



Chronic undernutrition, short-term hunger, and student functioning in rural northwest China



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ARTICLE INFO

Article history:

Received 29 March 2016

Received in revised form 9 December 2016

Accepted 13 December 2016

Keywords:

Hunger
Height-for-age
Dropout
Internalizing problems
Externalizing problems
Non-cognitive behavior

ABSTRACT

Chronic undernutrition and hunger remain significant problems for children, in global perspective, and may have important implications for children's ability to function effectively at school. In this paper, we capitalize on a longitudinal data set of children in 100 villages in Gansu Province to estimate differences in achievement, behavior, and long-term persistence associated with chronic undernourishment and short term hunger. We show that chronic undernourishment and short-term hunger relate to children's school functioning in distinct ways: chronically undernourished children have poorer literacy acquisition and subsequent school persistence, while children who report subjective hunger have more behavioral problems.

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1. Introduction

Chronic undernutrition and hunger remain significant problems for children, in global perspective. In 2011, at least 165 million children were affected by stunting, or low height-for-age, a common indicator of chronic undernutrition (Black et al., 2013). In China, despite very rapid improvements in nutrition in recent decades, UNICEF figures indicate that there are about 12.7 million stunted children (Liang, 2013). In poor rural communities in China's central and western provinces, UNICEF figures indicate that one out of 10 children under 5 is stunted (Liang, 2013). In addition to chronic undernutrition, short-term hunger is widespread. The *World Food Program (2015)* estimates that 66 million primary school-age children attend classes hungry across the developing world. A recent study of boarding school students in a province in Western China revealed that over half of children surveyed reported sometimes or often feeling hungry in class and feeling hungry at night to the point that it keeps them awake (Luo et al., 2009, p. 14).

While childhood undernutrition and hunger are important concerns in their own right, they may also have important implications for children's ability to function effectively at school. "Material hardships related to food," including food insufficiency and hunger, are reliable correlates of cognitive, behavioral, and emotional problems among low-income children, though these hardships are

often closely intertwined with other dimensions of household disadvantage (Belsky et al., 2010). Hungry children may perform more poorly in school due to previous damage to their basic cognitive capacity or to current hunger, which can affect attention spans (Howe and World Food Programme, 2006, p. 43). Yet, these concerns have been only partially incorporated into studies of children's educational outcomes in low-income, developing country contexts. Studies have considered chronic hunger, typically measured by height-for-age for age, in relation to test performance and educational outcomes (Hannum et al., 2014; for reviews, see Hoddinott et al., 2013a, 2013b; for studies related to China, see Jamison, 1986; Kingdon and Monk, 2010). Another line of work has considered short-term hunger, usually by investigating whether meal provision or missing meals is related to children's adjustment, behavior, and achievement (Adolphus et al., 2015; for reviews, see 2013; Hoyland et al., 2009; Jomaa et al., 2011).

However, few studies in highly deprived settings, where undernutrition and hunger might be prevalent, have been able to make use of longitudinal data that might reveal persisting as well as short-term effects. Moreover, little research has incorporated these two dimensions of food-related deprivation simultaneously, or investigated their relationships with a range of short- and long-term school functioning indicators. In this paper, we capitalize on a unique longitudinal study of children from 100 villages in one of China's poorest provinces to investigate the associations of both chronic undernutrition and short-term hunger with multiple dimensions of school functioning, and with school persistence over time. We consider potential relationships to learning outcomes—namely

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literacy—and to behavioral outcomes—namely, internalizing and externalizing behavior problems and teacher-reported behavior problems. Specifically, we ask, are children exposed to chronic undernourishment and who report short-term hunger at heightened risk for poor learning and behavioral outcomes, or for subsequent school dropout five years later?

One problem that has plagued existing literature has been the likely coincidence of hunger and undernutrition with other unmeasured confounders. While the current study cannot completely address this concern, we are able to adjust for a rich set of potential confounders, including household wealth and, in some specifications, children's prior academic performance, internalizing and externalizing behavior problems, and behavioral problems in the classroom. Further, for analyses of short-term hunger effects on behavioral outcomes, we are able to estimate individual fixed-effects specifications that adjust for any unmeasured, stable attributes of individuals. As we will show, chronic undernourishment and short-term hunger relate in distinct ways to children's school functioning in rural Northwest China: chronically undernourished children have poorer literacy acquisition and subsequent school persistence, while children who report subjective hunger have more behavioral problems.

2. Context

2.1. Chronic undernutrition

Chronic undernutrition remains pervasive in developing countries. In 2011, at least 165 million children were affected by stunting, or low height-for-age,¹ a common indicator of chronic undernutrition (Black et al., 2013). In China, despite rapid progress in reducing stunting, almost one in ten children were stunted as of 2010, the most recent year for which data are available ("2015 Nutrition country profile: China, 2015"), and rural children are more vulnerable than are urban children (Chen et al., 2007). A large body of research has examined the association of chronic undernourishment in early childhood with educational outcomes, test scores, and behavioral problems (Berkman et al., 2002; for a review, see Fanjiang and Kleinman, 2007; Jamison, 1986; Walker et al., 2005). Chronic under-nourishment is associated with poorer cognitive development, grade retention and dropout from school in developing countries (Grantham-McGregor et al., 2007). For example, low height-for-age has been associated with school enrollment (Alderman et al., 2001), grade-for-age attainment (Jamison, 1986), test scores (Kingdon and Monk, 2010), and behavioral problems in adolescence (Liu et al., 2004; Raine et al., 2014). A study from Jamaica shows that early childhood stunting is associated with lower self-esteem, hyperactivity, and more anxiety and depressive symptoms at adolescence (Walker et al., 2007). Children's exposure to chronic under-nourishment in early childhood also places them at risk of shorter stature at adolescence, which could impede their social skills accumulation during adolescence (Persico et al., 2004).²

¹ Low height-for-age, a common measure of "nutritional stock," picks up slow growth from birth, usually due to repeated episodes of poor nutrition and/or other illnesses (Wisniewski, 2010).

² Persico et al. (2004) examine the relationships between wages and height at multiple life stages jointly and show that height in early childhood and height in adolescence are both strong predictors of wages in labor markets. They show that youths with shorter stature are more likely to be excluded from participation in sport clubs than their taller counterparts. These youth are impeded in accumulating social skills, which are an important determinant of wages. Their research extends the prior literature by highlighting the relationship between height at adolescence and later life-outcomes, rather than solely focusing on height in early childhood.

Causal impacts of chronic undernourishment on subsequent educational outcomes and productivities in labor markets are challenging to estimate (Behrman, 2009). However, some studies have sought to address estimation problems in investigating the impact of height-for-age on educational outcomes. In the Philippines, using sibling difference models with various instrumental variables, Glewwe et al. (2001) found that better-nourished children performed significantly better in school in part because these children tended to enter school earlier, but also because they learned more per year of schooling. In India, Kingdon and Monk (2010) found a positive effect of height-for-age z-scores on test scores, after addressing the endogeneity of health caused by omitted variables bias with a household fixed-effects estimator on a sub-sample of siblings as well as extensions and robustness checks using instrumental variables and alternative estimators. In Sri Lanka, Wisniewski (2010) showed that positive effects of height-for-age on test scores persisted with the use of a variety of instrumental variables to adjust for endogeneity and after adjusting for current health and nutrition status. In a study that utilized instrumental variables approaches to deal with potential confounders, height-for-age was linked to numerous outcomes in young adulthood, including family formation, reproduction, men's wage rates, and the avoidance of poverty, which are likely mediated through schooling and cognitive achievement (Hoddinott et al., 2013a, 2013b). In Bangladesh, Khanam (2014) found significant effects of height-for-age on enrollment and grade attainment using parental height as an instrument for child height.

In China, Jamison (1986) analyzed data on the height, weight, age and grade level of over 3000 children in five different locations in as part of a World Bank project. After controlling for location, lower height-for-age was associated with being further behind in grade-for-age attainment. Yu and Hannum (2007) replicated these findings using multi-province China Health and Nutrition Survey data from 1993, with additional adjustments for socioeconomic status and location, and showed further with data from Gansu Province in the year 2000 that a home nutritional environment scale could be linked to school performance, especially for children in the early grades. Hannum et al. (2014) studied the associations of poverty, undernutrition and food insecurity, and investigated literacy gaps associated with these forms of deprivation in Gansu Province. Results showed that the poorest children were at heightened risk of both low height-for-age and food insecurity, and both low height-for-age and food insecurity were associated with literacy acquisition. Further analyses suggested that height-for-age results might be emerging via an early nutritional effect on school performance and grade attainment.³

2.2. Short-term hunger

A largely separate line of work has considered the ways that short-term hunger is related to children's ability to function in the classroom. For example, existing literature suggests that skipping breakfast is associated with emotional and behavioral problems and may possibly have an adverse impact on cognitive function and academic performance (Rampersaud et al., 2005); research has also suggested adverse impacts of breakfast-skipping on alertness, attention, memory, processing of complex visual display, problem solving, and mathematics (Basch, 2011). A recent systematic review identified 36 studies that examined the effects of breakfast—habitual or acute—on in-class and academic performance among children and adolescents (Adolphus et al., 2013). Adolphus and her colleagues reported that increased frequency of

³ Other recent studies in China have focused not on undernutrition, but on nutrient deprivation and supplementation (Luo et al., 2012; Sylvia et al., 2013).

habitual breakfast was consistently positively associated with academic performance and sometimes associated with improved classroom behavior, but these findings might be attributed in part to confounders such as socio-economic status.

An additional difficulty in estimating the relationship between outcomes of interest and subjective hunger is that personality traits of children are potential confounders that could be correlated with behavioral problems, school performance, and subjective hunger. Without taking into account this omitted variable bias, the relationship between outcomes of interests and short-term hunger may be overstated. For example, higher reporting of externalizing behavioral problems may be partly rooted in personality traits that could also predispose children to report higher levels of hunger than their peers (Hinshaw, 1992; Murphy et al., 1998). Intervention studies attempt to address this bias problem. Intervention studies and within-student design acute experimental studies demonstrate positive effects of breakfast on performance and mixed effects on classroom behavior (Adolphus et al., 2013).

Other recent systematic reviews of school breakfast programs designed to alleviate short-term hunger found consistent positive effects on energy intake, micronutrient intake, school enrollment, and attendance, but also that effects on cognition and achievement were less conclusive⁴ (Jomaa et al., 2011). Hoyland et al. (2009) reviewed studies about the effects of school-based food and nutrition intervention programs on educational outcomes, and indicate that children who participate in these programs have perceptible improvements in educational performance. However, the authors also reported that this improvement was partly explained by having a stronger incentive for children to attend school, rather than by direct causal effects (Hoyland et al., 2009). We are not aware of studies of short-term hunger among students in China.

2.3. Summary

To borrow the terminology of Belsky et al. (2010), empirical research has linked at least two dimensions of children's "material hardships related to food" to educational and behavioral outcomes: chronic nutritional deprivation and short-term hunger. However, few studies in highly deprived settings, where undernutrition and hunger might be prevalent, have been able to make use of longitudinal data that might reveal persisting as well as short-term effects. Moreover, little research has incorporated these two dimensions of food-related deprivation simultaneously, or investigated their relationships with a range of short- and long-term school functioning indicators.

3. Objectives

In this paper, we contribute a case study from a poor rural region in Northwest China to the literature on nutrition, hunger and school functioning over time. We investigate differences in achievement, behavior, and long-term persistence associated with chronic undernourishment and short-term hunger. We utilize rich longitudinal data to adjust for community effects, economic background, demographic characteristics, and prior achievement. Further, for the analysis of short-term hunger and behavioral outcomes, we are able to present individual fixed-effects specifications that estimate within-individual changes in behavioral outcomes as a function of changes in short-term hunger measures.

⁴ For example, evaluation of a school breakfast program in rural Peru showed positive effects of breakfast on short-term memory, arithmetic and reading comprehension, but primarily in multi-grade classrooms (Cueto and Chinen, 2008).

4. Data

4.1. Study site

In 2010, the most recent census year, Gansu's population was 25.58 million people (Gansu Bureau of Statistics 2011). This figure would make Gansu the 47th most populous country in the world in that year—the province is about the size of Ghana or North Korea (US Bureau of the Census, 2010). Gansu is one of China's poorest provinces: in 2010, it ranked last among provinces in per capita rural household income and third to last in per capita GDP (China National Bureau of Statistics, 2011a, 2011b). Per capita GDP in 2010 was \$4031 USD—about equivalent to the 2010 figure for Iraq (NA, 2012). Gansu remains a majority rural province: in 2010, 64% of the population resided in rural areas (Gansu Bureau of Statistics, 2011).

The data source is the Gansu Survey of Children and Families (GSCF), which was collected using multistage sample design to collect a sample of 2000 rural children aged 9 to 12 in 100 villages⁵ in Gansu Province in the year 2000, plus linkable secondary samples of mothers, fathers, teachers, school administrators, and village heads. Children and/or their families were revisited in 2004, 2007, and 2009. We use information from the 2000, 2004 and 2009 waves in which dependent and key independent variables are available (Appendix Table A). There were 2000 children in 2000, but the sample size fell to 1918 in 2004 and 1867 in 2009, due to sample attrition.⁶

4.2. Measurement

4.2.1. Chronic undernutrition and short-term hunger

4.2.1.1. Chronic undernutrition (2004). Chronic undernutrition is measured by height-for-age z-score (HAZ), a commonly used proxy for chronic undernutrition. One advantage of this dataset is that height was measured objectively by trained interviewers in 2004 and was not self-reported. The height-for-age z-score is calculated based on the WHO (2007) growth reference for children and adolescents.⁷

4.2.1.2. Short-term hunger (2000, 2004). Most of the existing literature on the relationship between short-term hunger and school functioning is based on indirect measurements, such as skipping breakfast or participation in school-based food intervention program. Here, we adopt two measures of short-term hunger: one based on subjective degree of hunger and one based on getting full at meals.

Subjective hunger is measured by the following question, asked in both 2000 and 2004: "Have you ever had the problem of not

⁵ Twenty counties were randomly selected from eighty-six counties in Gansu. Secondly, forty-townships were randomly selected from sampled counties. Thirdly, a hundred villages were randomly selected from sampled townships. Lastly, a random sample of 20 children were selected from a list of all 9 to 12 year-old children in each selected village.

⁶ The overall attrition rate is only 7% across the 9-year period. Attrition is due in part to the high prevalence of outmigration from rural areas in China. In addition, missing values ranged from 4% to 20% of cases for variables we use in this study. Missing values for independent variables in each wave are handled by multiple imputation with chained equations. By utilizing the longitudinal data, each variable with missing values is imputed based on information from all three waves of data (Allison, 2002). Dependent variables are also included in the imputation models to impute independent variables, but in all analysis, the analytical sample is limited to the sample without missing values for dependent variables (Von Hippel, 2007).

⁷ Measurement of height at multiple life stages is necessary if one wishes to make statements about when stature matters. However, the data only includes one wave of height-for-age, therefore we are not able to fully address when stature matters. Nonetheless, children with low height-for-age z score during early childhood also tend to be short during adolescence.

Table 1
Descriptive Table of Variables.

Variable	N	Mean	Std. Dev.
Dropout prior to completing middle school	1833	0.19	0.39
Standardized IBP ^a , 2000	1970	0	1
Standardized IBP, 2004	1869	0	1
Standardized EBP ^b , 2000	1975	0	1
Standardized EBP, 2004	1868	0	1
Standardized PSBP ^c , 2000	1980	0	1
Standardized PSBP, 2004	1650	0	1
Height-for-age z scores	1783	-1.18	1.09
Subjective hunger, 2000	1985	0.43	0.50
Subjective hunger, 2004	1858	0.50	0.50
Can't get full at meals, 2000	2000	0.20	0.40
Can't get full at meals, 2004	1862	0.28	0.45
Standardized Chinese grade, 2000	1951	0.00	1
Standardized Chinese grade, 2004	1397	0.00	1
Standardized math grade, 2000	1957	0.00	1
Standardized math grade, 2004	1398	0.00	1
Girl	2000	0.46	0.50
Child age	2000	11.05	1.15
Birth order (2 st child as reference)			
2	2000	0.38	0.49
3+	2000	0.15	0.36
Mother's education (less than primary as reference)			
Less than middle school	1986	0.27	0.44
Middle school and above	1986	0.22	0.42
Father's education (less than primary as reference)			
Less than middle school	1987	0.26	0.44
Middle school and above	1987	0.51	0.50
Father away from home, 2000	1980	0.08	0.28
Father away from home, 2004	1881	0.22	0.41
Mother away from home, 2000	1985	0.02	0.13
Mother away from home, 2004	1899	0.03	0.16
Wealth quintile, 2000			
Poor	2000	0.20	0.40
Relatively poor	2000	0.20	0.40
Average	2000	0.20	0.40
Relatively well-off	2000	0.20	0.40
Well-off	2000	0.20	0.40

^a Internalizing behavior problems.

^b Externalizing behavior problems.

^c Pro-social behavior problems.

being able to concentrate in class because of hunger?" Children rated their level of subjective hunger as never (0), sometimes (1) and often (2). Because of the relatively small number of cases reporting "often", we group "sometimes" and "often" as one category. Subjective hunger is coded "0" if children reported "never" and otherwise "1".

Can't get full at meals could be viewed as an indicator of child's food security, and is measured by the following questions, asked in both in 2000 and 2004: "Can you get full at every breakfast?" and "Can you get full at every lunch?" Based on these two questions, we further construct a categorical variable: *can't get full at meals*. This variable was initially coded as follows: get full at both meals (0), get full at one meal (1) and doesn't get full at either meal (2). Because the proportion reporting can't get full at either meal is small, we combine get full at one meal and can't get full at either meal into a single category *can't get full at meals*. Researchers usually highlight the importance of breakfast for school functioning. The purpose of this research is not to evaluate whether one meal is more important than another. Rather, we use both meals to provide more information about child's perceived food sufficiency.

Although these two measures are associated with each other, they pick up distinct elements of short term hunger.⁸ Many children in rural Gansu have access to a fairly limited diet (Yu and Hannum, 2007). Children may be able to get full at mealtimes by consuming cheap carbohydrates, but they may still experience high levels of subjective hunger.

The prevalence of hunger can be seen in Table 1. Stunting, defined as height-for-age $z < -2$ based on the WHO criteria, was around 17%. Moreover, the figures for *subjective hunger* and *can't get full at meals* among sample children in 2000 were around 43% and 20%, respectively. Corresponding figures were higher, at 50% and 28%, in 2004, despite rapid economic development between 2000 and 2004.

4.2.2. Behavioral problems

4.2.2.1. *Standardized externalizing and internalizing behavioral problems (2000, 2004)*. One set of measurements of children's psychosocial adjustment are externalizing and internalizing behavior problems (hereafter EBP and IBP). Scale items were adapted⁹ from the internalizing and externalizing scales in the Achenbach's Child Behavioral Checklist (Achenbach, 1991). There are 19 items for externalizing behavioral problems and 17 items for internalizing behavioral problems. Each item is reported by children themselves on a 4-point scale, as 1 "strongly disagree", 2 "disagree", 3 "agree", or 4 "strongly agree".¹⁰ The final raw scores for both internalizing and externalizing behavioral problems are constructed by summing up each item. The raw mean scores for externalizing behavioral problems are 37.45 and 33.53 in 2000 and in 2004. They are 37.80 and 34.91 for internalizing behavioral problems in 2000 and in 2004. We further calculate standardized externalizing and internalizing behavioral problems based on the raw scores. Positive and higher values represent more severe behavioral problems than average. The Cronbach's alpha measures for externalizing and internalizing behavior problems were 0.88 and 0.83 in 2000, respectively. In 2004, the Cronbach's alpha measures for externalizing and internalizing behavior problems were 0.87 and 0.79, respectively (Appendix Table B).

4.2.2.2. *Standardized pro-social behavioral problems (2000, 2004)*. The pro-social behavioral problems scale is a standardized scale of homeroom teacher-reported child behaviors in both 2000 and 2004. There are 9 items included in the scale. Each item is reported by homeroom teacher on a 3-point scale, as 1 "never", 2 "sometimes", or 3 "often". The final pro-social scores are constructed by summing up all items and standardizing (Appendix Table B). The Cronbach's alpha is 0.69 in 2000 and 0.68 in 2004. Higher scores indicate that children have more behavioral problems, as reported by their homeroom teachers. As

⁸ Unsurprisingly, there is a highly significant association between subjective hunger and can't get full at meals in both 2000 and 2004. Children who report subjective hunger are also more likely to report can't get full at meals.

⁹ The Gansu Survey of Children and Families received support from the Spencer Foundation to pretest the project starting in 1998, with tests ongoing up until the first round of the survey in 2000. With Xiaodong Liu leading pretesting of the psychosocial measures as documented in Chen and Liu (2012, p. 492), the team conducted three rounds of pilot testing of scale items with children in three counties of Gansu to ensure cultural appropriateness. An item analysis was conducted on the pilot data, with items deemed not appropriate for Chinese children in rural Gansu or revealing low internal consistency being deleted. The team also conducted focus groups with teachers to review the items and suggest wording changes or deletion of items perceived as unclear or irrelevant to the target population. For a detailed discussion and analysis of internalizing and externalizing problems among children in Gansu, see Liu (2003).

¹⁰ For behavioral problems scales, items were reverse-coded as needed such that higher scores represented more problems.

an alternative to child-reported behavioral problems, this measure allows us to address the potential concern that children who are inclined to report more behavioral problems may also be more inclined to perceive hunger than those who report fewer behavioral problems. If children's behavioral problems are sufficient to be noticed by their homeroom teachers, this is possibly a stronger signal of problematic behaviors than problems reported by children themselves. At the same time, children had to be in school to have a teacher report about their behavior, and so this measure, unlike the self-reported internalizing and externalizing behavior problems measures, necessarily restricts the analytic sample to children who were in school in both 2000 and 2004.

4.2.3. Educational achievement and persistence

4.2.3.1. Literacy (2004). Literacy scores were based on an assessment administered in 2004 that was devised to test fundamental reasoning, numeracy and problem-solving ability. The assessment was modeled after the International Adult Literacy Surveys (Statistics Canada and Organisation for Economic Co-operation and Development, 2000) and was designed for the Gansu Survey of Children and Families by an expert from the China Educational Research Institute in Beijing, Professor Meng Hongwei (Li et al., 2002). Tests assessed three domains of life skills: prose literacy (reading comprehension of everyday materials such as newspaper stories and information pamphlets), document literacy (the ability to understand maps, diagrams, charts, etc.) and numeracy (adding numbers on bank account slip, calculating interest charges on loans, etc.) (Li et al., 2002). In these analyses, the raw score is standardized with mean equal to 0 and standard deviation equal to 1 to create literacy scores. The assessment is designed to not be dependent on a specific curriculum, but rather to capture children's problem-solving skills.

4.2.3.2. Persistence (2009). Educational persistence is measured by dropout prior to completing middle school as reported in 2009. Six years of primary school and three years of middle school are compulsory, according to national policy. Dropout is coded as 1 if dropped out prior to completing middle school and otherwise 0. Almost 20% of sample children had dropped out prior to completing middle school in rural Gansu as of 2009 (see Table 1).

4.2.4. Other controls

4.2.4.1. Prior school achievement (2000). We include prior achievement measured in the year 2000 for children in estimations of internalizing and externalizing behavioral problems, pro-social behavior problems and literacy assessment with chronic hunger and short-term hunger. We utilize math and language grade in the preceding semester in 2000 to measure prior school achievement. Instead of using child self-reported grade, head teachers of the target child were asked to report the child's math and Chinese grade based on transcripts or records kept by them.

4.2.4.2. Demographic and socioeconomic background (2000). Demographic variables include child's age in 2000, girl and birth order. Girl is coded as 1 if the child is a girl, else 0. Birth order is treated as a set of dummy variables. First child is treated as a reference group. The proportion of sample children with birth order of 3 or higher is small and we include a single category for 3 and above.¹¹

¹¹ Although a one-child policy was in force in China during the period of this study, policies for rural areas tended to be looser.

As additional family background factors, we include parental migration status, parental education and wealth quintile. Father and mother away from home are reported by household heads and are asked in both 2000 and 2004. *Father away from home* is coded as 1 and father always at home is reference group. *Mother away from home* is coded in the same manner. *Father's* and *mother's education level* are treated as a set of dummy variables: 0 "less than primary education", 1 "less than middle school," and 2 "middle school and above".¹² Wealth is measured by the estimated value of durable goods, agriculture products, livestock and land possessions and is broken down into *wealth quintiles*. The poorest group is the reference group in all analyses. *Community dummies* based on village codes are also included in the analysis since level of community development is likely to be a confounding factor that could be correlated with hunger, nutrition status and children's behavioral problems, performance and attainment. Without controlling for unequal levels of community development, the influences of hunger and nutrition status on school functioning might be overstated.

5. Methods

We adopt two modeling approaches. First, we employ a longitudinal approach to adjust for prior school functioning and other background characteristics. We use this approach to investigate behavioral problems and educational achievement associated with hunger and chronic undernutrition in the year 2004, after adjusting for characteristics in the year 2000. These models are specified as $Y_{i2004} = \beta_j X_{ij2004} + \gamma_k X_{ik2000} + \alpha_v + \varepsilon_i$, where Y_{i2004} represents outcome Y for individual i in 2004, β_j represents estimated coefficients for predictors X_j for individual i in 2004, γ_k represents estimated coefficients for predictors X_k in 2000, α_i is a village-specific fixed effect, and ε_i is the error term. We adopt a parallel approach to model school dropout five years after the 2004 observation of hunger measures, to investigate long-term implications of hunger. These models are specified as $\frac{P_i}{1-P_i} = \exp(\beta_j X_{ij2004} + \gamma_k X_{ik2000} + \alpha_v)$, where P_i represents the probability of having dropped out by 2009. We include community-fixed effects in the analysis to adjust for different levels of regional development or different community resources, such as infrastructure, educational and health facilities, which could be important confounders in our estimation.

Second, we employ individual random- and fixed-effects models to analyze the contemporaneous relationship of short-term hunger with behavioral problems and literacy. The random effects approach allows for time-invariant attributes of individuals to be incorporated into the model, and thus to gain estimation of time-invariant attributes of individuals. The fixed-effects approach allows us to gain traction on the omitted variable bias problem in estimation of the relationship between outcomes of interest and subjective hunger. Personality traits of children are potential confounders that could be correlated with behavioral problems, cognitive ability and subjective hunger. Without taking into account omitted variable bias, the relationship between outcomes of interest and short-term hunger may be overstated. In the fixed-effects approach, the difference *within* individuals across years is linked to the difference in outcome *within* individuals across years.

¹² In general, there is a positive correlation between father's and mother's education, but existing literature suggests that father's and mother's education have independent implications: they are linked to different child outcomes, and may have influences that are specific to the gender of the child (Currie and Moretti, 2002; Johnston et al., 2005; Lamb, 2004; Thomas, 1994). A similar logic may be applied to parental migration. Thus, we include both mother's and father's attributes in the models.

Any “fixed” differences across individuals will be swept away (accounted for with dummy variables or fixed effects), such that estimates cannot be attributed to long-standing, stable differences in children’s traits.

The random effects models are specified as $Y_{it} = \beta_k X_{ikt} + \alpha_i + u_{it}$, where Y_{it} represents outcome Y for individual i at time t , β_k represents estimated coefficients for predictors X_k , α_i is unobserved effects and u_{it} is an error term. The random effects approach assumes α_i is uncorrelated with independent variables. The random effects approach allows for time-invariant attributes of individuals to be incorporated into the model, and thus to gain estimations of time-invariant attributes of individuals. In the

random effects specification, each coefficient represents the average effect on the outcome as each predictor changes over time and between individuals by one unit.

To provide a more conservative set of results, we present a set of fixed-effects specifications. Using the same notation as above, these are estimated as $Y_{it} = \beta_k X_{ikt} + \alpha_i + u_{it}$, where α_i is the individual-specific fixed effect. The fixed-effects model specification includes dummy variables for each individual in the analysis, and thus sweeps out effects of time-invariant individual differences. By controlling for time-invariant unobservable characteristics, this approach allows us to more conservatively analyze causes of changes *within* an individual. Each coefficient represents

Table 2
OLS Regression Estimations of Internalizing and Externalizing Behavioral Problems (EBP, IBP) and Pro-social Behavior Problems (PSBP) in 2004.

Outcomes	Standardized literacy scores, 2004		Standardized IBP, 2004		Standardized EBP, 2004		Standardized PSBP, 2004	
	Baseline	1 + Prior controls	Baseline	1 + Prior controls	Baseline	1 + Prior controls	Baseline	1 + Prior controls
Model specifications	CE ^a		CE		CE		CE	
Model types	1a	1b	1a	1b	1a	1b	1a	1b
Height-for-age, 2004	0.117*** (0.022)	0.123*** (0.021)	0.013 (0.023)	0.014 (0.023)	-0.034 (0.023)	-0.032 (0.023)	0.027 (0.024)	0.023 (0.024)
Subjective hunger, 2004	0.004 (0.047)	-0.004 (0.046)	0.274*** (0.050)	0.275*** (0.050)	0.193*** (0.049)	0.192*** (0.049)	0.105** (0.053)	0.104** (0.052)
Can't get full at meals, 2004	-0.022 (0.051)	-0.024 (0.049)	0.075 (0.054)	0.073 (0.054)	0.046 (0.053)	0.045 (0.053)	0.023 (0.056)	0.031 (0.056)
Standardized IBP, 2000				0.029 (0.025)				
Standardized EBP, 2000						0.106*** (0.024)		
Standardized PSBP, 2000								0.057** (0.028)
Standardized Chinese grade, 2000		0.090** (0.039)		-0.064 (0.043)		-0.052 (0.042)		-0.081* (0.044)
Standardized math grade, 2000		0.121*** (0.038)		0.027 (0.042)		-0.011 (0.041)		-0.044 (0.044)
Child age	0.152*** (0.020)	0.162*** (0.020)	0.102*** (0.021)	0.103*** (0.021)	0.057*** (0.021)	0.070*** (0.021)	0.063*** (0.023)	0.060*** (0.023)
Father away from home, 2000	0.140* (0.084)	0.137* (0.083)	-0.024 (0.089)	-0.021 (0.089)	-0.049 (0.088)	-0.045 (0.087)	0.014 (0.094)	0.012 (0.093)
Girl	-0.248*** (0.044)	-0.273*** (0.044)	-0.038 (0.047)	-0.026 (0.047)	-0.214*** (0.046)	-0.198*** (0.046)	-0.196*** (0.050)	-0.161*** (0.050)
Wealth quintile (poor as reference), 2000								
Relatively poor	0.152** (0.073)	0.159** (0.071)	-0.143* (0.076)	-0.140* (0.076)	-0.101 (0.075)	-0.086 (0.075)	0.012 (0.083)	0.004 (0.082)
Average	0.134* (0.073)	0.102 (0.072)	-0.221*** (0.078)	-0.208*** (0.078)	-0.135* (0.077)	-0.108 (0.078)	-0.089 (0.083)	-0.072 (0.083)
Relatively well-off	0.205*** (0.078)	0.182** (0.076)	-0.112 (0.082)	-0.100 (0.082)	-0.148* (0.081)	-0.121 (0.081)	-0.073 (0.088)	-0.066 (0.087)
Well-off	0.209*** (0.081)	0.178** (0.079)	-0.159* (0.085)	-0.144* (0.085)	-0.009 (0.084)	0.018 (0.084)	0.060 (0.091)	0.069 (0.091)
Birth order (1st child as reference)								
2	-0.005 (0.048)	-0.002 (0.047)	0.044 (0.051)	0.043 (0.051)	0.019 (0.050)	0.012 (0.050)	0.018 (0.054)	0.024 (0.053)
3+	-0.024 (0.067)	-0.017 (0.065)	0.020 (0.071)	0.015 (0.071)	0.012 (0.069)	-0.003 (0.069)	-0.022 (0.075)	-0.028 (0.074)
Father's education (less than primary as reference)								
Less than middle school	0.103 (0.066)	0.089 (0.065)	0.098 (0.070)	0.101 (0.070)	0.026 (0.069)	0.027 (0.069)	-0.032 (0.076)	-0.018 (0.075)
Middle school and above	0.197*** (0.062)	0.164*** (0.061)	0.086 (0.065)	0.095 (0.065)	0.016 (0.065)	0.038 (0.064)	-0.131* (0.071)	-0.105 (0.071)
Mother's education (less than primary as reference)								
Less than middle school	0.082 (0.058)	0.080 (0.056)	-0.037 (0.061)	-0.040 (0.061)	-0.050 (0.061)	-0.061 (0.060)	0.039 (0.065)	0.046 (0.064)
Middle school and above	0.118* (0.064)	0.103 (0.063)	0.043 (0.068)	0.047 (0.068)	0.042 (0.067)	0.041 (0.067)	-0.049 (0.072)	-0.037 (0.071)
Constant	-1.394*** (0.260)	-1.474*** (0.255)	-1.113*** (0.274)	-1.129*** (0.276)	-0.418 (0.270)	-0.550** (0.271)	-0.810*** (0.295)	-0.795*** (0.293)
Observations	1701	1701	1846	1846	1852	1852	1632	1632

^a CE represents community effects models (community fixed-effects models).

the change in outcome for a given individual as the predictor varies across time by one unit.

6. Results

6.1. Behavioral problems

Table 2 shows results from regression models of academic and behavioral outcomes in 2004—literacy and behavioral problems—as a function of hunger and nutritional status in 2004, family background and demographic characteristics, and, in the second specifications for each outcome, for prior school functioning measured in the year 2000. All specifications include community fixed effects.

Two main findings emerge from Table 2. First, low height-for-age—the key measure of chronic or early undernutrition—is associated with poorer literacy acquisition by 2004,¹³ but is not associated with behavioral outcomes in 2004—whether psychosocial development scales or the pro-social behavior problems scale. Second, and in contrast, the subjective hunger measure is linked to behavioral outcomes. Children who report being so hungry they cannot concentrate have significantly greater externalizing problems, internalizing problems, and teacher-reported pro-social behavior problems. Can't get full at meals and height-for-age are not associated with any of the psychosocial measures. After adjusting for family background, demographic characteristics, and early school functioning, children who do report experiencing subjective hunger have higher scores on standard internalizing and externalizing problems indices (0.275 and 0.192 standard deviations, respectively). Their teachers report significantly more behavioral problems (0.104 standard deviations) and the coefficient is statistically significant at $p < 0.05$.¹⁴ Compared to children in the reference group who reported getting full at all meals, children who report being unable to get full at breakfast and lunch did not show significantly different behavioral problems in these specifications.

As an additional test of the short-term hunger relationships with outcomes, we capitalize on availability of both short-term hunger and behavioral outcomes at two points in time for each individual to estimate individual random and fixed-effects specifications in Table 3. We do not have data from two points on literacy or height-for-age, and so do not include these measures here. For each outcome, specifications listed as “a” are random effects specifications and specifications listed as “b” are fixed-effects specifications. Also for each outcome, model 1 is a baseline model that simply adjusts for demographic characteristics and socioeconomic status (explicitly, in random effects specifications, or implicitly, in fixed-effects specifications), while model 2 adjusts for academic performance.

Estimated coefficients from these specifications confirm the relevance of subjective hunger for behavioral problems. In the most conservative fixed-effects specifications (labeled “2b”), reporting subjective hunger is related to about a 0.21 standard

deviation greater score on the internalizing behavior problems scale and a 0.108 standard deviation greater score on the externalizing behavior problems scale.¹⁵ Not being able to get full at breakfast and lunch becomes significant in the within-models (though only at the 0.1 level for externalizing problems): within individuals over time, a change from being able to get full to not being able to get full is associated with about a tenth of a standard deviation change in both internalizing and externalizing problems. Finally, subjective hunger is related to about a tenth of a standard deviation greater score on the pro-social behavior problems scale in the baseline model and about a 0.075 standard deviation greater score in the grade-adjusted models, but the effect drops to insignificance in the fixed-effects specification. Most striking among these results is the finding that the same children have significantly more behavioral problems when they experience subjective hunger.

6.2. Lingering effects?

Table 4 addresses the question whether there are lingering implications of chronic undernourishment or the subjective hunger measures. Table 4 contains results from a binary logit model of middle school dropout five years after the 2004 observation of hunger measures. Specification 1 includes chronic undernourishment and subjective hunger measures from 2004, along with family background controls, without adjusting for 2000 measures of achievement or behavioral problems. Specification 2 adjusts for 2000 measurements of achievement and behavioral problems, based on specification 1. Specification 3 adds literacy scores in 2004, and thereby allows us to test for a lingering effect of undernourishment or hunger after adjusting for effects via early and middle-childhood learning. Specification 4 adds internalizing and externalizing behavioral problems in 2004.

Table 4 suggests that short-term hunger is not related to later dropout, after adjusting for family background, demographic characteristics, community differences, and early school functioning. However, chronic undernourishment measured in middle childhood does show a significant effect: greater height-for-age z-scores are significantly associated with a decrease in odds of dropping out of middle school. Importantly, this effect dissipates when literacy acquired by 2004 is incorporated into the model, suggesting that the protective effect may be via effects on performance. Findings from Table 4 also show that the lingering association of chronic undernourishment with dropping out is independent of parental education, family wealth and the level of community development.

6.3. Discussion

Results show that chronic-undernourishment and short-term hunger are both related to school functioning in significant ways, but are not at all similar in terms of their implications. Chronic undernourishment can be linked to literacy attainment and to long-term school persistence. In contrast, experiencing short-term subjective hunger is directly linked to self-assessed psychological

¹³ Other work utilizing the same data source has investigated relationship of literacy achievement to height-for-age, weight-for-age, and food security. Results from that analysis suggest that the association between height-for-age and literacy achievement documented here may occur via early academic achievement and educational attainment (Hannum et al., 2014).

¹⁴ To test whether chronically undernourished children were more strongly affected by hunger, and to test whether girls and boys were differently affected by hunger, we estimated a series of models containing hungerXchronic undernourishment interaction terms, and a series containing hungerXsex interactions. Among these, none of the interactions were significant at conventional levels, save an interaction between chronic undernourishment and subjective hunger in the model of pro-social behavior. In that case, stunted children who were hungry were significantly more likely than others to exhibit pro-social behavior problems.

¹⁵ We perform the same analyses (Table 3, specification 2b for each dependent variable) with subjective hunger and can't get full at meals alone in the models. The coefficients for subjective hunger are 0.230***, 0.129*** and 0.117** for internalizing, externalizing and pro-social behavior problems, respectively in fixed-effects models with prior controls. For can't get full at meals, the coefficients are 0.155***, 0.146*** and 0.014, respectively. The coefficients attenuate if we include both measures in the models, but each measurement still has independent effect on internalizing and externalizing behavior problems. (As shown in Table 3, the can't get full at meals coefficient becomes marginally significant in the internalizing behavior problems model.)

Table 3
Linear Regression with Random- and Fixed-Effects Estimations of Externalizing and Internalizing Behavioral Problems and Pro-social Behavior Problems.

Outcomes	Standardized IBP				Standardized EBP				Standardized PSBP			
	Baseline		1 + Prior controls		Baseline		1 + Prior controls		Baseline		1 + Prior controls	
	RE	FE	RE	FE	RE	FE	RE	FE	RE	FE	RE	FE
Model specification	1a	1b	2a	2b	1a	1b	2a	2b	1a	1b	2a	2b
Time-varying variables												
Subjective hunger	0.213*** (0.043)	0.211*** (0.049)	0.211*** (0.044)	0.210*** (0.050)	0.137*** (0.039)	0.107** (0.048)	0.133*** (0.039)	0.108** (0.048)	0.114*** (0.037)	0.119** (0.050)	0.075** (0.033)	0.078 (0.048)
Can't get full at meals	0.144 (0.109)	0.105* (0.056)	0.143 (0.108)	0.106* (0.056)	0.137 (0.082)	0.121** (0.054)	0.136 (0.083)	0.121** (0.054)	0.008 (0.049)	-0.008 (0.056)	0.006 (0.040)	-0.004 (0.054)
Standardized Chinese grade			-0.058 (0.073)	-0.008 (0.053)			-0.073 (0.067)	-0.008 (0.052)			-0.164*** (0.039)	-0.109** (0.043)
Standardized math grade			0.010 (0.081)	-0.002 (0.051)			0.000 (0.069)	0.006 (0.050)			-0.210*** (0.039)	-0.186*** (0.040)
Child age	0.007 (0.018)	-0.007 (0.009)	0.007 (0.016)	-0.008 (0.009)	-0.003 (0.014)	-0.004 (0.008)	-0.002 (0.012)	-0.005 (0.008)	-0.016 (0.017)	0.005 (0.009)	0.001 (0.014)	0.005 (0.009)
Father away from home	-0.012 (0.059)	0.006 (0.073)	-0.011 (0.058)	0.007 (0.073)	-0.024 (0.055)	-0.027 (0.070)	-0.024 (0.054)	-0.027 (0.071)	-0.012 (0.054)	0.012 (0.073)	-0.021 (0.051)	0.049 (0.071)
Mother away from home	0.154 (0.226)	-0.170 (0.184)	0.149 (0.222)	-0.174 (0.184)	0.165 (0.174)	-0.141 (0.178)	0.163 (0.175)	-0.144 (0.178)	-0.046 (0.139)	0.039 (0.196)	-0.024 (0.131)	-0.037 (0.190)
Wealth quintile, 2000 (poor as reference)												
Relatively poor	-0.057 (0.054)	-0.021 (0.081)	-0.057 (0.055)	-0.021 (0.081)	-0.057 (0.054)	-0.021 (0.081)	-0.057 (0.055)	-0.021 (0.081)	-0.012 (0.054)	0.065 (0.082)	-0.033 (0.051)	0.053 (0.080)
Average	-0.152** (0.056)	-0.114 (0.084)	-0.150** (0.055)	-0.115 (0.084)	-0.152** (0.056)	-0.114 (0.084)	-0.150** (0.055)	-0.115 (0.084)	0.042 (0.056)	0.165* (0.085)	0.030 (0.052)	0.141* (0.083)
Relatively well-off	-0.134** (0.056)	-0.068 (0.091)	-0.127** (0.057)	-0.069 (0.092)	-0.134** (0.056)	-0.068 (0.091)	-0.127** (0.057)	-0.069 (0.092)	0.012 (0.056)	0.187** (0.092)	0.027 (0.053)	0.163* (0.090)
Well-off	-0.161** (0.058)	-0.032 (0.100)	-0.153** (0.058)	-0.034 (0.100)	-0.161** (0.058)	-0.032 (0.100)	-0.153** (0.058)	-0.034 (0.100)	-0.034 (0.057)	0.153** (0.101)	0.277** (0.054)	0.180*** (0.098)
Time-invariant variables												
Girl			-0.036 (0.037)		-0.047 (0.035)		-0.036 (0.037)		-0.230*** (0.035)		-0.188*** (0.033)	
Birth order (1st child as reference)												
2			0.049 (0.038)		0.049 (0.038)		0.049 (0.038)		-0.061 (0.039)		-0.065* (0.035)	
3+			0.075 (0.052)		0.075 (0.052)		0.075 (0.051)		-0.037 (0.054)		-0.061 (0.049)	
Father's education (less than primary as reference)												
Less than middle school			0.068 (0.050)		0.068 (0.050)		0.072 (0.050)		-0.017 (0.053)		-0.004 (0.048)	
Middle school and above			-0.025 (0.046)		-0.025 (0.046)		-0.016 (0.048)		-0.016 (0.048)		0.006 (0.045)	
Mother's education (less than primary as reference)												
Less than middle school			-0.036 (0.043)		-0.036 (0.043)		-0.032 (0.044)		0.039 (0.045)		0.068 (0.041)	
Middle school and above			-0.021 (0.046)		-0.021 (0.046)		-0.012 (0.047)		-0.064 (0.048)		-0.013 (0.046)	
Constant	-0.088 (0.203)	0.019 (0.126)	-0.102 (0.179)	0.027 (0.127)	-0.088 (0.203)	0.019 (0.126)	-0.102 (0.179)	0.027 (0.127)	0.249 (0.173)	-0.273** (0.127)	0.014 (0.150)	-0.238* (0.126)
Observations	3986	3692	3986	3692	3986	3692	3986	3692	3970	3290	3970	3290

well-being, and, in some cases, to teachers' reports of behavior problems. Although both measures of short-term hunger are associated with psychosocial problems in individual fixed-effects specifications, subjective hunger is more robustly associated with psychosocial and behavioral problems, regardless of modeling strategy.

While it is certainly the case that long periods of hunger, especially in early childhood, might be expected to lead to stunting, findings suggest that chronic undernutrition and short-term subjective hunger are distinctive indicators of Belsky et al.'s (2010) concept of material hardship related to food. Consistent with the notion that chronic undernutrition and current hunger are distinctive indicators, it is the case that taller children are more

likely, not less likely, than shorter children to report subjective hunger. For example, binary logistic estimation of subjective hunger on height-for-age z scores shows that a one unit increase in height-for-age z scores is associated with an 8% increase in odds of reporting subjective hunger—an association that is marginally statistically significant at $p < 0.1$ (not shown). And whereas chronic undernutrition is a problem linked very clearly to economic deprivation, subjective hunger is less so, at least in this generally economically disadvantaged sample. For example, Appendix Fig. 1 shows height-for-age z-scores, Appendix Fig. 2 shows the proportion reporting subjective hunger, and Appendix Fig. 3 shows the proportion reporting not able to get full at breakfast and lunch by wealth quintile in 2004. Whereas the poorest children are at

Table 4
Binary Logistic Regression Estimates of Middle School Dropout with Chronic Undernutrition, Subjective Hunger and Can't Get Full at Meals.

Outcome	Dropout prior to completing middle school			
	Baseline	1 + prior controls in 2000	2 + Standardized literacy scores	3 + other controls in 2004
Mode type	CE	CE	CE	CE
	(1)	(2)	(3)	(4)
Height-for-age, 2004	0.847** (0.059)	0.830** (0.060)	0.895 (0.065)	0.891 (0.064)
Subjective hunger, 2004	0.862 (0.132)	0.885 (0.139)	0.840 (0.135)	0.806 (0.131)
Can't get full every breakfast and lunch, 2004	0.972 (0.243)	0.965 (0.236)	1.006 (0.216)	0.982 (0.202)
Standardized Literacy score, 2004			0.461*** (0.041)	0.473*** (0.041)
Standardized IBP, 2000		1.024 (0.134)	1.050 (0.143)	1.062 (0.145)
Standardized EBP, 2000		1.156 (0.153)	1.017 (0.140)	1.001 (0.139)
Standardized PSBP, 2000		0.964 (0.080)	0.947 (0.080)	0.947 (0.080)
Standardized IBP, 2004				1.114 (0.135)
Standardized EBP, 2004				1.075 (0.124)
Standardized Chinese grade, 2000		0.765** (0.098)	0.809 (0.107)	0.819 (0.109)
Standardized math grade, 2000		0.793* (0.097)	0.835 (0.107)	0.830 (0.106)
Girl	1.328** (0.177)	1.460*** (0.204)	1.126 (0.169)	1.149 (0.175)
Child age	1.078 (0.064)	1.085 (0.068)	1.196*** (0.081)	1.166** (0.081)
Birth order (1st child as reference)				
2	0.960 (0.141)	0.937 (0.142)	0.925 (0.147)	0.922 (0.147)
3+	1.076 (0.207)	1.039 (0.205)	1.031 (0.213)	1.025 (0.213)
Father's education (less than primary as reference)				
Less than middle school	0.746 (0.134)	0.754 (0.139)	0.792 (0.153)	0.779 (0.152)
Middle school and above	0.507*** (0.090)	0.534*** (0.097)	0.574*** (0.112)	0.563*** (0.110)
Mother's education (less than primary as reference)				
Less than middle school	0.948 (0.174)	0.950 (0.179)	1.040 (0.207)	1.059 (0.211)
Middle school and above	0.617** (0.139)	0.642* (0.148)	0.661* (0.161)	0.657* (0.160)
Father away from home, 2000	0.815 (0.208)	0.817 (0.214)	0.973 (0.265)	0.962 (0.263)
Wealth quintile, 2000 (poorest as reference)				
Relatively poor	0.400*** (0.078)	0.389*** (0.079)	0.391*** (0.084)	0.397*** (0.086)
Average	0.473*** (0.094)	0.511*** (0.104)	0.513*** (0.112)	0.539*** (0.118)
Relatively well-off	0.418*** (0.095)	0.442*** (0.102)	0.473*** (0.116)	0.491*** (0.121)
Well-off	0.373*** (0.091)	0.401*** (0.100)	0.429*** (0.113)	0.442*** (0.117)
Constant	0.202* (0.162)	0.146** (0.122)	0.058*** (0.052)	0.071*** (0.064)
Observations	1794	1794	1794	1794

^aCE represents community effects models (community fixed-effects models).

greater risk for low height-for-age, there is no such relationship for the two subjective hunger measures, and there is indeed a hint that reported hunger could be greater among slightly better-off children in the sample. In short, chronic undernutrition, which coincides most closely with deep poverty, is a risk factor for literacy

acquisition and persistence, while short-term hunger is a risk factor for behavioral problems.

One limitation of the study is that, although we utilize individual- and community- fixed effects model to control unobserved time-invariant characteristics of children and

variation in community development, it is possible that certain time-varying factors may still play a role in the linkages among chronic undernutrition, hunger and child outcomes. For instance, lending and borrowing money or food between friends or relatives may provide a buffer for alleviating subjective hunger over time for some individuals. Such a time-variant process may have a strong influence on subjective hunger, but less on chronic undernutrition. Hence, our estimation of lingering effects of chronic undernutrition on educational attainment may be less sensitive to time-variant factors, but the degree of subjective hunger may be underestimated if such processes occur.

7. Conclusions

These analyses build on prior research by including multiple measurements of food-related deprivation, detailed measures of school functioning, and a longitudinal analytical approach. However, lacking data on chronic undernourishment in early childhood, we are not able to conclusively rule out the possibility that short height-for-age is the result of diseases or poor care, rather than poor nutrition. Furthermore, our measurement of height-for-age at adolescence may be affected by growth associated with puberty, and thus may not precisely reflect early life nutrition environment.

Despite these limitations, our results indicate clearly that chronic undernourishment operates in a different manner than subjective hunger. The former is linked directly to degree of impoverishment in this generally disadvantaged sample, while the latter is not. The former is linked to learning outcomes and, partly via learning outcomes, to long-term school persistence, while the latter is linked consistently to internalizing and externalizing behavioral problems and sometimes to teacher-reported classroom behaviors. These findings are consistent with existing literature linking chronic undernourishment to educational attainment. On the other hand, our results are inconsistent with prior research in other settings suggesting that chronic undernourishment might be related to behavioral problems. In this setting, chronic undernourishment has negligible associations with two established scales of self-reported behavioral problems and a scale of teacher-reported department. This inconsistency may be due to the lack of unity in conceptualization and measurement of behavioral problems across papers.

The finding that subjective hunger measurement is unrelated to educational performance, as measured by literacy acquisition, may not be surprising in light of research indicating that school-based food and nutrition program effects on children's educational performance are not yet conclusive, and effects observed on achievement may operate in some part via incentivizing school attendance and continuation rather than via alleviating hunger effects on performance (Hoyland et al., 2009). However, our findings indicate that performance measures may not tell the full story: children who experience subjective hunger display more behavioral problems—sometimes to the point that these problems are measurable even in teacher reports. From a practical perspective, findings presented here imply that school feeding programs, which address both short-term hunger and chronic undernutrition and which have recently expanded in China,¹⁶ could have a more immediate effect on non-cognitive behavior than on achievement, though it is possible that school feeding programs in China might incentivize attendance or persistence in a manner documented elsewhere.

Beyond hunger and chronic nutrition, other recent studies in China have focused on nutrient deprivation in poor communities—and have linked nutrient supplementation to better test scores. For example, Luo et al. (2012) sampled fourth-grade elementary school students from 66 schools in eight rural counties in Shaanxi Province and implemented a nutritional supplement in a randomized control trial. Students receiving multi-vitamins with iron showed significantly improved math scores. A school-based anemia reduction program in rural Qinghai and Ningxia similarly showed that exam scores among students who were anemic at baseline improved when schools were given incentives and subsidies to improve address anemia (Sylvia et al., 2013). Together with results presented here, these findings speak to the importance of a multi-dimensional approach to conceptualizing material hardships related to food in childhood that encompasses undernutrition and hunger, as well as malnutrition. Future studies should also consider explicitly the multiple pathways—cognitive, psychological and behavioral—by which these dimensions could be linked to children's schooling outcomes.

Acknowledgements

Data collection for the Gansu Survey of Children and Families was supported by grants from the United Kingdom Economic and Social Research Council and Department for International Development (ESRC RES-167-25-0250), the Spencer Foundation Small and Major Grants Programs, the World Bank, and NIH Grants 1R01TW005930-01 and 5R01TW005930-02. The authors acknowledge additional research support from the Population Studies Center at the University of Pennsylvania (National Institutes of Health - National Institute on Aging, Grant number P30 AG12836, the Boettner Center for Pensions and Retirement Security at the University of Pennsylvania, and National Institutes of Health - National Institute of Child Health and Development Population Research Infrastructure Program R24 HD-044964).

Appendix Table A. Lists of Dependent and Key Dependent Variables by Wave.

	2000	2004	2007	2009
Dependent Variables				
IBP	V	V	n.a.	n.a.
EBP	V	V	n.a.	n.a.
PSBP	V	V	n.a.	n.a.
Chinese grade	V.	V	n.a.	n.a.
Math grade	V			
Literacy scores	n.a.	V	n.a.	V
Middle school dropout	n.a.	n.a.	n.a.	V
Key independent variables				
Height-for-age z scores	n.a.	V	n.a.	n.a.
Subjective hunger	V	V	n.a.	n.a.
Can't get full at meals	V	V	n.a.	n.a.

Notes: V represents variable used; n.a. denotes not available or not applicable.

¹⁶ According to a World Food Program report, in 2010, China implemented a pilot school feeding program that reached 12 million children, and in 2011, the program had been scaled up to reach an estimated 38 million children. (World Bank, 2013).

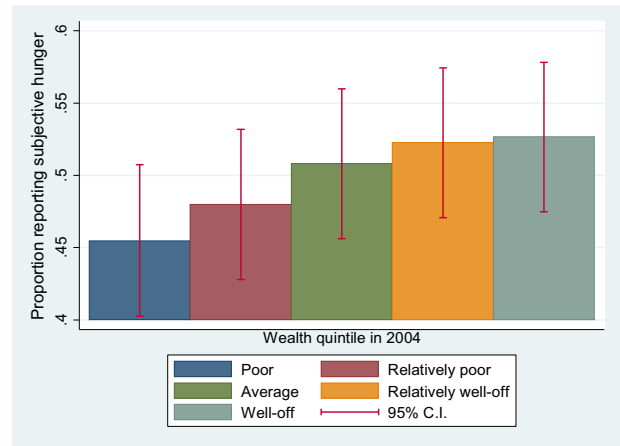
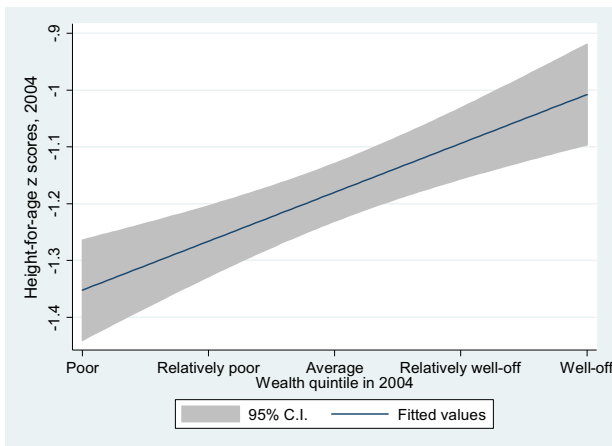
Appendix Table B. Behavioral Problem Scale Components.

<p>Externalizing behavior problems</p> <p>I quarrel with others.</p> <p>I lose my temper.</p> <p>I like to brag.</p> <p>I can't concentrate on what I am doing.</p> <p>I like to show off my strengths in front of others.</p> <p>I steal things from others or my home.</p> <p>I break things on purpose.</p> <p>I do not observe school discipline.</p> <p>It bothers me if others do things better than I do.</p> <p>Even if I know I am wrong, I am reluctant to listen to others.</p> <p>I always want to be the center of attention.</p> <p>I often am suspicious of others.</p> <p>I act impulsively</p> <p>I often say obscenities.</p> <p>I often make fun of others.</p> <p>I sometimes tell lies.</p> <p>I am easily angered.</p> <p>I often disregard other people's ideas.</p> <p>I sometimes menace and even hurt others.</p> <p>Raw mean = 37.45 (2000)</p> <p>Raw mean = 33.54 (2004)</p> <p>Cronbach's alpha = 0.88 (2000)</p> <p>Cronbach's alpha = 0.87 (2004)</p>	<p>Internalizing behavior problems</p> <p>I don't want others to meddle in my own business.</p> <p>I can't concentrate on what I am doing.</p> <p>I have many strange/weird ideas (often daydream.)</p> <p>I easily get flushed. (I am easily frustrated or anxious.)</p> <p>I can't do things well when my parents are not present. (I usually need help from adults to do something well.)</p> <p>I am very indifferent to others.</p> <p>I am very shy.</p> <p>I am often teased by classmates.</p> <p>I do not feel guilty, even if I have done something wrong.</p> <p>I always want to be the center of attention.</p> <p>I often am suspicious of others.</p> <p>My temper changes quickly and easily.</p> <p>I feel inferior to others.</p> <p>I prefer to be alone.</p> <p>I often feel nervous.</p> <p>I stay quiet when I am with my classmates or friends.</p> <p>There is always something to worry about.</p> <p>Raw mean = 37.80(2000)</p> <p>Raw mean = 34.91(2004)</p> <p>Cronbach's alpha = 0.83 (2000)</p> <p>Cronbach's alpha = 0.79 (2004)</p>	<p>Pro-social behavior problems</p> <p>Has difficulty focusing his/her attention.</p> <p>Likes to actively participate in class.</p> <p>Fearful or anxious.</p> <p>Disobedient.</p> <p>Has trouble getting along with other children.</p> <p>Obeys instructions</p> <p>Drowsy in class</p> <p>Disrupts class</p> <p>Unhappy, sad, depressed</p> <p>Raw mean = 15.70 (2000)</p> <p>Raw mean = 16.30 (2004)</p> <p>Cronbach's alpha = 0.69 (2000)</p> <p>Cronbach's alpha = 0.68 (2004)</p>
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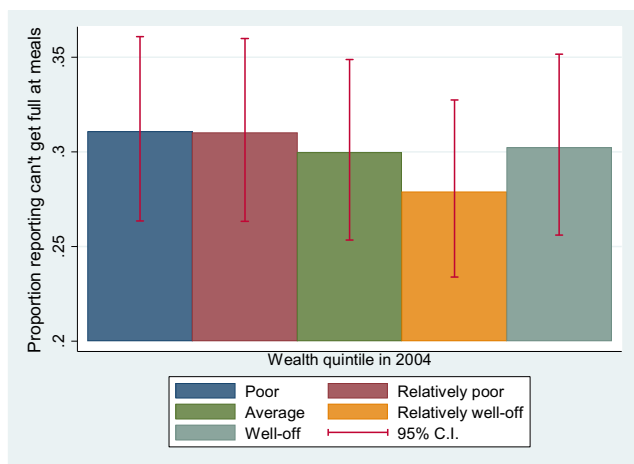
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Appendix Fig. 1. Height-for-age Z-scores by Wealth Quintile with 95% Confidence Interval in 2004.

Appendix Fig. 2. Proportion Reporting Subjective Hunger by Wealth Quintile with 95% Confidence Interval in 2004..



Appendix Fig. 3. Proportion Reporting Can't Get Full at Meals by Wealth Quintile with 95% Confidence Interval in 2004.

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