variable l2_011_m_3 in endline dataset's module "endline_male_module_L". This variable collected binary data from the respondent on the experience of erosion during 2019 and 2020 which were the years of implementation of the intervention arms. In this way, this variable is a suitable control for our study. The summary statistics of this variable show that 1,126 households did not experience erosion while 1,322 households did. The data was, however, missing for 1,338 households.

Indicators for relational resources

Number of agricultural cooperatives (kac). The data for presence of Kebele number of agricultural cooperatives (kac) was created from the variable b14 in endline dataset's module "SPIR_endline_kebele_survey". This variable collected numeric data on the Kebele level to report the number of agricultural cooperatives. This kebele level data was assigned to household level data. The summary statistics of this variable show that most households did not have access to any cooperative, or to one only. However, the data is skewed with a very few households with access to multiple cooperatives.

trt	count	mean_kac	sd_kac	median_kac	min_kac	max_kac
1	949	0.977	0.880	1	0	4
2	970	0.986	1.09	1	0	6
3	945	0.795	0.612	1	0	2
4	922	1.52	4.65	1	0	33

Number of RUSACCO (ksc). The data for presence of Kebele number of rural savings and credit cooperatives (ksc) was created from the variable b15 in endline dataset's module "SPIR_endline_kebele_survey". This variable collected numeric data on the Kebele level to report the Kebele number of rural savings and credit cooperatives. This kebele level data was assigned to household level data. The summary statistics of this variable show that most households did not have access to any cooperative, or to one only. However, the data is skewed with a very few households with access to multiple cooperatives.

trt	count	mean_ksc	sd_ksc	median_ksc	min_ksc	max_ksc
1	949	0.756	0.685	1	0	4
2	970	0.720	0.684	1	0	3
3	945	0.931	2.09	1	0	14
4	922	0.621	0.695	1	0	3

Number of village savings and loan associations (kla). The data for presence of Kebele number of village savings and loan associations (kla) was created from the variable b16 in endline dataset's module "SPIR_endline_kebele_survey". This variable collected numeric data on the Kebele level to report the Kebele number of village savings and loan associations. This kebele level data was assigned to household level data. The summary statistics of this variable show that most households did not have access to any associations, or to one only. However, the data is skewed with few households with access to multiple associations.

trt	count	mean_kla	sd_kla	median_kla	min_kla	max_kla
1	949	10.7	12.4	6	0	48
2	970	11.3	11.2	7	0	40
3	945	11.9	13.0	8	0	45
4	922	3.41	8.94	0	0	37

Presence of Kebele farmer training center (kft). The data for presence of Kebele farmer training center (kft) was created from the variable b17 in endline dataset's module "SPIR_endline_kebele_survey". This variable collected binary data on the Kebele level to report the presence of farmer or pastoral training center. This kebele level data was assigned to household level data. The summary statistics of this variable show that 556 households did not have access to farmer training center at Kebele level while 3,214 households did. The data was, however, missing for 16 households.

trt	count_kft_0	count_kft_1	count_na
1	186	763	0
2	160	810	0
3	149	780	16
4	61	861	0

Presence of credit sources (pcs). The data for presence of credit sources (pcs) was created from the variable loan_count_drop in endline dataset's module "endline_female_module_F". This variable collected data from the respondent on the number of loans availed during 2020. In this way, this variable is a suitable control for our study. The summary statistics of this variable show that while data is only available for 670 households, almost half obtained at least one loan. The data, however, has low spread with small variance.

trt	count	mean_pcs	sd_pcs	median_pcs	min_pcs	max_pcs
1	949	1.22	0.538	1	1	5
2	970	1.13	0.459	1	1	4
3	945	1.08	0.269	1	1	2
4	922	1.19	0.570	1	0	4

Presence of NGOs (ngo). The data for presence of NGOs (ngo) was created from the variable e1_05_m_10_1, and e1_05_m_10_2 in endline dataset's module "endline_male_module_E". This variable collected binary data on the household level to report the support of NGOs for household business. If any of the two variables reported the support of NGOs, the NGO variable was give value 1. The summary statistics of this variable show that while data is only available for 11 households, most did not have support from NGOs.

trt	count_ngo_0	count_ngo_1	count_na
1	1	1	947
2	2	0	968
3	3	1	941
4	3	0	919

Availability of fetilizers (aof). The data for availability of fertilizers (aof) was created from the variable d10 in endline dataset's module "SPIR_endline_kebele_survey". This variable collected binary data on the Kebele level to report the presence of fertilizers. This kebele level data was assigned to household level data. The summary statistics of this variable show that 963 households did not have access to fertilizers at Kebele level while 2,807 households did. The data was, however, missing for 16 households.

trt	count_aof_0	count_aof_1	count_na
1	326	623	0
2	184	786	0
3	234	695	16
4	219	703	0

Indicators for household assets

Level of education (loe). The data for level of education (loe) was created from the variable b1_06_hh_10 in the midline dataset's module "spir_midline_household_module_b". The variable collected household data about the level of education obtained. The data was categorized as following: values 0 or 96 were categorized as 0, implying no education attained. The values 66-68 were categorized as 1, implying basic education. The values 1-6 were categorized as 2, and 7-22

were categorized as 3, implying order of the level of education attained. The summary statistics showed that a majority 1,620 did not attend any education while a few 295 obtained the maximum level of education per our categories. The data was missing for 888 households. The data from loe was further categorized to prepare a binary variable on whether a household's head ever attended any kind of education (edu). The summary statistics showed that more than half never attended any kind of education.

Summary statistics of level of education

0	1	2	3	NA's
1620	185	798	295	888

Ownership of agricultural land (oal). The data for ownership of agricultural land (oal) was created for baseline and endline. Endline data came from variable c1_00_m, and baseline data came from variable mcp1_c101_01_mm in modules endline_male_module_C and baseline_male_module_C respectively. A binary variable was created to show if the household had any ownership of agricultural land.

Ownership of livestock head (olv). The data for ownership of livestock head (olv) was created for baseline and endline. Baseline data was created as a sum of variables from mbp1_b101_01_mm to mbp1_b101_11_mm in baseline dataset's module "baseline_male_module_A". However, this data had some fallacies that needed correction. For example, for household with hh_id 1110900069, each kind of livestock head at baseline was entered 88. It seemed that the total number of livestock was entered repeatedly in each cell at the stage of data entry. However, there was no way to be sure of the actual data for such households. In such cases when the data clearly looked wrong, it was decided to remove those entries and keep the data as missing values NA. For endline, the data was created as a sum of variables c0_01_1, c0_01_2, c0_01_5, and c0_01_6 in endline dataset's module "endline_female_module_C". The summary statistics show that the changes in livestock ownership were not as pronounced.

Ownership of poultry (opl). The data for ownership of poultry (opl) was created for baseline and endline. Baseline data was created as a sum of variables from mbp1_b101_16_mm and mbp1_b101_17_mm in baseline dataset's module "baseline_male_module_A". However, this data had some fallacies that needed correction. However, there was no way to be sure of the actual data for such households. In such cases when the data clearly looked wrong, it was decided to remove those entries and keep the data as missing values NA. For endline, the data was created as a sum of variables c0_01_3, c0_01_4 in endline dataset's module "endline_female_module_C". The summary statistics show that the poultry ownership, on average, increased at the endline.

Expense on furniture (eof). The data for expense on furniture (eof) was created for baseline and endline. Baseline data was created from variable mhp1_h101_10_mm in the baseline dataset's module "baseline_male_module_H". Endline data was created from variable h1_01_m_9 in the endline dataset's module "endline_male_module_H". The summary statistics on both baseline and endline show that while a few households were outliers, most households did not spend any money on furniture, with average around 26 bir at baseline and 58 bir at the endline.

Construction material of house roof (cmr). The data for variable construction material of house roof (cmr) was created using variable a1_10_ff from baseline dataset's module "baseline_female_module_A". The data categorized roof material into four types: (i) Thatched roof; (ii) Corrugated metal roof; (iii) Mud/sand/stone, etc. and (iv) Plastic sheeting. Summary statistics show that most households had first two types of roof material.

Summary statistics of house roof material

Thatched roof (1)	Corrugated metal roof (2)	Mud/sand/stone, etc. (3)	Plastic sheeting (4)	NA's
1690	1307	20	39	730

Construction material of house floor (cmf). The data for variable construction material of house floor (cmf) was created using variable a1_11_ff from baseline dataset's module "baseline_female_module_A". The data categorized floor material into five types: (i) Earth; (ii) Cow dung or cow dung mixed with soil; (iii) Concrete/stone/cement; (iv) Tile/bricks; and (v) Other. Summary statistics show that most households had earth floor.

Summary statistics of house floor material

Earth (1)	Cow dung or cow dung mixed with soil (2)	Concrete/stone/cement (3)	Tile/bricks (4)	Other (6)	NA's
2556	323	74	98	3	732

Construction material of house toilet (cmt). The data for variable construction material of house toilet (cmt) was created using variable map2_a201_ff from baseline dataset's module "baseline_female_module_A". The data categorized toilet material into six types: (i) Pit latrine/traditional pit toilet; (ii) Ventilated improved pit latrine (VIP); (iii) Flush toilet; (iv) Communal (shared w other hh) latrine; (iv) No facility/bush/field; and (v) Other. Summary statistics show that most households either had Pit latrine or no facility at all.

Summary statistics of toilet material

Pit latrine/traditional pit toilet (1)	Ventilated improved pit latrine (VIP) (2)	Flush toilet (3)	Communal (shared w other hh) latrine (4)	No facility/bush/field (5)	Other (6)	NA's
1931	20	1	31	1059	8	736

Ownership of bank account (oba). The data for ownership of bank account (oba) was created for baseline and endline. Baseline data was created from variable mfp3_f313_ff in the baseline dataset's module "baseline_female_module_F.dta". Endline data was created from variable f3_13 in the endline dataset's module "endline_female_module_F.dta". The summary statistics on both baseline and endline show that while a few households were outliers, most households did not have bank account at either baseline or endline.

Non-farm income (nfi). The data for non-farm income (nfi) was created for baseline and endline. Baseline data was created from variable mip1_i10a_13_ff in the baseline dataset's module "baseline_female_module_I.dta". Endline data was created from variable e1_01_m in the endline dataset's module "endline_male_module_E.dta". The summary statistics on both baseline and endline show that while a few households were outliers, most households did not have non-farm income at either baseline or endline.

Production-related assests (pra). The data for production related assets (pra) was created from endline data as the sum of variables a1_03_m_1 through a1_03_m_11 in the baseline dataset's module "endline_male_module_A". The summary statistics show that while a few households were outliers, most households owned an average of around 6 production related assets.

Non-production related assests (npa). The data for non-production related asset (npa) was created for baseline and endline. Baseline data was created as a sum of variables mbp1_b10a_1_ff; mbp1_b10a_2_ff; mbp1_b10a_3_ff; mbp1_b10a_4_ff; and mbp1_b10a_5_ff in the baseline dataset's module "baseline_female_module_B". These variables reported household ownership of radio, mobile phone, gold or gold jewelry, silver or silver jewelry, wristwatches respectively. The same for endline was created as a sum of variables a2_03_m_8; a2_03_m_9; a2_03_m_12; a2_03_m_15 in the endline dataset's module "endline_male_module_A". The summary statistics show that while a few households were outliers, most households owned an average of around less than one production related assets.

Having farming experience (hfe). The data for having farming experience (hfe) was created from baseline data using variables c3a_fil_mm, and mmcp2a_filt_mm in the baseline dataset's module "baseline_male_module_A". These variables collected household data on cultivating a crop during recent Mehr or Belg season. The summary statistics show that most households had farming experience in either of the seasons.

Having family savings (hfs). The data for having family savings (hfs) was created for midline and endline. For midlines, the variable g3_18_m from midline dataset's module "SPIR_midline_male_module_G" was used while for endline the same variable name from endline dataset's module "endline_male_module_G" was used. The summary statistics show that while most households did not have much savings at both midline and endline, the data was far more spread at the midline than the endline.

Attending supply chain training session (ats). The data for attending a supply chain training session (ats) was created for midline using variables m1_09_m_1, m1_09_m_2, m1_09_m_3, m1_09_m_4, m1_09_m_5, m1_09_m_6 from midline dataset's module "SPIR_midline_male_module_M". These variables collected data on household level about animal rearing training sessions including Sheep/goat fattening or rearing, Poultry production, Ox fattening, Beekeeping/honey, and food production sessions including Haricot Bean production, and Vegetable production. The summary statistics showed that while data was only available for a few households, most attended animal rearing sessions.

Summary statistics of supply chain training attendance

Attended no training (0)	Animal rearing (1)	Food production (2)	Both animal rearing and food production (3)	NA's
3	322	24	44	3393

Female personal savings (fps). The data for having female personal savings (fps) was created for midline and endline. For midlines, the variable f3_25 from midline dataset's module "SPIR_midline_female_module_F" was used while for endline the same variable name from endline dataset's module "endline_male_module_F" was used. The summary statistics show that while most households did not have much savings at both midline and endline. The average female personal savings, however, increased at the endline.

Indicators for other control variables

Death of family member (dfm). The data for death of a family member (dfm) was created using variable l2_011_m_7 from endline dataset's module "endline_male_module_L". This variable includes household data on observing the shock of death of a family member. Summary statistics shows that most households did not experience death of a family member.

Presence of violence (pvk). The data for presence of violence at Kebele level (pvk) was created at the household level by assigning Kebele reported violence in variable g01 in the endline dataset's "SPIR_endline_kebele_survey". Summary statistics show that most households did not report existence of violence.

Indicators for women empowerment

Female personal income (fpi). Data on female personal income (fpi) was created at endline using data on income from Livestock ownership and management using variables c0_05d_1 to c0_05d_6, and income from specified agricultural products using variables c1_04_1, c1_04_2, c1_04_3, and c1_04_4. However, the data at the baseline through variables mcp1_c1_04_1_ff, mcp1_c1_04_2_ff, mcp1_c1_04_3_ff, mcp1_c1_04_4_ff, mcp1_c1_04_5_ff, mcp1_c1_04_6_ff was only available for products Eggs, Milk/cream/cheese, Butter, Hides, & Honey, but not on income from selling livestock.

Female perception of physical violence (fpv). Female perception about physical violence (fpv) was created at the household level at endline and baseline using endline variables i5_07_a; i5_07_b; i5_07_c; i5_07_d in module "endline_female_module_I" and baseline variables i5_07a_ff; i5_07b_ff; i5_07c_ff; i5_07d_ff in module "baseline_female_module_I". These variables collected data of women's perception about husband hitting or beating in case she (i) goes out without telling husband; (ii) neglects the children; (iii) argues with him; and (iv) burns the food, respectively. While these variables collected binary data, we created an ordinal data from these variables with the following categories: Unjustified in any case '0', justified in one scenario '1', justified in two scenarios '2', justified in three scenarios '3', and justified in four scenarios '4'. While the data on endline was richer than that at baseline, the variable overall showed that women across the board found physical violence less justified at the endline than at the baseline.

Summary statistics for Female perception about physical violence

	0	1	2	3	4	NA's
fpv_e	1787	615	483	421	371	109
fpv_b	2082	220	103	76	113	1192

Female perception of freedom to travel alone (fft). Female perception about freedom to travel alone (fft) was created at the household level at endline and baseline using endline variables i5_08_a, i5_08_b, and i5_08_c in module "endline_female_module_l" and baseline variables i5_8a_ff, i5_8b_ff, and i5_8c_ff in module "baseline_female_module_l". These variables collected data of women's perception freedom of mobility to go to (i) market; (ii) meet family or friends; and (iii) hospital. We created an ordinal data from these variables with the following categories: No freedom of mobility, unconditional freedom of mobility in one case '1', unconditional freedom of mobility in two cases '2', unconditional freedom of mobility in all three cases '3', and only conditional freedom of mobility in all three cases '4'. While the data on endline was richer than that at baseline, the variable overall showed that lower number of women reported freedom to move alone at endline compared to baseline.

Summary statistics for Female perception about freedom to travel alone

	0	1	2	3	4	NA's
fft_e	1008	587	579	1386	40	186
fft_b	617	175	211	1181	199	1403

Female input in decision-making (frs). Female report input in decision regarding spending of income from livelihood sources (frs) was created at the household level at endline and midline using variables i1_09_1, i1_09_2, i1_09_3 at both endline module "endline_female_module_l" and midline module "SPIR_midline_female_module_l". These variables collected data of women's input in decision regarding spending of income from (i) agriculture; (ii) livestock; and (iii) poultry. We created an ordinal data from these variables with the following categories: No say in spending '0', say in spending on one kind of income '1', say in spending on two types of income '2', and say in spending on all three types of income '3'. While the data on endline was richer than that at midline, the variable overall showed that higher number of women reported a say in spending of income compared to midline.

Summary statistics for Female input in decision regarding spending of income

	0	1	2	3	NA's
frs_e	130	1148	960	851	697
frs_m	68	1258	190	0	2270

Male support of gender equitable roles (mrs). Male report support in gender equitable roles (mrs) was created at the household level at endline and midline using variables j2_12, j2_13, j2_14 at both endline module "endline_female_module_l" and midline module "SPIR_midline_female_module_l". These variables collected data of men's support in household including (i) cleaning; (ii) cooking; and (iii) collecting firewood and water. We created an ordinal data from these variables with the following categories: No support at all '0', support in one type of household task '1', support in two types of

household tasks '2', and support in three types of household tasks '3'. The data did not seem to differ much from midline to endline.

Summary statistics for Male support in gender equitable roles

	0	1	2	3	NA's
mrs_e	720	738	411	564	1353
mrs_m	985	801	616	557	827

Female mental health score (fmh). Female mental health score (fmh) N/A was created at the household level at endline and midline using variables l3_03_1 to l3_03_9 at both endline module "endline_female_module_L;" and midline module "SPIR_Midline_female_module_L". A ratio variable was created as sum of the types of disturbances reported by the respondent female, hence higher the score, lower the mental health. The summary statistics show that the female mental health score decreased on average, though only by a slight margin, at the endline, highlighting better mental health.

Female undertaking work in last 12 months (fuw). Data for female undertaking work in last 12 months (fuw) was created as binary 0 and 1 using data from variables d2_01 and d2_02 at both endline and midline modules endline_female_module_D and SPIR_midline_female_module_D. The summary statistics showed that a slightly larger number of women took work at endline as compared to midline.

Female's belonging to micro credit institutions (fbc). Data for female's belonging to micro credit finance institutions (fbc) as Binary 0 and 1 was created using data from variables f3_09 from endline and mfp3_f309_ff from baseline modules endline_female_module_F and baseline_female_module_F respectively. The summary statistics showed that a slightly lower number of women belonged to micro credit finance institutions at endline as compared to baseline.

Indicators for nutrition

Household's number of food types consumed (nft). The data for household's number of food types consumed (nft) was developed to find food types consumed by the family from 31 total types (see appendix) for which data came from select variables among h2_01_1 to h2_01_39 in Endline module endline_female_module_H, and Baseline: select variables among hp2_h201_01_ff to hp2_h201_60_ff from Baseline module baseline_female_module_H. The summary statistics show that number of food types consumed by a family, on average, increased at the endline as compared to the baseline.

Child nutrition indicators. Six variables for child nutrition and health were created using child_anthro modules at endline and midline. There was a decision made in creation of these variables. Many households had more than one child, and additional children at endline. In order to keep the single data for each household for consistency of analysis, the data for the youngest child for each household was used at both the endline and the midline. Here is the detail of the six variables created in this way:

- Child sex at birth (csb) a Binary 1 for male and 2 for female using ch_sex at endline and at midline.
- Child age in months (cam) using ch_agem at both endline and midline.

- Child Height-for-age z-score (haz) using ch_haz at both endline and midline.
- Child Weight-for-height z-score (whz) using ch_whz at both endline and midline.
- Child Weight-for-age z-score (waz using ch_waz at both endline and midline.
- Child Mid-upper-arm circumference (mac) z-score using average of j8_13b, j8_13ba, at both endline and midline.

Child food diversity (cfd). Child food diversity (cfd) variable was created using UN's eight food group categories for children using the variables enlisted in the following table.

Groups/rows on the Questionnaire	Eight Food Groups	Endline variables	Baseline variables
Breastmilk	1. Breastmilk	j3_08	mjp3_j313_01_ff
A: Foods made from grains	2. Grains, white roots and tubers, and plantains	j3_13_8; j3b_03_1; j3b_03_2; j3b_03_4; j3b_03_5	mjp3b_j3b03_01_ff; mjp3b_j3b03_02_ff; mjp3_j3b03_04_ff; mjp3_j3b03_05_ff
B: White roots, tuber and plantains		j3b_03_6	mjp3_j3b03_06_ff
C: Pulses (beans, peas and lentils)	3. Legumes and nuts	j3b_03_16	mjp3_j3b03_16_ff
D: Nuts and seeds		j3b_03_17	mjp3_j3b03_17_ff
E: Milk and milk products	4. Dairy products (milk, infant formula, yogurt, cheese)	j3_13_3; j3b_03_18	mjp3_j3b03_18_ff
F: Dairy Foods		j3_13_7	
G: Organ meats	5. Flesh foods (meat, fish, poultry and organ meats)	j3b_03_10	mjp3_j3b03_10_ff
H: Red flesh mammals' meat		j3b_03_12	mjp3_j3b03_12_ff
I: Processed meat		j3b_03_11	mjp3_j3b03_11_ff
J: Poultry and other white meats		j3b_03_13	mjp3_j3b03_13_ff
K: Fish and seafood		j3b_03_15	mjp3_j3b03_15_ff
L: Eggs	6. Eggs	j3b_03_14	mjp3_j3b03_14_ff
M: Dark green leafy vegetables	7. Vitamin A-rich fruits and vegetables	j3b_03_8	mjp3_j3b03_08_ff
N: Vitamin A-rich vegetables, roots and tubers		j3b_03_7	mjp3_j3b03_07_ff
O: Vitamin A-rich fruits			
P: Other vegetables	8. Other fruits and vegetables	j3b_03_9	mjp3_j3b03_09_ff
Q: Other fruits			

Women minimum dietary diversity (mdd). Minimum dietary diversity for women (mdd) was created using ten food group categories for women using the variables enlisted in the following table.

No.	MDD-W Food Groups	Endline variables	Baseline variables
1	Grains, roots, and tubers	h1_01_1, h1_01_3	hp1_h101_ff, hp1_h203_ff
2	Pulses	h1_01_11	hp1_h211_ff
3	Nuts and seeds	h1_01_12	hp1_h212_ff
4	Dairy	h1_01_13	hp1_h213_ff
5	Meat, poultry, and fish	h1_01_8a, h1_01_8b, h1_01_10	hp1_h208_ff, hp1_h210_ff
6	Eggs	h1_01_9	hp1_h209_ff
7	Dark leafy greens and vegetables	h1_01_4	hp1_h204_ff
8	Other Vitamin A-rich fruits and vegetables	h1_01_2, h1_01_6	hp1_h102_ff, hp1_h206_ff
9	Other vegetables	h1_01_5	hp1_h205_ff
10	Other fruits	h1_01_7	hp1_h207_ff

https://inddex.nutrition.tufts.edu/data4diets/indicator/minimum-dietary-diversity-women-mdd-w?back=/data4diets/indicators

Indicators for specifics in treatment arms

Poultry and cash benefits (pcb). Data for poultry and cash benefits (pcb) was created Binary 0 and 1 using data from variables m1_13 in module SPIR_midline_female_module_M. The summary statistics show that 793 households received such support.

Treatment for severe malnutrition (rfm). The data for receiving a specific food or milk as treatment for severe malnutrition (rfm) was created as a binary 0 and 1 using Endline variable j4_13 and Midline variable j4_13_bic from modules endline_female_module_J and SPIR_midline_female_module_J respectively. The data statistics, however, shows that data was missing for most of the households.

Annex 6. Calculation of a Wealth Index for SPIR I

To create a wealth index for the SPIR I data, we examine two approaches. These approaches are first explored using the SPIR II data where price estimates for assets are available along with quantities of each asset owned by households.

Overall Wealth - Monetized Value of All Assets

Overall wealth for each household is computed as the monetized value of all assets owned by the household. We take this monetized value of all assets (W_i) to be the most valid measure of household wealth available in the SPIR II data (with the caveat that savings or any asset on which data is not collected is omitted). We then use two approaches as described below to develop a wealth index and examine how well they track this overall wealth measure.

Approach 1. Min-Max Index based Wealth Measure

We use a Min-Max index to normalize the quantity of each asset owned by households to a range of 0 to 1. A value of 0 corresponds to the minimum reported quantity for that asset across all households and a value of 1 corresponds to the maximum. If x_{ij} is the quantity of asset j for household i, the normalized measure for that asset is:

$$s_{ij} = \frac{x_{ij} - min\ (x_i)}{max\ \ (x_i) - min(x_j)}$$

We then compute an asset class index for durable goods (S_1), production assets (S_2), and livestock (S_3) by taking the average of s_{ij} for assets in that asset class. Finally, these three indices are combined into a weighted overall wealth index for each household i as follows:

$$S_i = \sum_{k=1}^{3} w_k s_{ik}$$

Since the asset category indices are based on quantity of units owned, combining them without weights would give equal importance to assets that are significantly different in value. The weights w_k are selected to reflect the contribution of durable goods, production assets, and livestock to overall wealth. We derive these weights based on the proportion of total monetized value from each asset group. In SPIR II, durable goods, production assets and livestock make up 17.8%, 8.5%, and 73.7% of total monetized value across all households. These proportions are used as weights.

Approach 2. Principal Component Analysis (PCA) based Wealth Measure

PCA transforms correlated variables into a set of uncorrelated components. The first principal component, $PC1$, captures the largest variance among the components and can serve as a proxy for wealth. For SPIR II data, $PC1$ captures 6.5% of the variance across 54 assets[5].

Comparison of wealth indices against overall wealth

We compare how well S and $PC1$ track with W using correlation and visual inspection of household wealth rankings:

Correlation: The correlation matrix between the three variables is given below. The Min-Max based index is much more closely correlated with the monetized value of assets than the principal component-based index.

	W_i	S_i	$PC1_i$
W_i	1.000	0.938	0.639
S_i	0.938	1.000	0.681
$PC1_i$	0.639	0.681	1.000

Table 1. Correlation matrix

Household wealth rank: We plot the wealth rank of households based on S and $PC1$ as compared to their rank based on W. Figure 1 shows that S tracks W much more closely than $PC1$.

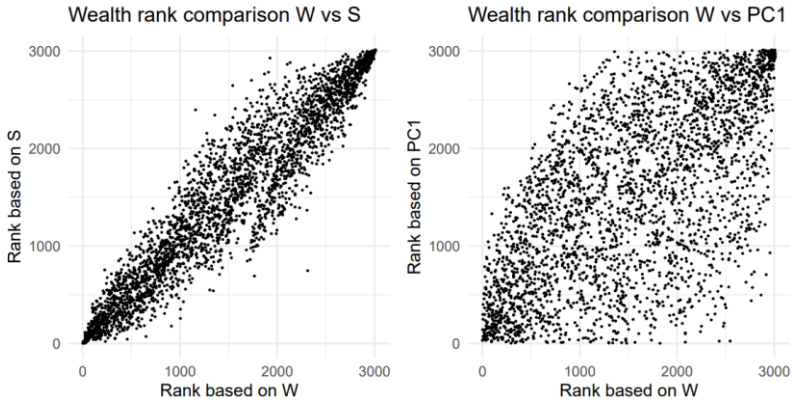


Figure 1. Rank comparison plot

[5] The PCA was applied to 3,011 observations in SPIR II. Three households with very high numbers of livestock were not included in Min-Max as well as PCA based analysis.

Sensitivity to outliers: We re-estimate the Min-Max index and the PCA based wealth indices after removing potential outliers and compare them against the same indices before the removal of outliers[6]. After outliers were removed, the weights for combining the asset indices in the Min-Max index remained stable (18%, 8.5%, 73.5% vs. the original 17.8%, 8.5% and 73.7%). For the 2,899 households in the data, we plot their wealth index rank under the original and outlier-removed analysis. As can be seen in Figure 2 the min-max index retains the rank order better than the PCA based measure.

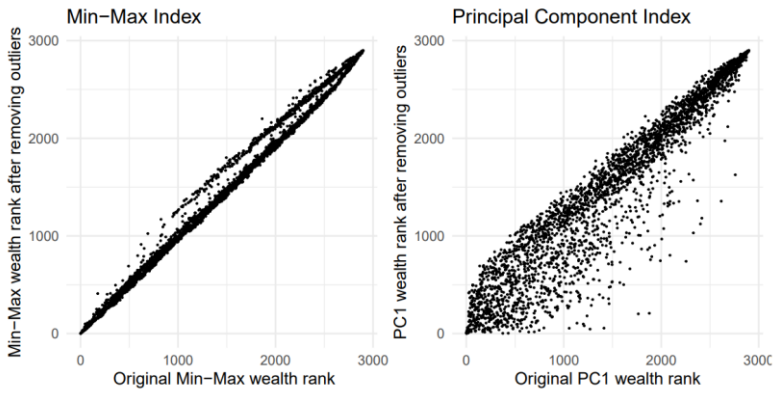


Figure 2. Index sensitivity to removal of outliers

[6] For this analysis, we flag any household whose production asset value, durable goods asset value, or livestock asset value is more than 3 standard deviations from the mean for the asset category for at least one asset class. This removes 112 households from the data leaving 2899 for the index creation. It also reduces the number of assets to be used in the index computation by 4 from 55 to 51. An asset for which all households reported owning zero units cannot be used in the Min-Max or PCA index since it cannot be standardized. The original indices didn't use Iron (for pressing cloths) since no household reported owning one. The removal of outliers removed all households that had reported owning bicycles, Knapsack chemical sprayers, wheelbarrows, and camels leaving 51 assets for the index creation.

Annex 7. Specification of the Nutrition model

We employed a stepwise regression approach to analyze the factors influencing women's nutrition outcomes, specifically focusing on changes in the Minimum Dietary Diversity (mdd_diff). This process unfolded sequentially, gradually increasing the complexity of the model by adding various predictor variables and controls at each stage. We offer a description of the evolution of the model development, explaining the rationale behind each adjustment and the introduction of new variables.

Model I: Baseline Treatments

The first model represents the simplest form of our analysis, focusing solely on the treatment variable (trt) as the predictor of the change in women's dietary diversity. In this model, we test how different treatment conditions (T1, T2, T3) influence the outcome. The model specification is as follows:

```
m1 <- lmerTest::lmer(mdd_diff ~ trt + (1 | kbg), data = data)
```

Here, trt represents the treatment variable, and the (1 | kbg) term introduces a random effect for the variable kbg, which represents kebele group-level variance. This random effect accounts for the Kebele group level clustering in the data, which influence the outcome independently of the treatment itself. The purpose of Model I was to isolate the effect of the treatment and evaluate its initial impact on changes in women's dietary diversity.

Model II: Baseline Covariates

As we progress to the second model, we add baseline variables to control for other factors that made theoretical sense to influence dietary diversity changes beyond the treatment itself. In this case, we introduce baseline ownership of poultry (opl_b), female personal savings (fps_m), presence of flooding (pof), ownership of livestock (olv_b), and non-farm income at baseline (nfi_b), as well as interaction terms between treatment and baseline non-farm income. The inclusion of these covariates allowed for estimation of their impacts on women's nutrition. For example, poultry ownership at baseline may provide an ongoing source of protein or income, while flooding could negatively affect food security.

```
m2 <- lmerTest::lmer(mdd_diff ~ trt + I(opl_b>0) + fps_m + apw + pof + I(olv_b > 0) + trt * nfi_b + (1 |
kbg), data = data)
```

The inclusion of interaction terms like trt * nfi_b allows for the possibility that the effect of the treatment may differ depending on the baseline level of non-farm income. This was important because individuals with higher non-farm income could have more resources to invest in improving their nutrition, making them more likely to benefit from nutritional interventions.

Model III: Endline Control Variables

In the third iteration of the model, we expand the model further to incorporate endline control variables, specifically the endline versions of poultry (opl_e) and livestock ownership (olv_e). Adding

these variables allows us to account for changes in asset ownership over time, which could affect women's ability to access or purchase nutritious foods.

```
m3 <- lmerTest::lmer(mdd_diff ~ trt + I(opl_b>0) + I(opl_e>0) + fps_m + apw + pof + I(olv_b > 0) +
I(olv_e > 0) + trt * nfi_b + (1 | kbg), data = data)
```

At this stage, the model became more comprehensive, accounting for both baseline and endline conditions. We expected these variables to help refine our understanding of how asset ownership dynamics—both at the start and at the end of the intervention—affected women's dietary diversity. Including these controls helped ensure that any observed treatment effects are not confounded by changes in asset ownership.

Model IV: Addressing Small Sample Size (N)

During the modeling process, we realized that the models had an issue with sample size, particularly in the case of certain variables for which their missing values caused a reduction in the number of observations available for analysis. In next iteration of the model, we addressed this by revising the specification to exclude the variables that were causing the drop in sample size, improving the model's robustness and interpretability. This step helped maintain statistical power, as a smaller sample size can lead to unreliable estimates and conclusions.

```
m4 <- lmerTest::lmer(mdd_diff ~ trt + mdd_b + I(opl_b>0) + I(opl_e>0) + apw + I(olv_b > 0) + I(olv_e >
0) + trt * nfi_b + (1 | kbg), data = data)
```

Model IV reintroduces some key baseline variables like mdd_b (Minimum Diet Diversity at baseline), while removing the variables with huge number of missing entries. This revision allowed us to focus on a more tractable set of variables while ensuring we still capture essential predictors related to women's nutrition.

Model V: A Refined, Confident Model

At this point in the process, fifth iteration of the model incorporated a thoughtful selection of both baseline and endline variables, providing a solid foundation for understanding the factors that influence changes in dietary diversity. By maintaining relevant controls such as baseline Minimum Diet Diversity (mdd_b) and baseline non-farm income (nfi_b), this model strikes a balance between explanatory power and statistical precision.

```
m5 <- lmerTest::lmer(mdd_diff ~ trt + mdd_b + nfi_b + I(opl_b>0) + I(opl_e>0) + apw + I(olv_b > 0) +
I(olv_e > 0) + (1 | kbg), data = data)
```

In Model V, we focus on variables that are likely to have direct, meaningful effects on women's nutrition, including asset ownership and income. Additionally, by ensuring a reasonable sample size and avoiding overfitting with too many predictors, this model provided a reliable basis for evaluating the impact of the treatments on the nutritional outcomes.

Model VI: Introducing Spatial Variables

Finally, we take the analysis a step further by incorporating spatial variables (hpo, prd, mkt, khd, dpr) to explore the spatial dimensions of nutrition outcomes. The rationale for introducing these spatial variables is to investigate whether geographical or location-based factors influence the outcomes. For instance, proximity to markets (mkt) or access to paved road (prd) could affect access to nutritious foods, and access to health post office (hpo) could shape dietary patterns.

```
m6 <- lmerTest::lmer(mdd_diff ~ trt + mdd_b + nfi_b + I(opl_b>0) + I(opl_e>0) + apw + I(olv_b > 0) +
                     I(olv_e > 0) + hpo + prd + mkt + khd + dpr + (1 | kbg), data = data)
```

At this stage, we aim to capture the potential influence of broader spatial factors on women's nutrition, beyond individual-level and household-level variables. This model helps us understand if regional or spatial characteristics—such as market access, health infrastructure, or road infrastructure—play a significant role in determining nutritional outcomes.

The stepwise development of our regression models represents a thoughtful, iterative process aimed at building a robust understanding of the factors that influence changes in women's nutrition. Starting with a simple treatment-based model, we gradually introduced baseline and endline controls, addressed issues with sample size, and ultimately incorporated spatial variables to explore more complex, location-specific factors. Each stage in this process revised a layer of control, ensuring that the final model is as comprehensive and accurate as possible for understanding the drivers of women's dietary diversity in the context of the intervention.