COVID-19, climate shocks, and food security linkages: evidence and perceptions from smallholder farming communities in Tanzania

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ONLINE APPENDIX

Appendix A. Figures

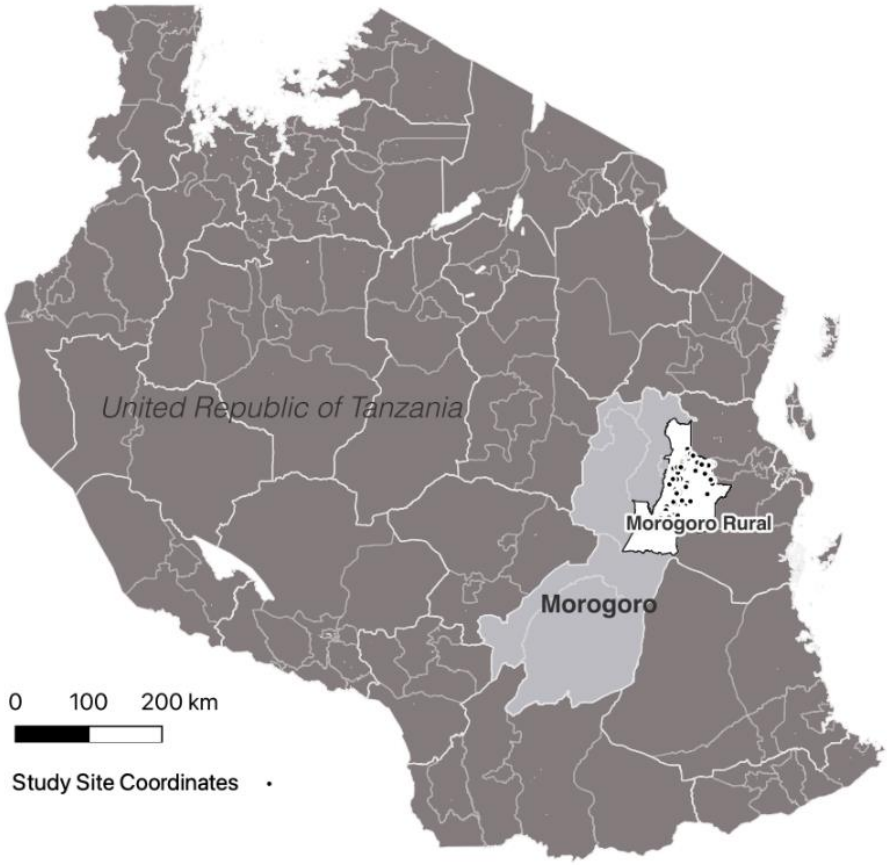

Figure A1. Map of study sites in Morogoro Rural District.

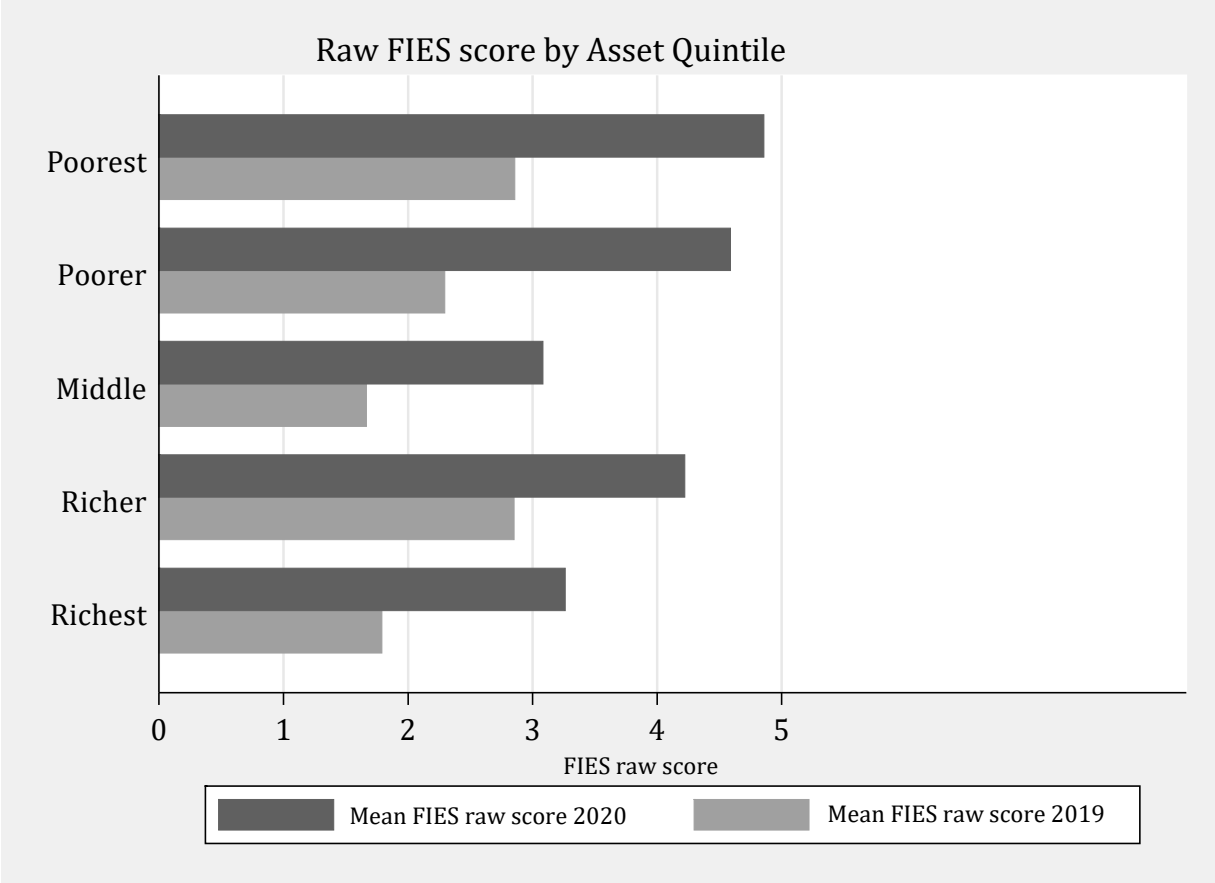

Figure A2. Raw FIES score by asset quintile.

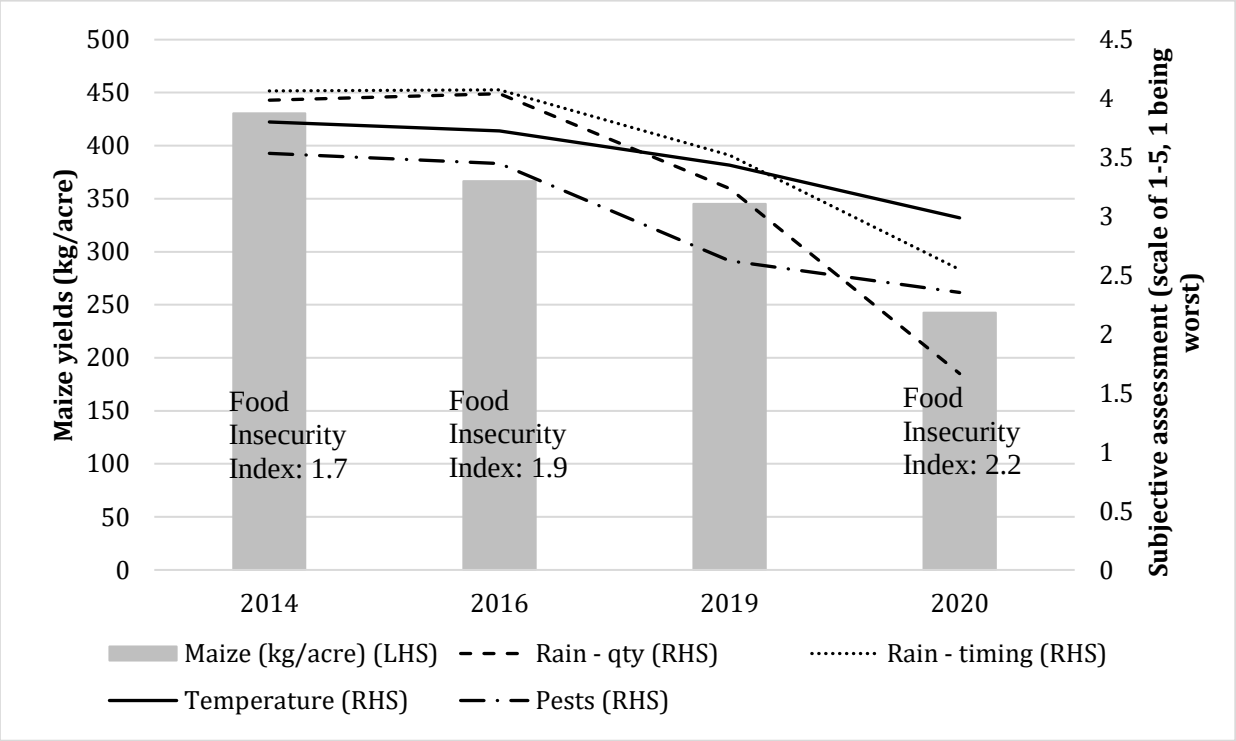

Figure A3. Climatic factors impacting maize yields and food security.

Notes: The bars show average maize yields in kilograms per acre, measured on the left-hand axis (LHS). The lines show respondents' subjective assessments of climatic factors (rain quantity, rain timing, temperature, and pests), which are measured on the right-hand axis (RHS). The Food Insecurity Index is also listed for each year in which we collected data.

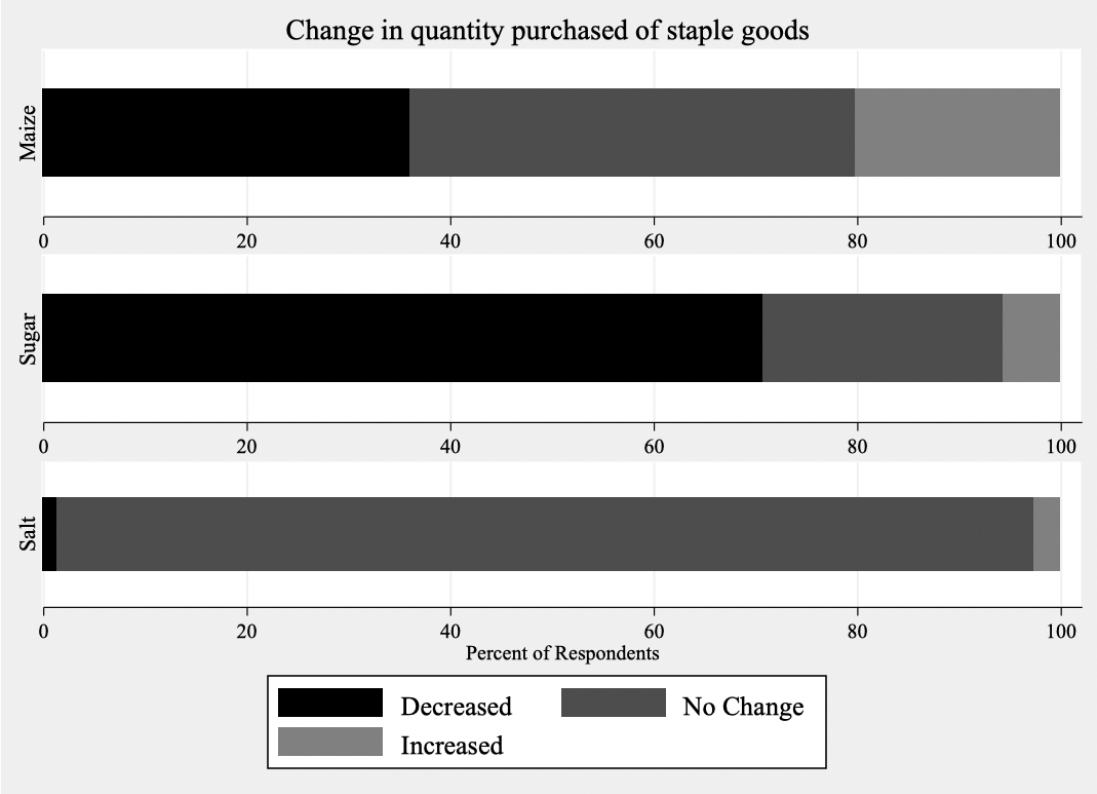

Figure A4. Change in quantity purchased of staple foods during pandemic months relative to this period of a typical year.

Appendix B. Randomization

The initial randomization took place at the village and household levels, with 47 villages randomly selected from a roster of 214 villages in Morogoro Rural that were accessible by vehicle and known to grow maize, provided by the Morogoro District Agricultural Office. In each village, a list was obtained from village leaders of all households who grew maize in 2013. Participant households were drawn randomly from these lists using a random number generator, and assigned to treatment or control groups in the 2014 study.

Appendix C. Tables

Table A1. Summary statistics of household characteristics

	2014		2016		2019		2020	
Descriptive variables	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N
Gender of household head (=1 if female)	0.160 (0.367)	545	-	-	-	-	0.248 (0.432)	315[a,b]
Education completed by household head (yrs)	6.349 (2.022)	545	-	-	-	-	6.894 (2.036)	315[a,b]
Age of household head	45.653 (13.782)	545	-	-	-	-	49.34 (13.21)	315[a,b]
Household size	5.455 (3.709)	545	-	-	-	-	5.6 (2.767)	545
Dependency ratio	157.026 (118.623)	545	-	-	-	-	158.655 (114.378)	545
Land owned (acres)	4.769 (4.027)	545	5.432 (4.353)	521	5.660 (4.239)	532	5.633 (4.545)	545
Land cultivated (acres)	3.769 (2.199)	545	3.288 (2.255)	521	3.377 (2.421)	532	2.639 (2.047)	545
Cultivated maize (=1 if yes)	1 (0)	545	0.906 (0.292)	521	0.763 (0.426)	532	.8377 (.369)	488[b]
Owned main maize plot (=1 if yes)	0.886 (0.317)	545	0.837 (0.370)	521	-	-	0.904 (0.294)	408[b,c]
Maize yield (kg/acre)	430.544 (377.598)	482[c]	365.165 (393.156)	521	345.038 (375.165)	406[c]	243.021 (299.902)	408[b,c]
Sold maize (=1 if sold any maize)	0.158 (0.365)	450[d]	0.294 (0.456)	521	-	-	0.066 (0.248)	408[b,c]

Flooding (= 1 if experienced crop loss due to flooding)	-	-	-	-	-	-	0.689 (0.464)	408[b,c]
Asset Index	0.138 (1.712)	545	0.089 (1.896)	521	0.141 (2.030)	532	0.000 (2.286)	545
Distance to nearest market (km)	-	-	-	-	-	-	4.007 (5.757)	545
Distance to nearest road (km)	-	-	-	-	-	-	2.087 (3.380)	545

Notes: We report summary statistics of household characteristics for the 545 households we reached in the 2020 survey from each year in which they are available.

[a] Observation counts are low for household head demographics, as we only asked about respondent characteristics so N omits respondents who were not the household head.

[b] We asked these questions in a follow-up survey in 2020 in which we reached only 488 out of 545 households.

[c] These questions were only asked to respondents who did grow maize in the relevant year.

[d] Questions about maize sales in 2014 were asked in a follow-up survey in 2015 that did not reach all households.

Table A2. Summary statistics for outcome variables

	2014		2016		2019		2020	
Outcome variables	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N
Total remittances (Tzs)	107,238.6 (96495.4)	88[b]	154,4743.6 (145,197.9)	195[b]	-	-	99296 (91,980)	125[b]
Agricultural wage (Tzs/day)	-	-	-	-	5818.59 (5962.439)	156[a,b]	5365.385 (5116.534)	156[b]
Non-agricultural wage (Tzs/day)	-	-	-	-	13,870.75 (31,022.68)	106[a,b]	9508.491 (15,852.69)	106[b]
Max price paid for maize (Tzs/kg)	460.146 (183.809)	141[b]	-	-	660.797 (163.627)	303[a,b]	672.367 (163.627)	303[b]
Max price paid for salt (Tzs/kg)	-	-	-	-	1109.044 (4270.538)	544[a,b]	1069.504 (785.565	544[b]
Max price paid for sugar (Tzs/kg)	-	-	-	-	2801.357 (465.511)	515[a,b]	4135.107 (2548.452)	515[b]
Food Insecurity Index	1.673 (1.497)	545	1.923 (1.759)	521	-	-	2.165 (1.829)	545
FIES Score	-	-	-	-	2.396 (2.130)	96[a,c]	4.094 (2.335)	96[c]

Notes: We report summary statistics of outcome variables for the 545 households we reached in 2020, for each year in which they are available.
[a] These are recall data asked over the phone in 2020.
[b] Measures of these variables were only elicited from households that indicated that they did receive income from this source or did purchase the specified good during the period under review.
[c] The FIES score was elicited in a follow-up survey in 2020 among 96 randomly selected households from the 2020 respondent pool.

Table A3. Food Insecurity Experience Scale

During the months of March – August (2020) was there a time when, because of lack of money or other resources:	(1) 2020	(2) 2019	(3) Difference
You worried you would not have enough food to eat?	79.17	45.83	33.34 (6.33)
You were unable to eat healthy and nutritious food?	71.88	51.04	20.84 (4.08)
You ate only a few kinds of food?	68.75	51.04	17.71 (3.32)
You skipped a meal?	51.04	25	26.04 (4.83)
You ate less than you thought you should?	64.58	37.5	27.08 (4.98)
Your household ran out of food?	39.58	16.67	22.91 (4.22)
You were hungry but did not eat?	25	10.42	14.58 (3.11)
You went without eating for a whole day?	9.34	2.08	7.26 (2.39)

Notes: Column (1) reports the percentage of respondents who answered yes to the corresponding food insecurity item regarding the period March–August 2020 because of lack of money or other resources. Column (2) reports the same statistic regarding the period March–August 2019. Column (3) reports the difference between 2020 and 2019 levels, with t-stat in parentheses. Number of respondents is 96.

Table A4. Differential changes in market prices by asset quintile

Variables	(1) Max maize price	(2) Max sugar price	(3) Max salt price
2020	78.31	1,558	21.73
	(20.89)	(282.7)	(107.7)
Q1 (Richest)	-	-	-
2020 X Q1	17.81	-367.0	-147.1
	(24.36)	(259.8)	(118.5)
Q5 (Poorest)	-	-	-
2020 X Q5	-10.39	-337.4	-1,058
	(29.20)	(201.8)	(902.7)
Rainfall	0.0238	4.997	-5.530
	(0.487)	(4.235)	(3.130)
Land owned (acres)	5.922	-6.962	-3.492
	(2.305)	(10.03)	(5.902)
Land cultivated (acres)	-12.62	-3.275	5.363
	(4.848)	(13.31)	(5.206)
Constant	583.2	708.8	3,623
	(221.2)	(1,866)	(1,472)
Observations	589	1,001	1,056
R-squared	0.191	0.198	0.010
Number of respondent ID	309	505	534

Notes: The outcome variables are regressed on year dummies and include farmer fixed effects. Q1 refers to the highest quintile, which is the richest 20%, Q5 refers to the lowest asset quintile, or poorest 20%. The asset breakdown uses 2019 asset index scores. Robust standard errors are clustered at the village level and shown in parentheses. Q1 and Q5 omitted because they are time invariant. Regressions are weighted to account for attrition. 2019 is the base year, adjusted for inflation using the Tanzania consumer price index. N is the number of respondents who purchased a given staple good in 2020, respondents who did not purchase the good are omitted.

Appendix D. Constructing attrition weights and measuring cellphone attrition

We calculate the following attrition probit model to determine whether attrition between 2014 and 2020 is random, or whether certain variables predict the likelihood of attriting:

$$A^* = \beta_0 + \beta_1 X_1 + \cdots + \beta_k X_k + \varepsilon$$

$$A = \begin{cases} 1 & A^* > 0 \\ 0 & otherwise \end{cases}$$

where

$$P(A = 1 \,|X_1, X_2, \cdots, X_k) = \phi(\beta_0 + \beta_1 X_1 + \cdots + \beta_k X_k), \qquad (1)$$

where the X_k are a vector of baseline household characteristics thought to be correlated with the likelihood of owning a cellphone, and ϕ is the normal cumulative distribution function. The outcome variable A is equal to 1 for households we do not reach in 2020. As we see in table A5, column (1), asset index, education, and age of household head are negative and significant predictors of attrition. A Wald test shows us that the selected baseline characteristics are jointly significant in predicting attrition, despite their low predictive power (2.3%). The low predictive power can in part be explained by the fact that attrition between 2014 and 2020 occurred for various reasons and cannot be explained solely by phone ownership. For example, a new law went into effect in February 2020 requiring Tanzanians to biometrically register their SIM card, which caused many participants to drop or change their listed phone number, presumably at random. Also, we reached non-phone owning households through community networks. It is worth noting that when we run the same attrition probit specified in (3) with the attrition variable defined as households that did not own a cellphone in 2019, the resulting R-Squared is 13.5, indicating a relatively high ability of our model to predict cellphone-based attrition (column (2) of table A5).

Table A5. Attrition probit predicting households reachable by phone in 2020

Variables (2014 levels)	(1) Attrition	(2) Cellphone attrition	(3) Sample mean
Gender of household head	0.0004	0.1610	0.1673
	(0.0997_	(0.1000)	(0.3734)
Level of education of hh head	-0.0661	-0.0499	5.75
	(0.0175)	(0.0162)	(2.494)
Age of household head	-0.0347	0.0201	46.257
	(0.0158)	(0.0197)	(14.911)
Age of household head squared	0.0004	0.0000	2361.79
	(0.000162)	(0.0002)	(1504.203
Dependency ratio	-0.000238	-0.0003	155.094
	(0.000287)	(0.000388)	(124.099)
Total land owned (acres)	0.00805	-0.0088	5.211
	(0.00793)	(0.0111)	(6.13)
Asset index score	-0.0627	-0.2290	-0.188
	(0.0254)	(0.0504)	(9.525)
Food Insecurity Index score	-0.0348	0.0548	1.649
	(0.0290)	(0.0345)	(1.509)
Constant	1.1090	-1.7680	
	(0.366)	(0.474)	
Observations	1,052	922	1,052
Pseudo R-Squared	0.0296	0.1347	

Notes: Model (1) predicts the likelihood of a household being contacted in 2020, interpreted as total attrition. Model (2) predicts the likelihood of a household listing a phone number in 2019, interpreted as cellphone ownership. Model (1) is used for constructing the attrition weights used throughout this paper. Robust standard errors in parentheses.

Given attrition is not random, we follow Baulch and Quisumbing (2011) to construct inverse probability weights to correct for attrition. We first run an unrestricted probit regression identical to equation (1) except we predict remainers in 2020 (R = 1 for households we do reach in 2020) instead of attritors (A). We then run a restricted version of equation (1), omitting household demographics. The inverse probability weights are then determined by the ratio of the predicted values from the restricted to the unrestricted regressions:

$$W_i = \frac{p^r}{p^u}.$$

This weighting method gives more representation to households that are more similar, along the observed baseline characteristics listed in table A5, to households who were not reached in the 2020 survey. More details can be found in Baulch and Quisumbing (2011). We apply these weights throughout our analysis.

References

Baulch B and Quisumbing A (2011) Testing and adjusting for attrition in household panel data. CPRC Toolkit Note.

Appendix E. Using continuous indices to measure asset and remoteness heterogeneity

Tables A6–A8 show what happens if we interact the asset index as a continuous variable to examine heterogeneous time trends, instead of using this index to generate dummy variables for the top and bottom quintiles, as we do in our primary analysis. We keep the quintile breakdown in our central analysis to show what happens to the poorest and richest segments of the sample who are most likely to face a differential effect. The results of using the continuous variable are in line with our intuition. We use an asset score constructed using principal component analysis of household, productive, and livestock assets in 2019. This variable drops out of the regressions as it is time invariant. The interaction term between asset index and year is negatively correlated with food insecurity (richer households experienced less insecurity and score lower on the Food Insecurity Experience Scale) (table A6), and largely uncorrelated with income (table A7) and staple goods prices (table A8).

Table A6. Food Insecurity regressions with Continuous Asset Index

Variables	(1) Food Insecurity Index	(2) 0 skipped meals	(3) 1 skipped meal	(4) 2 skipped meals	(5) FIES score
Asset Index	-	-	-	-	-
2016	0.262	-0.651	0.667	0.0603	-
	(0.0867)	(0.203)	(0.211)	(0.123)	
2020	0.525	-1.552	1.677	-0.0503	1.414
	(0.159)	(0.389)	(0.343)	(0.132)	(0.377)
2016*Asset Index	-0.125	0.303	-0.222	-0.0773	-
	(0.0398)	(0.101)	(0.0999)	(0.0406)	
2020*Asset Index	-0.170	0.452	-0.389	-0.0598	-0.0255
	(0.0392)	(0.0915)	(0.0764)	(0.0410)	(0.141)
Rainfall	0.000720	-0.00210	0.00204	5.79e-05	-0.00730
	(0.00151)	(0.00410)	(0.00438)	(0.00118)	(0.0089)
Land owned (acres)	-0.00875	0.0230	-0.0229	-0.00166	0.0341
	(0.00810)	(0.0208)	(0.0208)	(0.00802)	(0.0471)
Land cultivated (acres)	-0.0422	0.0895	-0.0538	-0.0364	-0.131
	(0.0198)	(0.0471)	(0.0447)	(0.0215)	(0.0789)
Constant	1.539	8.159	2.942	0.837	5.867
	(0.722)	(1.948)	(2.064)	(0.588)	(4.054)
Observations	1,585	1,585	1,585	1,585	189
R-squared	0.056	0.068	0.073	0.008	0.370
Number of respondent ID	535	535	535	535	96

Notes: Asset Index is a continuous variable taking the 2019 asset score level for each respondent household. It drops out because it is time invariant. Regressions are weighted to account for attrition and include farmer fixed effect. Robust standard errors are clustered at the village level and shown in parentheses.

Table A7. Income source regressions with Continuous Asset Index

Variables	(1) Total remittances (Tzs/year)	(2) Agricultural wages (Tzs/day)	(3) Non-agricultural wages (Tzs/day)
Asset Index	-	-	-
2016	84,735	-	-
	(25,991)		
2020	-4,658	-1,057	-3,197
	(29,241)	(407.2)	(1,678)
2016*Asset Index	-8,743	-	-
	(8,820)		
2020*Asset Index	966.0	-348.3	-282.9
	(13,121)	(224.2)	(473.3)
Rainfall	319.3	-4.918	64.59
	(195.9)	(8.553)	(85.52)
Land owned (acres)	-415.4	68.24	-27.24
	(3,087)	(82.81)	(184.4)
Land cultivated (acres)	12,156	-47.93	-45.57
	(8,175)	(89.33)	(330.4)
Constant	-63,142	8,096	-13,477
	(94,319)	(3,671)	(37,328)
Observations	402	300	203
R-squared	0.189	0.102	0.096
Number of respondents	289	151	102

Notes: Asset Index is a continuous variable taking the 2019 asset score level for each respondent household. It drops out because it is time invariant. Households that do not report receiving income from a given source are dropped from the corresponding regression. Wage and remittance data are deflated using the Tanzania consumer price index. Regressions are weighted to account for attrition and include farmer fixed effects. Robust standard errors are clustered at the village level and shown in parentheses.

Table A8. Price regressions with Continuous Asset Index

Variables	(1) Max maize price (Tzs/kg)	(2) Max sugar price (Tzs/kg)	(3) Max sugar price (Tzs/kg)
Asset Index	-	-	-
2020	79.15	1,393	-259.9
	(20.02)	(193.6)	(296.6)
2020*Asset Index	3.091	25.15	116.1
	(5.395)	(30.42)	(110.3)
Rainfall	0.0205	4.654	-5.810
	(0.485)	(4.092)	(3.312)
Land owned (acres)	5.954	-11.55	-9.516
	(2.307)	(12.07)	(7.651)
Land cultivated (acres)	-12.82	1.470	10.22
	(4.728)	(14.21)	(7.081)
Constant	585.2	873.4	3,770
	(220.2)	(1,799)	(1,569)
Observations	589	1,001	1,056
R-squared	0.190	0.195	0.004
Number of respondents	309	505	534

Notes: Asset Index is a continuous variable taking the 2019 asset score level for each respondent household. It drops out because it is time invariant. The outcome variables are regressed on year dummies and include farmer fixed effects. Regressions are weighted to account for attrition and include farmer fixed effects. 2019 is the base year, adjusted for inflation using the Tanzania consumer price index. N is the number of respondents who purchased a given staple good in 2020, respondents who did not purchase the good are omitted. Robust standard errors are clustered at the village level and shown in parentheses

Table A9 shows the results of interacting year dummies with a continuous remoteness index, constructed by summing the distance of the household to the nearest market plus distance to the nearest road. Interestingly, while the quintile dummy interactions included in our central analysis did not show significant heterogeneity in food insecurity outcomes on the basis of remoteness, when using the continuous remoteness variable we find a positive significant correlation – i.e., more remote households faced additional food insecurity in 2020. Figure A4 presents a likely explanation for this inconsistency. Q5 – the most remote households – are shown to have a lower food insecurity score, whereas the score increases from Q1 – Q4. Further research is needed to understand why the most remote households face less food insecurity. For income and price outcomes, the approach using the continuous remoteness variable is consistent with the quintile approach in that neither yields significant interaction terms. We do not report these here.[1]

[1] Results are available upon request from the corresponding author.

Table A9. Food insecurity regressions with continuous remoteness variable

Variables	(1) Food Insecurity Index	(2) 0 skipped meals	(3) 1 skipped meal	(4) 2 skipped meals	(5) FIES Score
Remoteness	-	-	-	-	-
2016	0.128	-0.432	0.557	-0.0861	-
	(0.113)	(0.295)	(0.287)	(0.126)	
2020	0.307	-0.915	0.991	-0.0349	1.586
	(0.180)	(0.446)	(0.400)	(0.153)	(0.477)
2016*Remoteness	0.0199	-0.0289	0.0114	0.0241	-
	(0.0131)	(0.0312)	(0.0249)	(0.0141)	
2020*Remoteness	0.0331	-0.0939	0.101	-0.000945	-0.0315
	(0.0126)	(0.0303)	(0.0323)	(0.0173)	(0.0498)
Rainfall	0.000736	-0.00181	0.00155	0.000330	-0.00711
	(0.00151)	(0.00413)	(0.00438)	(0.00116)	(0.009)
Land owned (acres)	-0.0136	0.0350	-0.0317	-0.00456	0.0278
	(0.00776)	(0.0200)	(0.0201)	(0.00765)	(0.0508)
Land cultivated (acres)	-0.0420	0.0876	-0.0498	-0.0381	-0.130
	(0.0200)	(0.0481)	(0.0456)	(0.0214)	(0.0693)
Constant	1.555	7.964	3.209	0.729	5.813
	(0.725)	(1.975)	(2.083)	(0.575)	(4.098)
Observations	1,585	1,585	1,585	1,585	189
R-squared	0.049	0.061	0.074	0.009	0.374
Number of respondents	535	535	535	535	96

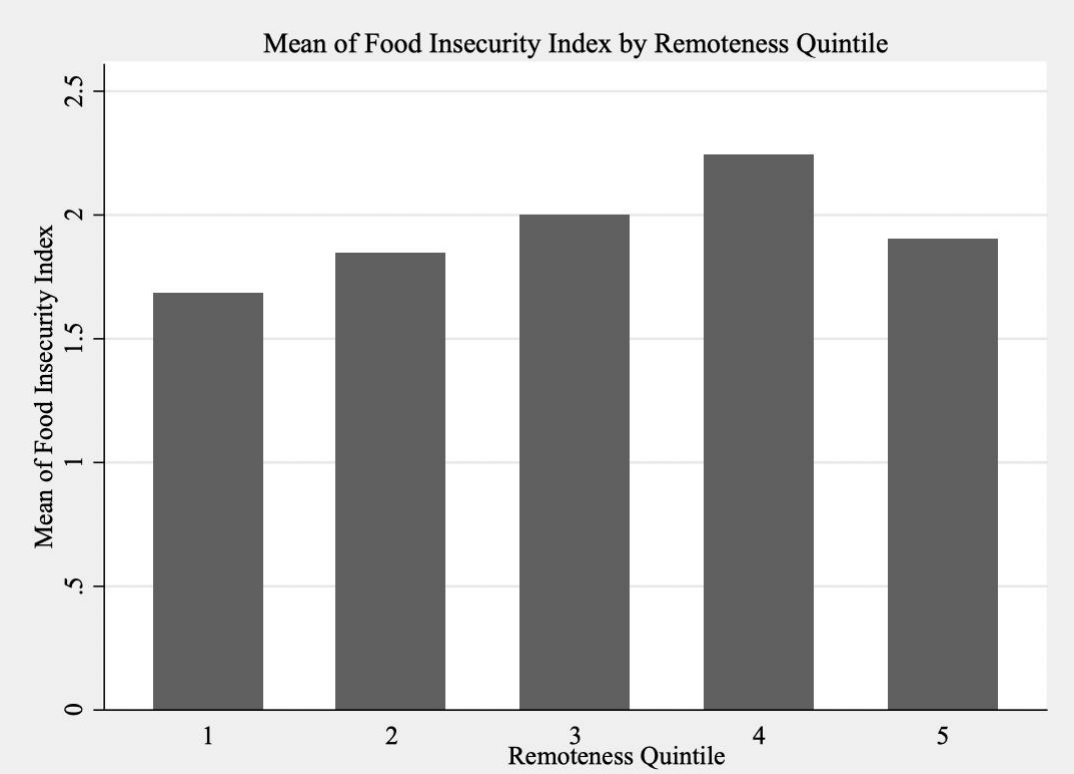

Figure A5. Mean of Food Insecurity Index by remoteness quintile.