**Supplementary Material**

**Additional information on the model specification and complete coefficients for the models.**

We estimated three-level Multinomial Hierarchical Linear Models. Hierarchical Models were granted because null models indicated that the variance partition at both the municipal and the state levels was statistically meaningful (i.e. the variance to explain food insecurity is clustered or distributed along the three levels and is not exclusively an individual phenomenon[[1]](#footnote-1)).

Even though the food security scale seems to yield an ordinal score it was necessary to examine with a Brant test a key assumption of ordinal logistic models i.e. the same independent variables, with the same strength, predict the odds of passing from food security to mild food insecurity as they would predict passing from moderate food insecurity to severe food insecurity. A significant Brant test with the person-level models indicated that the assumption was violated and therefore odds ratios do not change in the same way for every category. The Brant test showed that the ordinal nature of the data is questionable and the assumption of proportional odds was violated, thus a multinomial regression model was deemed more adequate(27).

These models use the multinomial logit link function and yield unit-specific results (i.e. they can be interpreted as the expected change in the outcome associated with a one-unit increase in the relevant predictor, holding constant other covariates). Once the three equivalent models at the person level were established, levels two and three were built following parallel forms as to keep comparability (27). For parsimony in the results, all the estimated models had random intercepts at the three levels and all the slopes were fixed. The models were estimated with sampling weights at the household level and the maximum number of macro-iterations was set at 1,000. We used STATA version 15(28) and HLM software version 7(29) to run the analyses.

The modeling strategy went from the person-level to the municipality level and then to the state level. The upper levels were adjusted with variables at the previous levels. Dummy variables were left uncentered and continuous variables at the municipality and state levels were grand-mean centered to estimate between-cluster variation(30). This means that each model has different specifications and therefore each one provides a different perspective of the phenomenon. For instance, the economic variables operating as predictors at the municipality level aim to explain greater variance than when an equivalent measure is used at the state level. Moreover, when state-level models are estimated, less controls are used at the municipality level as means to avoid multicollinearity issues. The consequence of the modelling technique is that the coefficients of the variables may change when used as covariates or as independent variables because models at different levels explain different between-group variability i.e. different clustering. The results section focuses on the coefficients specified at the appropriate level of estimation. All the models included person-level sociodemographic variables to adjust the prevalence of food insecurity. Therefore, the adjusted models are estimated for a person with an average education and living in an average household size in their municipality, that has a man as head of household, in a family without children under 5 years old and without elders 70 years or older. Variance estimates remained always significant at the municipality and state levels. The results from the null model and the complete models one to four are in tables 1-5. In contrast to the tables presented in the paper, these models include all the coefficients for person level covariates and the variance decomposition.

As a robustness test, the same models were estimated using a fixed-effects approach. While Hierarchical Linear Models allow the intercepts to randomly vary across municipalities and across states, the fixed-effects approach works with the opposite assumption. In these models group means (i.e. municipality-level means and state-level means) are fixed in a single group-mean and assumes that there is no clustering at any level. The assumption implies that the observed associations prevail regardless of the group variability. The importance of the robustness check is that the results are less likely to be a statistical artifact based on the choice of using a Hierarchical Linear Model.

**Table 1. HLM null model for Food Insecurity.**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Model | **Severe FI** | | | **Moderate FI** | | | **Mild FI** | | |
| **Null** | Coeff | OR | CI | Coeff | OR | CI | Coeff | OR | CI |
| **Intercept** | -1.315 | 0.269 | (0.210,0.344) | -1.027 | 0.35 | (0.277,0.463) | -0.567 | 0.567 | (0.440,0.732) |
|  |  |  |  |  |  |  |  |  |  |
| **Random effects** | **SD** | **Var** |  | **SD** | **Var** |  | **SD** | **Var** |  |
| **Muni. level** | 0.686 | 0.470 |  | 0.635 | 0.404 |  | 0.532 | 0.283 |  |
| **ICC** |  | 63.86% |  |  | 57.3% |  |  | 48.54% |  |
| **State Level** | 0.516 | 0.266 |  | 0.548 | 0.301 |  | 0.548 | 0.300 |  |
| **ICC** |  | 36.14% |  |  | 42.7% |  |  | 51.45% |  |
| **Total Variance** |  | 0.736 |  |  | 0.705 |  |  | 0.583 |  |

*Note:* The dependent variable was always the Food Insecurity Scale (ELCSA) and the reference category is “Food Security”. The null model indicates the prevalence of each level of FI once clustering is accounted. Moreover, it provides a baseline for the variance decomposition of subsequent models. Abbreviations: FI, Food Insecurity; Coeff, Coefficient; OR, odd Ratio; CI, confidence Interval; GDP, *Per Capita* Gross Domestic Product (quintiles); HH, Household.

**Table 2. HLM Model 1 for Food Insecurity.**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Model | **Severe FI** | | | **Moderate FI** | | | **Mild FI** | | |
| **Mod 1** | Coeff | OR | CI | Coeff | OR | CI | Coeff | OR | CI |
| **Intercept** | -4.041 | 0.018 | (0.014,0.022) | -3.165 | 0.042 | (0.033,0.054) | -2.035 | 0.131 | (0.103,0.166) |
| **Person level** |  |  |  |  |  |  |  |  |  |
| Child <5 | 0.125 | 1.133 | (1.121,1.146) | 0.134 | 1.143 | (1.132,1.154) | 0.068 | 1.070 | (1.061,1.080) |
| Elder>70 | -0.541 | 0.582 | (0.570,0.595) | -0.407 | 0.665 | (0.653,0.678) | -0.188 | 0.828 | (0.815,0.842) |
| Education | -0.729 | 0.482 | (0.480,0.484) | -0.559 | 0.572 | (0.570,0.574) | -0.374 | 0.687 | (0.686,0.689) |
| HH size | 0.162 | 1.176 | (1.172,1.179) | 0.150 | 1.162 | (1.159,1.166) | 0.130 | 1.139 | (1.136,1.142) |
| Female as head of HH | 0.376 | 1.456 | (1.439,1.473) | 0.200 | 1.221 | (1.209,1.234) | 0.085 | 1.088 | (1.079,1.099) |
|  |  |  |  |  |  |  |  |  |  |
| **Muni. level** |  |  |  |  |  |  |  |  |  |
| Disasters | 0.458 | 1.581 | (1.284,1.945) | 0.323 | 1.382 | (1.144,1.671) | 0.198 | 1.220 | (1.050,1.417) |
| Density | -0.295 | 0.744 | (0.693,0.799) | -0.258 | 0.772 | (0.725,0.823) | -0.274 | 0.760 | (0.722,0.801) |
| **Random effects** | **SD** | **Var** |  | **SD** | **Var** |  | **SD** | **Var** |  |
| **Muni. level** | 0.659 | 0.435 |  | 0.598 | 0.358 |  | 0.457 | 0.209 |  |
| **ICC** |  | 66.5% |  |  | 56.2% |  |  | 44.1% |  |
| **State Level** | 0.468 | 0.219 |  | 0.529 | 0.279 |  | 0.514 | 0.265 |  |
| **ICC** |  | 33.5% |  |  | 43.8% |  |  | 55.9% |  |
| **Total Variance** |  | 0.654 |  |  | 0.637 |  |  | 0.474 |  |
| **R2** |  | **0.111** |  |  | **0.096** |  |  | **0.187** |  |

*Note:* The dependent variable was always the Food Insecurity Scale (ELCSA) and the reference category is “Food Security”. Model 1 focuses on the influence of two municipality level variables on food insecurity (i.e. vulnerability to disasters and population density) while accounting for individual level covariates. Results show that disasters are positively associated with all levels of FI and density is negatively associated with all levels. Abbreviations: FI, Food Insecurity; Coeff, Coefficient; OR, odd Ratio; CI, confidence Interval; GDP, *Per Capita* Gross Domestic Product (quintiles); HH, Household.

**Table 3. HLM Model 2 for Food Insecurity.**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Model | **Severe FI** | | | **Moderate FI** | | | **Mild FI** | | |
| **Mod 2** | Coeff | OR | CI | Coeff | OR | CI | Coeff | OR | CI |
| **Intercept** | -3.926 | 0.019 | (0.017,0.023) | -3.038 | 0.048 | (0.042,0.055) | -1.9277 | 0.145 | (0.127,0.167) |
| **Person level** |  |  |  |  |  |  |  |  |  |
| Child <5 | 0.128 | 1.136 | (1.124,1.149) | 0.132 | 1.141 | (1.130,1.152) | 0.070 | 1.073 | (1.063,1.082) |
| Elder>70 | -0.550 | 0.577 | (0.565,0.589) | -0.415 | 0.660 | (0.648,0.673) | -0.192 | 0.825 | (0.811,0.840) |
| Education | -0.733 | 0.481 | (0.479,0.483) | -0.561 | 0.571 | (0.569,0.573) | -0.376 | 0.687 | (0.685,0.689) |
| HH size | 0.159 | 1.172 | (1.168,1.176) | 0.149 | 1.161 | (1.158,1.165) | 0.128 | 1.1365 | (1.133,1.140) |
| Female as head of HH | 0.378 | 1.458 | (1.441,1.476) | 0.203 | 1.225 | (1.212,1.238) | 0.086 | 1.090 | (1.079,1.100) |
|  |  |  |  |  |  |  |  |  |  |
| **Muni. level** |  |  |  |  |  |  |  |  |  |
| Disasters | 0.253 | 1.287 | (1.066,1.555) | 0.109 | 1.115 | (0.941,1.323) | 0.015 | 1.015 | (0.883,1.168) |
| Poverty Quintiles | 0.410 | 1.507 | (1.419,1.600) | 0.388 | 1.474 | (1.398,1.555) | 0.354 | 1.425 | (1.362,1.490) |
|  |  |  |  |  |  |  |  |  |  |
| **Random effects** | **SD** | **Var** |  | **SD** | **Var** |  | **SD** | **Var** |  |
| **Muni. level** | 0.591 | 0.349 |  | 0.534 | 0.285 |  | 0.421 | 0.177 |  |
| **ICC** |  | 82.7% |  |  | 79.4% |  |  | 69.4% |  |
| **State Level** | 0.269 | 0.073 |  | 0.273 | 0.074 |  | 0.280 | 0.078 |  |
| **ICC** |  | 17.3% |  |  | 20.6% |  |  | 30.6% |  |
| **Total Variance** |  | 0.422 |  |  | 0.359 |  |  | 0.255 |  |
| **R2** |  | **0.427** |  |  | **0.491** |  |  | **0.562** |  |

*Note:* The dependent variable was always the Food Insecurity Scale (ELCSA) and the reference category is “Food Security”. Model substitutes population density for a composite index of poverty. Results show how poverty is significant for all levels of FI while disasters now affect only severe FI. Abbreviations: FI, Food Insecurity; Coeff, Coefficient; OR, odd Ratio; CI, confidence Interval; GDP, *Per Capita* Gross Domestic Product (quintiles); HH, Household.

**Table 4. HLM Model 3 for Food Insecurity.**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Model | **Severe FI** | | | **Moderate FI** | | | **Mild FI** | | | |
| **Mod 3** | Coeff | OR | CI | Coeff | OR | CI | Coeff | | OR | CI |
| **Intercept** | -4.087 | 0.017 | (0.014,0.020) | -3.224 | 0.040 | (0.032,0.049) | -2.131 | | 0.119 | (0.097,0.145) |
| **Person level** |  |  |  |  |  |  |  | |  |  |
| Child <5 | 0.124 | 1.138 | (1.119,1.144) | 0.133 | 1.143 | (1.132,1.154) | 0.068 | | 1.070 | (1.061,1.079) |
| Elder>70 | -0.543 | 0.581 | (0.569,0.593) | -0.407 | 0.666 | (0.654,0.678) | -0.191 | | 0.826 | (0.812,0.839) |
| Education | -0.729 | 0.482 | (0.480,0.484) | -0.559 | 0.571 | (0.570,0.574) | -0.375 | | 0.687 | (0.686,0.689) |
| HH size | 0.162 | 1.175 | (1.172,1.179) | 0.150 | 1.162 | (1.159,1.166) | 0.130 | | 1.139 | (1.136,1.142) |
| Female as head of HH | 0.378 | 1.459 | (1.442,1.476) | 0.199 | 1.220 | (1.209,1.233) | 0.087 | 1.091 | | (1.081,1.101) | |
|  |  |  |  |  |  |  |  | |  |  |
| **Muni. level** |  |  |  |  |  |  |  | |  |  |
| Disasters | 0.453 | 1.573 | (1.281,1.932) | 0.318 | 1.374 | (1.138,1.661) | 0.197 | | 1.218 | (1.051,1.412) |
| Density | -0.264 | 0.768 | (0.719,0.820) | -0.235 | 0.791 | (0.744,0.841) | -0.263 | | 0.768 | (0.732,0.807) |
| **State Level** |  |  |  |  |  |  |  | |  |  |
| Food Programs | -0.034 | 0.967 | (0.918,1.018) | -0.020 | 0.980 | (0.918,1.046) | 0.006 | | 1.006 | (0.943,1.073) |
| Change in power | 0.022 | 1.022 | (0.789,1.325) | 0.039 | 1.039 | (0.755,1.430) | 0.091 | | 1.095 | (0.800,1.498) |
| Per Capita GDP | -0.277 | 0.758 | (0.692,0.831) | -0.276 | 0.758 | (0.677,0.850) | -0.248 | | 0.780 | (0.697,0.873) |
| **Random effects** | **SD** | **Var** |  | **SD** | **Var** |  | **SD** | | **Var** |  |
| **Muni. level** | 0.67003 | 0.449 |  | 0.606 | 0.367 |  | 0.458 | | 0.210 |  |
| **ICC** |  | 90.5% |  |  | 79.6% |  |  | | 67.7% |  |
| **State Level** | 0.21747 | 0.047 |  | 0.308 | 0.094 |  | 0.317 | | 0.100 |  |
| **ICC** |  | 9.4% |  |  | 20.4% |  |  | | 32.3% |  |
| **Total Variance** |  | 0.496 |  |  | 0.462 |  |  | | 0.310 |  |
| **R2** |  | **0.326** |  |  | **0.655** |  |  | | **0.531** |  |

*Note:* The dependent variable was always the Food Insecurity Scale (ELCSA) and the reference category is “Food Security”. Model 3 is equal to Model 1 at the municipal level, but the three state-level variables were added. Population Density and Disaster remain as significant predictors for all levels of FI. Per Capita GDP was the only state-level variable associated with the three levels of FI. Abbreviations: FI, Food Insecurity; Coeff, Coefficient; OR, odd Ratio; CI, confidence Interval; GDP, *Per Capita* Gross Domestic Product (quintiles); HH, Household.

**Table 4. HLM Model 4 for Food Insecurity.**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Model | **Severe FI** | | | **Moderate FI** | | | **Mild FI** | | |
| **Mod 4** | Coeff | OR | CI | Coeff | OR | CI | Coeff | OR | CI |
| **Intercept** | -3.911 | 0.020 | (0.017,0.023) | -3.036 | 0.048 | (0.041,0.056) | -1.971 | 0.139 | (0.120,0.161) |
| **Person level** |  |  |  |  |  |  |  |  |  |
| Child <5 | 0.126 | 1.134 | (1.122,1.148) | 0.132 | 1.141 | (1.130,1.152) | 0.069 | 1.072 | (1.063,1.082) |
| Elder>70 | -0.551 | 0.576 | (0.564,0.589) | -0.415 | 0.660 | (0.648,0.673) | -0.193 | 0.824 | (0.810,0.838) |
| Education | -0.732 | 0.481 | (0.479,0.483) | -0.561 | 0.571 | (0.569,0.572) | -0.376 | 0.687 | (0.685,0.688) |
| HH size | 0.159 | 1.172 | (1.168,1.176) | 0.149 | 1.161 | (1.158,1.165) | 0.128 | 1.136 | (1.133,1.139) |
| Female as head of HH | 0.377 | 1.458 | (1.441,1.476) | 0.202 | 1.224 | (1.212,1.237) | 0.086 | 1.089 | (1.079,1.100) |
|  |  |  |  |  |  |  |  |  |  |
| **Muni. level** |  |  |  |  |  |  |  |  |  |
| Disasters | 0.287 | 1.333 | (1.105,1.608) | 0.139 | 1.149 | (0.969,1.362) | 0.047 | 1.048 | (0.913,1.203) |
| Poverty Quintiles | 0.374 | 1.453 | (1.366,1.546) | 0.358 | 1.430 | (1.354,1.512) | 0.324 | 1.383 | (1.323,1.446) |
| **State Level** |  |  |  |  |  |  |  |  |  |
| Food Programs | -0.051 | 0.951 | (0.909,0.994) | -0.037 | 0.963 | (0.922,1.006) | -0.019 | 0.981 | (0.938,1.027) |
| Change in power | -0.059 | 0.942 | (0.752,1.180) | -0.057 | 0.945 | (0.759,1.177) | 0.019 | 1.019 | (0.814,1.275) |
| Per Capita GDP | -0.138 | 0.871 | (0.800,0.948) | -0.143 | 0.867 | (0.799,0.941) | -0.135 | 0.874 | (0.804,0.950) |
| **Random effects** | **SD** | **Var** |  | **SD** | **Var** |  | **SD** | **Var** |  |
| **Muni. level** | 0.596 | 0.355 |  | 0.538 | 0.289 |  | 0.420 | 0.176 |  |
| **ICC** |  | 91.4% |  |  | 88.9% |  |  | 79.3% |  |
| **State Level** | 0.183 | 0.033 |  | 0.189 | 0.036 |  | 0.214 | 0.046 |  |
| **ICC** |  | 8.5% |  |  | 11.1% |  |  | 20.7% |  |
| **Total Variance** |  | 0.388 |  |  | 0.325 |  |  | 0.222 |  |
| **R2** |  | **0.473** |  |  | **0.539** |  |  | **0.619** |  |

*Note:* The dependent variable was always the Food Insecurity Scale (ELCSA) and the reference category is “Food Security”. Model 4 is equal to Model 2 at the municipal level, but the three state-level variables were added. Coefficients for the poverty index decreased slightly but Disaster was now only significant for Severe FI. State-level predictors confirm that GDP per capita is significant at all levels and change in political party is not significant. However, Food Assistance Programs reduce severe FI in municipalities without disaster vulnerability, on the third quintile of the poverty index, and in an average state-level GDP. Abbreviations: FI, Food Insecurity; Coeff, Coefficient; OR, odd Ratio; CI, confidence Interval; GDP, *Per Capita* Gross Domestic Product (quintiles); HH, Household.

1. Interestingly, the variability was higher at the municipality level for severe (64%) and for moderate food insecurity (57%) but it was slightly lower for mild insecurity (48.5%); estimates in the null model of table 1. This means that the differences between states are more important in explaining mild food insecurity while differences between municipalities matter more in explaining the other types of food insecurity. [↑](#footnote-ref-1)