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Food Insecurity and Educational Achievement: A Multilevel

Generalization of Poisson Regression

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Food Insecurity and Educational Achievement: A Multi-level Generalization of Poisson Regression

Abstract

This research examined the relationship between food insecurity, the National School Lunch Program, and academic achievement in Georgia public schools. A multilevel Poisson regression model was used to examine these relationships. Findings confirm a strong inverse relationship between poverty, as exhibited by participation in the National School Lunch Program, and academic achievement. The strength of the relationship was stronger for fifth grade students than for eighth grade students. Human capital, as measured by percent of population with college degrees, had a positive relationship with academic achievement measures.

Background and Objectives

Food insecurity has been shown to be especially detrimental to children's mental and educational development. In Georgia, 300,000 more people fell into poverty from 2008 to 2009, a 20-percent increase that exceeded the national average (Schneider 2010). Moreover, in 2011, an estimated 26.3% of the state's children live in poverty (FRAC 2011 (a)). Along with poverty, food insecurity has also risen in the state. Georgia is currently ranked seventh highest in the nation for food hardship rates, with 22% of Georgia's residents indicating times in the past twelve months without adequate resources to secure sufficient food for the family (FRAC 2013). This research examines the relationship between food insecurity, the National School Lunch Program (NSLP) and academic achievement in Georgia public schools using a multilevel generalized linear model.

The NSLP subsidized the cost of lunch for over one million students in Georgia schools in 2011 (FRAC 2013). Participation in NSLP and the School Breakfast Program (SBP) provides significant ramifications on educational achievement. Several studies (*e.g.*, Alaimo, Olson and Frongillo 2001; Meyers *et al*. 1988) have indicated that children who are hungry are less likely to be ready to learn and more apt to exhibit behavioral problems than children that arrive at school with adequate nutrition. Schools where 40% or more of the students get free or reduced price lunches also qualify for Title I federal funds to pay for special programs to close this achievement gap. The objective of this study is to identify the key associations between NSLP participation and academic performance of 5th and 8th grade students in Georgia. The hypothesis of interest is that there is a strong inverse relationship between poverty/food insecurity, as exhibited by participation in NSLP, and achievement test scores in reading and mathematics at those levels.

Introduction

Despite federal food assistance and private charitable programs, food insecurity is a persistent national and local problem, affecting 17.8% of all households and 27.9% of households with children in Georgia (Gunderson *et al*. 2011). Food insecurity refers to limited or uncertain availability of, or inability to acquire, nutritionally adequate, safe, and acceptable foods due to financial resource constraint (Bickel *et al*. 2000). According to the USDA, 635,000 (16.9%) households in Georgia were food insecure from 2008-2010, and approximately 240,000 households in Georgia (6.4%) were classified as very low in food security (FRAC, 2012).

One problem arising from food insecure households is that children in these homes are at increased risk for academic and socio-emotional difficulties (Cook & Frank 2008). The federal government's response to inadequate sources of food includes food assistance programs such as the Supplemental Nutrition Assistance Program (SNAP), the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) and others. These programs attempt to alleviate hunger and address the negative effects that hunger and malnutrition have on an individual's health, educational development, and growth. Programs aimed at assisting children in particular include the NSLP and the School Breakfast Program (SBP). The NSLP exists in roughly 97% of the nation's school districts, serving 30 million lunches per day (Estey & Ciambella 2005).

Food Insecurity in Georgia

As the nation's economy declined during the Great Recession (2007 to 2009) and slow recovery, an increasing number of Georgians lived on the financial edge, where even a small change in a family's employment situation could immediately plunge them into poverty. Major cities in the state had poverty rates at critical levels, including Athens-Clarke (33.8%) and Atlanta (22.6%; U.S. Census 2010). These areas demonstrated high levels of food insecurity among children, especially among the working poor, as Georgia's unemployment rate increased rapidly over this period.

As the unemployment rate climbed, along with gas prices, food prices, and housing costs, "getting-by", especially for households with children, meant relying on low-cost foods or cutting the size of meal portions. Against this backdrop, the importance of subsidized or free school meals becomes obvious (Bradford & Medora 2008), especially because food insecurity and poverty are highly correlated. Other factors associated with an increased likelihood of experiencing food insecurity include low levels of education, living in a single parent household, and living in a Hispanic-headed household (Hamilton *et al*. 1997). Dunifon and Kowaleski-Jones (2004) concluded that family income is significantly and negatively associated with continuous food insecurity. They also indicated that black children are more likely to be marginally food insecure and that paternal education is associated with a reduced likelihood of marginal food insecurity.

The consequences of food insecurity in early childhood include limiting a child's cognitive and socio-emotional development which ultimately can impair school achievement and, thus, long-term productivity and economic potential. Jyoti, Frongillo, and Jones (2005) have shown that, by the third grade, children who had been food insecure in kindergarten incurred a 13% decline in their reading and math test scores compared to their food secure peers. Hungry children are also more likely to suffer from hyperactivity, absenteeism, generally poor behavior, and poor academic functioning (Murphy *et al*. 1998). Nord (2009) echoed other findings and found that food insecure children exhibit more behavioral problems and lower math and reading achievement scores. To prevent or alleviate hunger at school, and potentially prevent several of the consequences arising from food insecurity, the USDA's Food and Nutrition Service developed the NSLP, established under the National School Lunch Act in 1946.

Hinrichs (2010) found the NSLP led to a significant increase in educational opportunity and attainment, but he did not observe a significant increase in health levels from childhood to adulthood. Subsidized lunches offered to children in the program may, however, have encouraged children to attend school more consistently than they otherwise would have.

Meals served through the NSLP are required to meet national nutrition standards by federal law, and schools receive reimbursement for each meal served. Children in families with incomes at or below 130% of the poverty level are eligible for free meals, and those with household incomes between 130% and 185% of the poverty level are eligible for reduced-price meals, for which the student cannot be charged more than 40 cents. During the 2010 federal fiscal year, 20.6 million low-income children received free or reduced-price meals through the NSLP (FRAC 2011).

The state of Georgia has a particularly troubling number of students at risk for decreased academic performance due to food insecurity. While 46% of the households in Georgia qualify for free lunch, an additional 21% of households with children qualify to receive reduced-price lunches (FRAC 2012). Georgia's population is 17.9% food insecure (FRAC 2011). It is in light of these numbers that the importance of examining food insecurity's effects on the state's children is seen.

Theoretical Framework

As poor health and nutrition may hinder a child's ability to learn **(**Pollitt 1990), school meals have become a critical part of the safety net against food insecurity, benefiting students' academic achievement, because those who participate demonstrate more positive behavior in the classroom. The focus of this paper is to bring awareness of the importance these meals serve as safety nets to alleviate hunger in low-income households. Children experiencing hunger have lower math scores and are more likely to have to repeat a grade than those who are not hungry (Alaimo, Olsen, & Frongillo 2001). Thus, the hypothesis to be tested is that there is a strong inverse relationship between poverty and food insecurity, as exhibited by participation in NSLP, and achievement test scores in reading and mathematics. To measure student achievement, an "achievement score" and an "exceeding standards" score were used as the dependent variables at each grade level, 5^{th} and 8^{th}.

The NSLP explanatory variable represents the percent of total students eligible to participate in the NSLP in each school system in Georgia, and is a proxy for poverty/food insecurity. Another factor included in the analysis is county expenditures per full time enrollment (FTE) students, as school expenditure variables are hypothesized to have positive relationships with the dependent variables – 'achievement' and 'exceeds standards'. This study also includes explanatory variables that are representative of human growth, as well as socioeconomic status of students. To illustrate the human capital factor, the percentages of the county population with college degrees was included as an explanatory variables. Lastly, measurements of single parent households and race/ethnic groups are included to capture their hypothesized associations with educational achievement.

Data and Methodology

Achievement data were taken from the Georgia Department of Education and Governor's Office of Student Achievement, as reported in the "2008 Georgia Report Card for Parents" (Georgia Public Policy Foundation 2009). The Report Card provides information to help parents make informed decisions about the quality of public education in Georgia based on data for the 2008/9 school year. This analysis was performed at the school level for both fifth grade and eighth grade data. There are 1,283 elementary schools included in the analysis of fifth grade students and 506 middle schools included in the analysis of eighth grade students from Georgia's 159 counties. Data on the *NSLP* and *College* variables came from the USDA-ERS' Food Environment Atlas (2011) and the U.S. Census Bureau (2009), respectively .

In the generalized linear model (glm) framework, a generalization of Poisson regression was used to model the percentage of those achieving standards employing SAS Proc Glimmix (SAS/STAT *User's Guide* 2008). The glm framework was used for two primary reasons, with the first being that the outcomes of interest were non-normal. The "exceeding standards" outcome is a count variable, distributed Poisson, and "achievement score" is also considered a count, as negative values are impossible and results are bounded by a maximum score. Typical log-transformations for non-normal count data have been shown to be ineffective (O'Hara and Kotze 2010). Specifically, with count data, transformations have been shown to have biased results and can lead to impossible predictions, such as a negative number of individuals achieving the academic standard of interest. Use of Poisson distribution was supported by histograms of the outcome variables (see figures 1 and 2), which reflected non-normality.

Figure 1: *Histogram of Outcome, Percent Exceeding Standards, Fifth Grade*

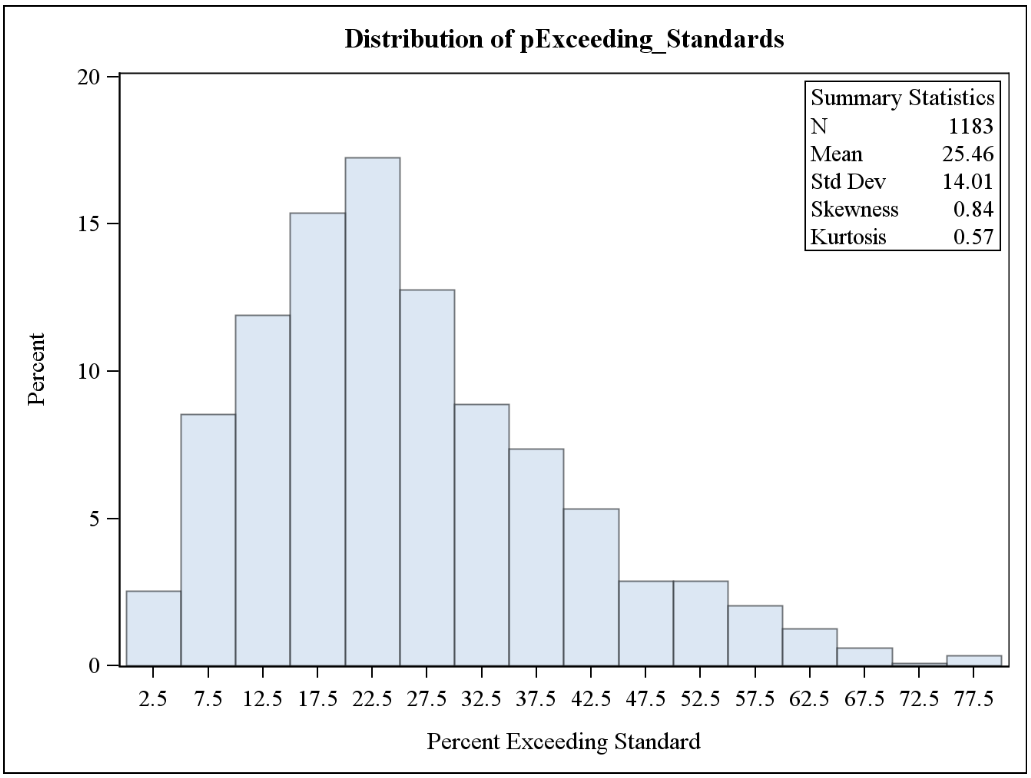
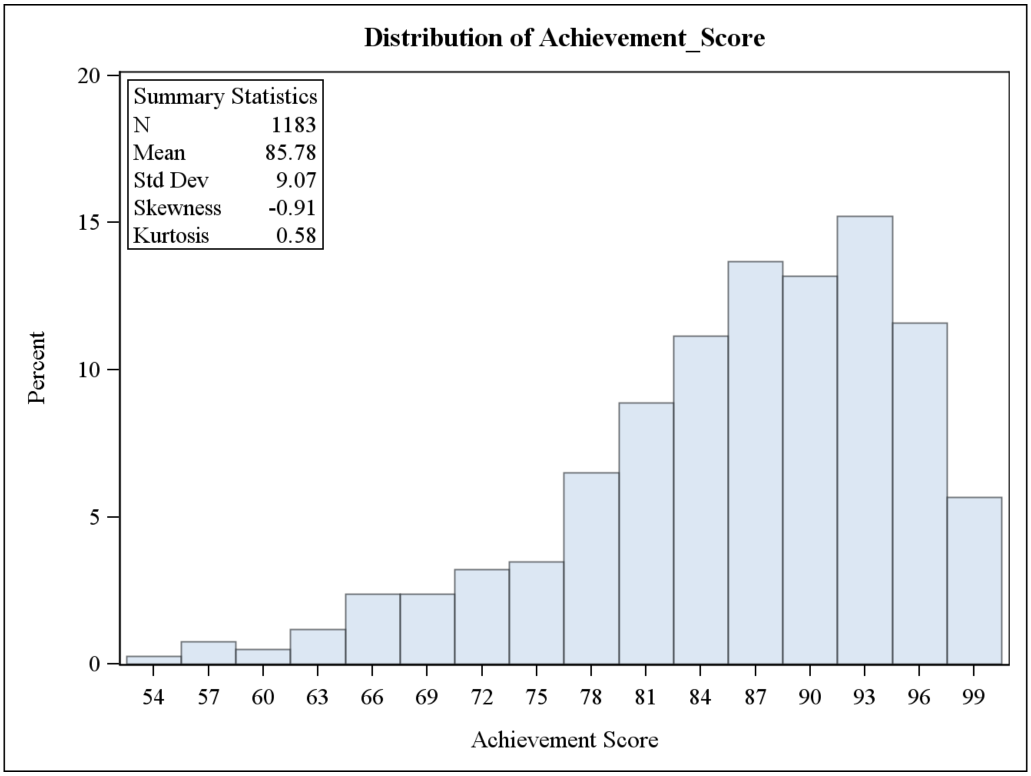


Figure 2: *Histogram of Outcome, Achievement Score, Fifth Grade*



Let $Y_i, \ldots, Y_n$ be independent random variables with Y_i denoting the number of events (i.e., number of students achieving an academic standard and achievement score). These events are out of n_i chances of success (i.e., FTE and possible achievement score). The expected value of the Y_i is:

$$E(Y_i) = \mu_i = n_i \theta_i,$$

where θ_i is some covariate pattern. The generalized linear model is, therefore:

$$E(Y_i) = \mu_i = n_i \exp(x_i^T \beta).$$

A natural link function for such an expression is the log-link:

$$\log(\mu_i) = \log(n_i) + x_i^T \beta.$$

Typically, $\log(n_i)$ is termed the “offset” and is a known constant, incorporated into the estimation procedure. Therefore, the natural log of the outcome was modeled as a linear function of the predictors.

Further complicating estimation of this data, the school data were clustered in counties, with the assumption that schools within counties would share similar characteristics. Traditional regression methods fail to account for such clustering, which creates a dependence of observations within a county (Raudenbush & Bryk 2002). To account for this, a multilevel model, in the glm framework discussed above, was used to capture this clustered data. Let the random intercepts multilevel regression equations be specified at school-level (for the i^{th} school in the j^{th} county), individually for the fifth grade analysis and for the eighth grade analysis:

(1) $Log(Num\_Achieve\_Stand_{ij}) = Log(FTE_{ij}) + \beta_{1ij} + \beta_{2ij} povrate_{ij} + \beta_{3ij} sitespend_{ij} + \varepsilon_{ij}$

and at County-level (for the j^{th} county):

(2) $\beta_{1j} = \gamma_{1j} + \gamma_{2j} PCTSingparHH_j + \gamma_{3j} PCTcollege_j + \gamma_{4j} PCTHisp_j + \gamma_{5j} PCTBlack_j + \gamma_{6j} PCTAsian_j + r_j$

Subtracting *Log(FTE)* from both sides and combining the school and county-level models yields the final model,

(3) $Log(percent\_achieve_{ij}) = \gamma_{1j} + \gamma_{2j} PCTSingparHH_j + \gamma_{3j} MedHHINC_j + \gamma_{4j} PCTcollege_j + \gamma_{5j} PCTHisp_j + \gamma_{6j} PCTBlack_j + \gamma_{7j} PCTAsian_j + \beta_{2ij} povrate_{ij} + \beta_{3ij} sitespend_{ij} + \varepsilon_{ij} + r_j$

This was the empirical model estimated in this analysis. Through exponentiation of equation (3) we find,

(4) $percent\_achieve_{ij} = \exp(\gamma_{1j} + \gamma_{2j} PCTSingparHH_j + \gamma_{3j} PCTcollege_j + \gamma_{4j} PCTHisp_j + \gamma_{5j} PCTBlack_j + \gamma_{6j} PCTAsian_j + \beta_{2ij} povrate_{ij} + \beta_{3ij} sitespend_{ij} + \varepsilon_{ij} + r_j)$

(5) $= \exp(\gamma_{1j}) * \exp(\gamma_{2j} PCTSingparHH_j) * \exp(\gamma_{3j} PCTcollege_j) * \exp(\gamma_{4j} PCTHisp_j) * \exp(\gamma_{5j} PCTBlack_j) * \exp(\gamma_{6j} PCTAsian_j) * \exp(\beta_{2ij} povrate_{ij}) * \exp(\beta_{3ij} sitespend_{ij}) \exp(\varepsilon_{ij}) \exp(r_j)$

Or, for the second outcome of interest,

(6) $achievescore_{ij} = \exp(\gamma_{1j} + \gamma_{2j} PCTSingparHH_j + \gamma_{3j} PCTcollege_j + \gamma_{4j} PCTHisp_j + \gamma_{5j} PCTBlack_j + \gamma_{6j} PCTAsian_j + \beta_{2ij} povrate_{ij} + \beta_{3ij} sitespend_{ij} + \varepsilon_{ij} + r_j)$

(7) $= \exp(\gamma_{1j}) * \exp(\gamma_{2j} PCTSingparHH_j) * \exp(\gamma_{3j} PCTcollege_j) * \exp(\gamma_{4j} PCTHisp_j) * \exp(\gamma_{5j} PCTBlack_j) * \exp(\gamma_{6j} PCTAsian_j) * \exp(\beta_{2ij} povrate_{ij}) * \exp(\beta_{3ij} sitespend_{ij}) \exp(\varepsilon_{ij}) \exp(r_j)$

where *achievescore* is the primary measure of student achievement for elementary and middle schools and is defined as the average of the percentage of students passing the Reading and Math sections of the Criterion-Referenced Competency Test (CRCT), while *percent_achieve* is the average of the percentage of students who exceeded standards on the Reading and Math sections of the CRCT.

The school-level independent variables were *sitespend*, the school spending per full-time equivalency (FTE) that was determined by dividing the funds expended at the school site by FTE, and *povrate*, the school-level poverty rate. The county-level independent variables were specified: *PCTSingparHH*, the percent of households defined as single parent by the US Census; *PCTcollege,* the percent of adults with college degrees; *PCTHisp*, the percent of the county population identified as Hispanic; *PCTBlack*, the percent of the county population identified as African American; and *PCTAsian*, the percent of the county population identified as Asian.

Equations (6) and (7) illustrate the multiplicative nature of the parameter estimates. Rather than a one-unit increase in a predictor leading to a β increase (or decrease) in the outcome, with the log-linear relationship, a one-unit increase in a predictor leads to a multiplicative increase (or decrease) of β in the outcome. Interpretations are provided in the section titled “Results”.

Results

Fifth Grade Analysis

Findings confirm the hypothesis that there is a strong inverse relationship between poverty, as exhibited by participation in NSLP, and achievement test scores for the fifth grade schools. The coefficient of Poverty/*NSLP* was negative and significant in both the *percent_achieve* and *achievescore* equations at the 1% level, found in Tables 1 and 2, respectively. Recall that interpretation of coefficients is multiplicative. That is, for a 1 unit increase in poverty rate, *percent_achieve* standards decreases by a multiplicative factor of 0.5735 (exp(β_{2ij})=0.5735, p<.0001). As this exponentiated coefficient is less than one, there is an inverse relationship between poverty and percent of students achieving standards. For a 1 unit increase in poverty rate, *achievescore* decreases by a multiplicative factor of 0.6733 (exp(β_{2ij})=0.6733, p<.0001) again indicating an inverse relationship between poverty and academic achievement scores.

For the outcome *percent_achieve*, there were other predictors significant at the 0.01 level. A positive relationship between *PCTcollege* and *percent_achieve* was found, indicating that as the human capital in the county increases, so does the rate of children achieving the academic standard (exp(γ_{3j})=1.2572, p<.0001) by a multiplicative of 1.2572. Also, a positive relationship between *SINGPHH* and *percent_achieve* was found, indicating that as the rate of single parent households in the county increases, so does the rate of children achieving the academic standard (exp(γ_{2j})=1.2258, *p*=.0070) by a multiplicative of 1.2258. Another predictor was significant at the .10 level. A positive relationship between *PCTAsian* and *percent_achieve* was found, indicating that as the percentage of Asian population in the county increases, so does the rate of children achieving the academic standard (exp(γ_{6j})=1.0831, *p*=.0988) by a multiplicative of 1.0831.

For the outcome *achievescore*, another predictor was significant at the .10 level. A positive relationship between *PCTAsian* and *achievescore* was found, indicating that as the percentage of Asian population in the county increases, so do academic achievement scores (exp(γ_{6j})=1.0596, *p*=.0817) by a multiplicative of 1.0596.

Table 1: Poisson Regression Results, *percent_achieve*

Effect	Estimate	SE	DF	t	p	Exp(Estimate)
Intercept	-0.6725	0.05790	86	-11.62	<.0001	
Poverty_Rate*	-0.5560	0.05101	418	-10.90	<.0001	0.5735
School_Site_Spending	0.02869	0.03727	418	0.77	0.4418	1.0291
SINGLEPHH*	0.2036	0.07364	86	2.76	0.0070	1.2258
pCollege_Graduate*	0.2289	0.05190	86	4.41	<.0001	1.2572
pASIAN_2010*	0.0798	0.04785	86	1.67	0.0988	1.0831
pBLK_2010	-0.0809	0.07942	86	-1.02	0.3110	0.9222
pHISP_2010	0.0364	0.04652	86	0.78	0.4365	1.0370

Table 2: Poisson Regression Results, *achievescore*

Effect	Estimate	SE	DF	t	p	Exp(Estimate)
Intercept	-0.6404	0.02879	102	-22.24	<.0001	
Poverty_Rate*	-0.3955	0.02921	568	-13.54	<.0001	0.6733
School_Site_Spending	0.0135	0.02462	568	0.55	0.5827	1.0136
SINGLEPHH	0.0318	0.04287	102	0.74	0.4603	1.0323
pCollege_Graduate	0.0267	0.03347	102	0.80	0.4263	1.0271
pASIAN_2010*	0.0579	0.03293	102	1.76	0.0817	1.0596

Effect	Estimate	SE	DF	t	p	Exp(Estimate)
pBLK_2010	-0.0040	0.04530	102	-0.09	0.9302	0.9960
pHISP_2010	-0.0408	0.02985	102	-1.37	0.1749	0.9600

Eighth Grade Analysis

Findings confirm the hypothesis that there is a strong inverse relationship between poverty, as exhibited by participation in NSLP, and achievement test scores for the eighth grade schools. The coefficient of Poverty/*NSLP* was negative and significant in the both the *percent_achieve* and *achievescore* equations at the 10% level, found in Tables 3 and 4, respectively. That is, for a 1 unit increase in poverty rate, *percent_achieve* standards decreases by a multiplicative factor of 0.7204 (exp(β_{2ij})=0.7204, p<.10). As this exponentiated coefficient is less than one, there is an inverse relationship between poverty and percent of students achieving standards. For a 1 unit increase in poverty rate, *achievescore* decreases by a multiplicative factor of 0.2637 (exp(β_{2ij})=0.2637, p<.0001), again indicating a strong inverse relationship between poverty/food insecurity in the home and academic achievement in the classroom.

For the outcome *percent_achieve*, there were two other significant predictors at the 10% level. A positive relationship between *PCTHisp* and *percent_achieve* was found, indicating that the higher the percent of the population that is Hispanic, the higher the rate of children achieving the academic standard (exp(γ_{5j})=1.4469). This is in contrast with previous findings (i.e., Hamilton *et al*. 1997). Also, similar to the fifth grade results, a positive relationship between *PCTcollege* and *percent_achieve* was found, indicating that the higher the percent of the population with college degrees, the higher the rate of children achieving the academic standard (exp(γ_{3j})=1.4016). This supports previous findings, which show parental education has a positive relationship with academic achievement (Dunifon *et al.* 2004; Hamilton *et al*. 1997).

Similarly, for the outcome *achievescore*, there were two other significant predictors. A positive relationship between *PCTHisp* and *percent_achieve* was found, indicating that the higher the percent of the population that is Hispanic, the higher are overall academic achievement scores (exp(γ_{5j})=1.5177).

Table 3: Poisson Regression Results, *percent_achieve*

Effect	Estimate	SE	DF	t	p	Exp(Estimate)
Intercept	-0.6291	0.2009	68	-3.13	0.0026	
Poverty_Rate*	-0.3280	0.1788	114	-1.84	0.0691	0.7204
School_Site_Spending	-0.0567	0.1638	114	-0.35	0.7297	0.9448

Effect	Estimate	SE	DF	t	p	Exp(Estimate)
SINGLEPHH	0.2950	0.2704	68	1.09	0.2790	1.3431
pCollege_Graduate*	0.3376	0.1754	68	1.93	0.0584	1.4016
pASIAN_2010	-0.1643	0.1559	68	-1.05	0.2957	0.8485
pBLK_2010	-0.1829	0.2780	68	-0.66	0.5127	0.8329
pHISP_2010*	0.3694	0.1117	68	3.31	0.0015	1.4469

Table 4: Poisson Regression Results, *achievescore*

Effect	Estimate	SE	DF	t	p	Exp(Estimate)
Intercept	-2.8652	0.4842	86	-5.92	<.0001	
Poverty_Rate*	-1.1404	0.3941	142	-2.89	0.0044	0.3197
School_Site_Spending	0.1478	0.2383	142	0.62	0.5360	1.1593
SINGLEPHH	-0.0668	0.4981	86	-0.13	0.8936	0.9353
pCollege_Graduate	0.5301	0.3840	86	1.38	0.1711	1.6991
pASIAN_2010	-0.6116	0.3796	86	-1.61	0.1109	0.5245
pBLK_2010	0.0110	0.5105	86	0.02	0.9828	1.0111
pHISP_2010*	0.4172	0.2334	86	1.79	0.0774	1.5177

Conclusions and Implications

Regarding both outcomes of interest, percent of students achieving academic standards and academic achievement scores, there was a significant inverse relationship with poverty/NSLP eligibility rates for both fifth and eighth grade students in Georgia. These findings support previous work. For the fifth grade students, that inverse relationship was strong. However, for the eighth grade students, the strength of the relationship was somewhat diminished (i.e., significant only at the .10 level compared to the .01 level with the fifth grade students).

Two reasons exist for the difference in the strength of the relationship. The first is that sample sizes were different. There were 1183 fifth grade schools in the analysis and 506 eighth grade schools, resulting in decreased power of the statistical tests.

The second explanation lies in the actual participation of eighth grade students in the NSLP rather than eligibility for free/reduced lunches. For instance, in San Francisco, only 37% of eligible high school students take advantage of a subsidized meal program

(Pogash 2008) and in other areas of the country, the percentage is even lower. Several studies have found a social stigma associated with redemption of free/reduced school lunch and breakfast, leading to students failing to utilize the nutritional assistance available to them (Mirtcheva *et al*. 2009; Bailey-Davis *et al.* 2013). Without capitalizing on the NSLP, students may remain hungry and therefore remain at risk for stunted academic performance. This becomes particularly true for the eighth grade analysis, as "most elementary-school children see no problem with free lunches, school officials say, but by the time they enter middle school, social status intervenes" (Pogash 2008). This translates into students from food insecure families either paying cash or going hungry if lunches are not available at home, particularly at the eighth grade level. This underutilization of NSLP may be a source of the different relationships in the eighth grade analysis when compared to the fifth grade analysis.

Finally, the importance and magnitude of the effects of poverty and/or food insecurity on school achievement have been clearly distinguished from other contributing factors, such as school funding and race. The multi-level estimation methods to incorporate demographics of the county together with school-level eligibility for NSLP and resulting achievement scores enabled this differentiation of factors to highlight the most pressing problem – poverty and food insecurity in a large proportion of households will undervalue attempts to educate and prepare school children for life and employment potential in the future. Continuing the study to the high school level achievement may also provide additional insights to this problem as students mature and prepare to leave school.

This research has provided insight into the relationship between poverty and academic achievement for Georgia's public elementary and middle school children. The NSLP is one measure of opportunity to overcome this restriction on potential, but only if participation better reflects the targeted population. Following in line with other states' attempts to reduce the social stigma associated with subsidized meals may enable Georgia's public school students to better utilize this resource, and ultimately lessen the gap between food insecure and food secure students.

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