Household Food Insecurity and Children's Development: A Longitudinal GEE Analysis

BIOSTAT 653 Final Project Presentation

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Research Question

Objective: How does food insecurity affect early academic growth, and does socioeconomic status (SES) mediate this effect?

Background:

- Early academic performance (kindergarten to 3rd grade) predicts long-term success
- Food insecurity: reduced food quality/quantity due to limited resources (USDA)
- Affects ~10–15% of U.S. households with children

From related studies:

- Cross-sectional studies link food insecurity to lower math scores and behavioral issues
- Longitudinal studies show persistent food insecurity predicts slower academic growth
- **Gap**: How does SES change the impact of food insecurity on learning?

Data Source & Sample

ECLS-K:2011 Dataset

- **~18,000 children** from kindergarten through 5th grade
- Nationally representative multistage probability sample
- Multiple sources: child assessments, parent/teacher surveys

Analytic Sample

- **Three waves:** Spring Kindergarten (Wave 2), Spring 1st grade (Wave 4), Spring 5th grade (Wave 9)
- ~54,000 person-wave observations

> **Sample Retention:** Wave 2 (~17,000) → Wave 4 (~15,000) → Wave 9 (~13,000)

ECLS-K:2011 = Early Childhood Longitudinal Study, Kindergarten Class of 2010-11

Variables & Data Processing

Key Variables

- **Outcomes:** Math & science IRT scores
- **Primary Predictor:** Food security (18-item USDA module)
- **Confounders:** Race, sex, SES, disability, household size, urbanicity

Data Processing

- Extracted from 2.3 GB raw data
- Reshaped wide to long format
- Cleaned categorical variables

> **Food Security Measures:** Raw scores (0-18), IRT scale scores, categorical status (secure/low/very low)

Missing Data: GEE uses all available data per wave. Wave-specific sampling weights ensure national representativeness.

IRT = Item Response Theory; GEE = Generalized Estimating Equations; USDA = U.S. Department of Agriculture

GEE Framework

Why GEE?

- Population-averaged effects
- Handles within-child correlation across time
- Robust to correlation misspecification
- Efficient handling of missing data

Main Model

$$E(Y_{it}) = \beta_0 + \beta_1(\text{TIME}_{it}) + \beta_2(\text{TIME}_{it}^2) + \beta_3(\text{FS\_SCALE}_{it}) + \beta_4(\text{TIME}_{it} \times \text{FS\_SCALE}_{it}) + \beta_5(\text{FS\_BASELINE}_i) + \beta_6(\text{TIME}_{it} \times \text{FS\_BASELINE}_i) + \boldsymbol{\gamma}^\top \mathbf{X}_i$$

β_3: Contemporaneous effect of food security

β_4: Effect on growth rate (trajectory)

β_5: Between-child baseline differences

Working Correlation: Independence structure (selected via QIC, an extended AIC for GEE models)

Candidates Tested: 1. **Independence**: No correlation between time points 2. **Exchangeable**: Equal correlation across all pairs 3. **AR(1)**: Exponentially decaying correlation by time lag 4. **Unstructured**

Results:

- Math QIC: 5,777,447 (Independence) vs. 5,855,001+ (others)
- Science QIC: 2,373,308 (Independence) vs. 2,386,789+ (others)

FS = Food Security; GEE = Generalized Estimating Equations; QIC = Quasi-likelihood under Independence Criterion

Moderation & Sensitivity Analyses

> **Research Question:** Does food insecurity impact differ by socioeconomic status (SES)?

Approach

- **Three-way interactions:** SES Quartile × Food Security × Time
- **Interpretation:** *Simple slopes* calculated for each SES quartile
- **Hypothesis:** Strongest effects in lowest SES quartile

$$
\begin{aligned}
E(Y_{it}) = {} & \beta_0 + \beta_1(\text{TIME}_{it}) + \beta_2(\text{TIME}_{it}^2) \\
& + \beta_3(\text{FS\_SCALE}_{it}) + \beta_4(\text{TIME}_{it} \times \text{FS\_SCALE}_{it}) \\
& + \beta_5(\text{FS\_BASELINE}_i) + \beta_6(\text{TIME}_{it} \times \text{FS\_BASELINE}_i) \\
& + \sum_{q=2}^{4} \beta_{7q}(\text{SES\_Q}_q) + \sum_{q=2}^{4} \beta_{8q}(\text{SES\_Q}_q \times \text{FS\_SCALE}_{it}) \\
& + \sum_{q=2}^{4} \beta_{9q}(\text{SES\_Q}_q \times \text{TIME}_{it} \times \text{FS\_SCALE}_{it}) \\
& + \boldsymbol{\gamma}^{\top}\mathbf{X}_i
\end{aligned}
$$

Sensitivity Analyses

- Alternative correlation structures (exchangeable, AR(1), unstructured)
- Categorical food security specification (high/marginal, low, very low)

Covariates Controlled:

- *Demographics*: sex, race/ethnicity, disability status
- *Family*: SES composite, household size
- *School:* type (public/private), urbanicity

Results: Main GEE Models

Food Security

No main effect on math or science

Weak negative time × food insecurity effect

Note: **fs_scale** and **fs_baseline** range from 0-18, with higher values indicating greater food insecurity.

Table 2: GEE Coefficients for Mathematics and Science Models

Mathematics Model				Science Model			
Predictor	**Estimate**	**p-value**	**Sig**	**Predictor**	**Estimate**	**p-value**	**Sig**
Intercept	50.16	<0.001	***	Intercept	35.58	<0.001	***
time	10.46	<0.001	***	time	-1.17	<0.001	***
$time^2$	12.65	<0.001	***	$time^2$	11.00	<0.001	***
fs_scale	-0.07	0.761		fs_scale	0.10	0.541	
fs_baseline	0.03	0.889		fs_baseline	0.09	0.593	
ses_baseline	6.13	<0.001	***	ses_baseline	3.93	<0.001	***
sex = Female	-2.00	<0.001	***	sex = Female	-0.88	<0.001	***
race = Black	-7.67	<0.001	***	race = Black	-5.58	<0.001	***
race = Hispanic	-4.56	<0.001	***	race = Hispanic	-4.51	<0.001	***
race = Asian	1.29	0.002	**	race = Asian	-3.30	<0.001	***
race = Other	-1.03	0.036	*	race = Other	-0.54	0.065	.
disability = No	7.06	<0.001	***	disability = No	3.31	<0.001	***
household_size	-0.39	<0.001	***	household_size	-0.52	<0.001	***
urban = Suburban	-0.66	0.010	**	urban = Suburban	0.11	0.512	
urban = Rural	-0.07	0.800		urban = Rural	0.74	<0.001	***
urban = Other	-1.66	0.011	*	urban = Other	0.27	0.516	
time × fs_scale	**-0.30**	**0.072**	**.**	**time × fs_scale**	**-0.22**	**0.069**	**.**
time × fs_baseline	-0.14	0.377		time × fs_baseline	-0.18	0.120	

Results: Main GEE Models

Socioeconomic Status

Higher SES strongly predicts higher scores

Other findings

- Math & Science Trends
- Girls scored lower in both subjects
- Children without disability scored higher

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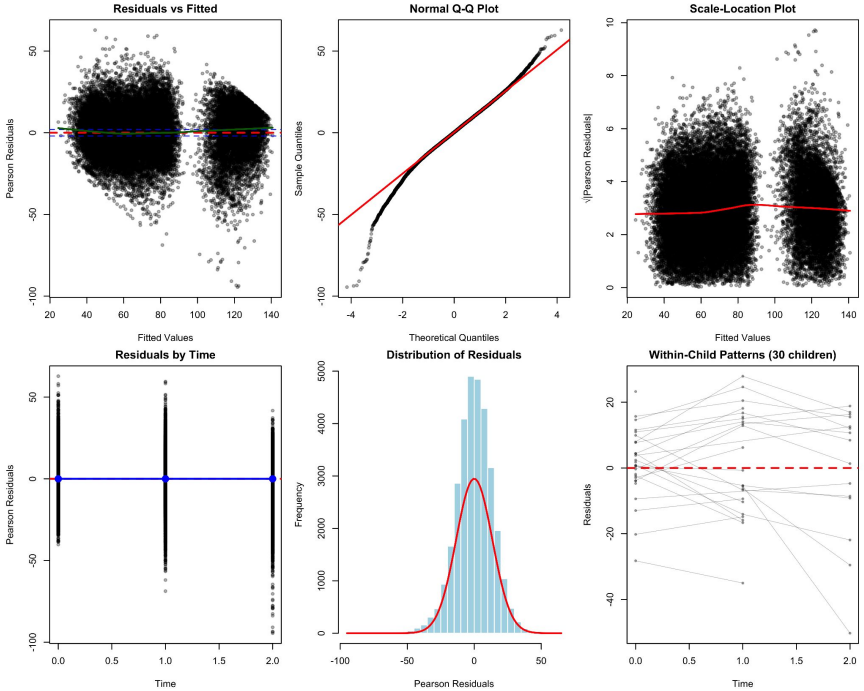
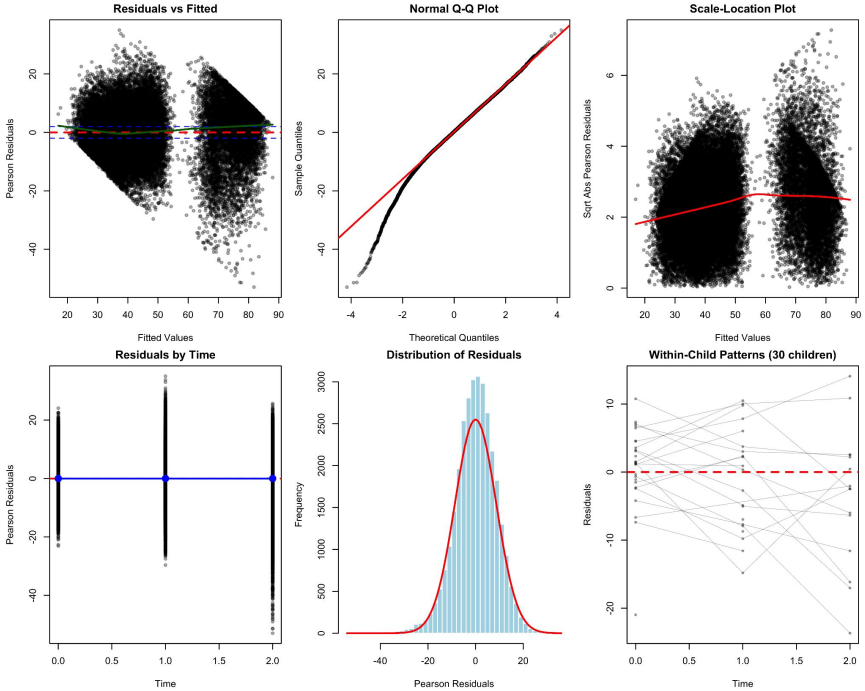
Model Diagnostic: Main GEE Models

Mathematics GEE Model



Science GEE Model



Results: SES Interaction

- **Lowest SES (Q1):**

Food insecurity slows growth
– Math: slope = –0.53
– Science: slope = –0.39

- **Middle SES (Q2–Q3):**

Positive interaction terms reduce the slowdown
– Effects become smaller as SES increases

- **Highest SES (Q4):**

Three-way interaction reverses the slope
– Math: –0.53 + 0.99 = +0.47
– Science: –0.39 + 1.08 = +0.69
– Food insecurity no longer slows growth

Table 3: SES Moderation Coefficients: Food Security × Time × SES Quartile

Term	Model	Estimate	p-value	Signif.
Main Effect				
Time × Food Security	Math	–0.529	0.0026	**
Time × Food Security	Science	–0.387	0.0025	**
Three-Way Interaction: SES Quartile				
Time × Food Security × Q2	Math	0.328	0.0020	**
Time × Food Security × Q3	Math	0.528	< 0.001	***
Time × Food Security × Q4	Math	0.994	< 0.001	***
Time × Food Security × Q2	Science	0.187	0.0179	*
Time × Food Security × Q3	Science	0.520	< 0.001	***
Time × Food Security × Q4	Science	1.078	< 0.001	***

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Conclusion & Discussion

Key Findings

- **No Robust Main Effects for Food Insecurity**
  - Food insecurity showed **no significant association** with math/science scores or with growth rate.
- **SES as a Key Moderator**
  - **Lowest SES** (Q1): **Strongest negative association** between food insecurity and academic growth.
  - **Higher SES** (Q3 – Q4): Effect drops sharply and is **nearly absent** in the highest SES group.
- **Why?**
  - **Low SES:** Food insecurity adds to existing stressors → **greater vulnerability**
  - **High SES:** More stable routines & parental support → **greater buffering**

Implications for Policy & Practice

- **School-Based Supports:** Strengthen schools' role in providing consistent meals and learning environments.
- **Tailored Interventions:** Support should reflect **family context**. Low SES: food assistance paired with tutoring and after-school programs. High SES: help maintain stable routines, manage transitional stress.

Limitations & Future Work

Limitations

- **Measurement Bias:** **Parent-reported** food insecurity and SES may involve recall or social desirability bias.
- **Unmeasured Confounders:** Parental stress, housing instability, unstable unemployment and other unobserved factors may influence associations.
- **Missing Data Assumptions:** Although GEE handles incomplete outcomes under MAR/MCAR, missingness related to **unobserved** factors may still bias estimates.

Future Work

- **Examine Underlying Pathways:** Examine **teacher-child relationships; children stress responses; school engagement** by integrating teacher reports and behavioral data with test scores.
- **Improve Measurement:** Use more **frequent** academic assessments to capture short-term learning changes and identify sensitive developmental periods.
- **Understand Family Experiences:** Use **qualitative/mixed-methods** to explore how families across SES levels experience and cope with food insecurity, helping design interventions that match their real needs.

Thank You!