1999

Nutrition and the cognitive ability of children: evidence from Egypt

Maria Patricia A. Cortez
Iowa State University

Nutrition and the cognitive ability of children:

Evidence from Egypt

by

Maria Patricia A. Cortez

A dissertation submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Major: Economics

Major Professor: Helen H. Jensen

Iowa State University

Ames, Iowa

1999

UMI Number: 9924711

Graduate College

Iowa State University

This is to certify that the Doctoral dissertation of

Maria Patricia A. Cortez

has met the dissertation requirements of Iowa State University

Signature was redacted for privacy.

Major Professor

Signature was redacted for privacy.

For the Major Program

Signature was redacted for privacy.

For the Graduate College

Not unto us, O Lord, not unto us,
but unto thy Name give the praise;
for thy loving mercy, and for thy truth's sake.

-Psalm 115

For my family

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

I would like to thank the following persons who served on my dissertation committee: Helen Jensen, Lehman Fletcher, Wallace Huffman, Fred Lorenz, and Peter Orazem. Helen Jensen and Peter Orazem were especially helpful in sorting through the issues in this dissertation. I would also like to extend special thanks to William Meyers, who had supported my graduate study. I would also like to thank the Department of Economics and the Center for Agricultural and Rural Development for the opportunity to earn a Ph.D. degree. For their permission to use the Nutrition Collaborative Research Support Program data set, I would like to thank the U.S. Agency for International Development. Gail Harrison of the University of California at Los Angeles, Suzanne Murphy of the University of California at Davis, and Theodore Wachs of Purdue University were also helpful at various stages of the study in providing information regarding the data. I thank them for their help. Other material used in this study was obtained with the assistance of Wayne Pedersen and the entire staff of the Interlibrary Loan Office at the library. They also provided invaluable assistance in obtaining material not available at the library throughout my graduate coursework. I thank them all. I cannot thank enough Godfrey Gibbison, who had been forced to listen to my almost incessant chatter about the issues dealt with in this study. I greatly appreciate his patience, emotional support, and understanding over the past few years. Finally, I am heavily indebted to my parents for their continuous support of all my endeavors.

ABSTRACT

Investing in nutrition is desirable in itself. Adequate nutrition is essential for the proper growth and development of individuals and partly determines the quality of life and well-being of individuals. But there is also an economic rationale for investing in nutrition. Nutrition may have a direct effect on the productivity of labor and an indirect effect through educational achievement. This dissertation focused on the indirect effect of nutrition on labor productivity by examining whether nutritional factors were associated with the cognitive ability of children. The children consisted of toddlers, aged 18-30 months, and schoolers, aged 6-9 years, from a peri-urban Egyptian village. The study found both current nutrition and long-term nutrition to have a significant influence on the cognitive ability of toddlers. For schoolers, only long-term nutrition appeared to have significant influence on their cognitive ability. These results suggest the importance of early nutrition programs for the proper cognitive development of children.

CHAPTER ONE
INTRODUCTION

The perception that investing in education leads to economic growth and higher future income has been the rationale for public and private expenditures on education. But there is a high degree of inefficiency in educational expenditures in developing countries. Rates of dropout and grade repetition, especially at the primary level, are high. There is also evidence of failure to learn from children who do complete primary school but lack basic reading, writing and computational skills (Lockheed and Levin, 1993). Efforts to improve educational outcomes have focused mainly on further increasing expenditures on education in order to improve school-related factors believed to influence school achievement, such as, the quality of teaching and infrastructure (World Bank, 1995). But such efforts ignore the role that child-related factors, such as, nutrition, health, ability, motivation, and persistence, play in student achievement.

There is growing empirical evidence that inadequate nutrition diminishes a child's educational achievement. Children whose growth was more stunted were more likely to be enrolled at a later age, with the average delay in enrollment to be about two years (Glewwe and Jacoby, 1995). Moreover, better nourished children were also more likely to be enrolled in school (Moock and Leslie, 1986) and were more likely to progress faster in school (Jamison, 1986). These findings suggest that inadequate nutrition can impair a child's ability to take advantage of educational opportunities and limit the level of educational achievement a child can attain.

This study examines another pathway through which nutrition may affect educational achievement that is through cognitive ability. Cognitive ability corresponds with the individual's ability to adjust or adapt to the environment, the ability to learn, and the ability to perform abstract thinking (Sattler, 1988, pp. 44-45). It has been shown to have a positive relationship with educational outcomes, such as, educational attainment (Boissiere et al., 1985) and achievement (Glewwe and Jacoby, 1992; Behrman and Lavy, 1994). Cognitive ability could also be an indicator for a schooler's capacity or ability to learn and a preschooler's readiness for school. Thus, identifying the significant determinants of children's cognitive ability may suggest other ways to improve educational outcomes.

Malnutrition may have a detrimental effect on biological and behavioral factors related to the cognitive growth and development of children. There are studies that have shown that early malnutrition may result in alterations or damage to structures of the brain and central nervous system that may not be fully reversible (Levitsky and Strupp, 1995). Malnutrition may also increase the risk of getting infections, delay motor development, and decrease a child's level of activity. This would result in fewer opportunities for a child to explore, interact, and learn from the environment, thus delaying the acquisition of cognitive skills (Pollitt et al., 1993). If children's cognitive ability were affected by their nutritional status, then a mix of interventions that include nutrition intervention programs may be optimal for improving educational outcomes than programs that focus on school-related factors alone.

The study uses data from the Nutrition Collaborative Research Support Program (Nutrition CRSP) in Kalama, Egypt on a sample of toddlers that included children 18-30 months old and a sample of schoolers that included school-aged children from 6-9 years old.

The Nutrition CRSP was a longitudinal study of the effect of mild-to-moderate malnutrition[1] on human function that included pregnancy outcome and lactation, infant morbidity and growth, growth of toddlers and schoolers, cognitive and behavioral outcomes, and individual and household morbidity burden.

Studies that have examined the effect of malnutrition on cognitive development have used either an experimental or a correlational approach. These studies provide some evidence that malnutrition adversely affects children's cognitive development, but the evidence they provide has not been consistent or conclusive. One reason for this is that researchers are precluded for ethical reasons from carrying out rigorous experimental studies with individuals randomly assigned to a treatment group or to a control group conducted under double blind conditions. Consequently, experimental studies conducted in the past tend to have methodological problems that are serious enough to undermine their findings. These include self-selection, differing levels of participation, and changes in the intrahousehold allocation of food induced by the experiment offsetting the effect of the treatment (Joos and Pollitt, 1984; Pollitt, 1988). Thus, it is not certain whether these studies were able to separate the effect of nutrition from the effect of other variables on cognitive development.

One example of such studies is a longitudinal study conducted in four Guatemalan villages between 1969 and 1977 to examine the effect of prenatal and early postnatal supplementary feeding on cognitive development (Pollitt et al., 1993, 1995). Two of the villages were provided with Atole, a high-protein, high-energy supplement, while the other

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[1] Mild-to-moderate malnutrition can be defined to be all subclinical forms of malnutrition, which are conditions thought to be related to nutritional inadequacies but not identifiable as a nutritional disease (Behar, 1981, p. 238).

village pair was provided with Fresco, a zero-protein, low energy supplement. Although several studies, for example, Klein et al. (1976), did find small but significant effects of supplementation on infants' and preschoolers' performance on cognitive tests, the findings may be biased due to problems with the research design.

One problem was that the subjects themselves decided whether to participate and how much of the supplement to consume. Mothers in each village, along with their children under the age of seven and their infants born during the study, were offered the supplements and were allowed to drink as much as they wanted. Subjects also were not blinded with regard to the nature of the supplement. Atole and Fresco are distinctly different from each other. Atole is a warm, thick, brown, sweet drink, similar to the porridge that mothers give to their children, while Fresco is a cool, clear, sweet drink, similar to the refreshments villagers drink. It is thus not surprising that investigators found strong evidence that mothers perceived Atole to be "good food" and Fresco as a "refreshment" (Joos and Pollitt, 1984). Hence, the estimated effect of the supplement may be biased by the effect of the determinants of participation in the supplementation program.

In another study conducted in Bogota, Colombia to examine whether prenatal versus postnatal supplementation affects cognitive development during the first three years of life, poor families living in Bogota were randomly assigned to six treatment groups (Herrera et al., 1980). These included an unsupplemented group, a group supplemented from three months before the infant's birth up to the infant's sixth month, a group supplemented after the infant is six months of age, and a group supplemented from three months before the infant's birth up to the infant's third year. Families were selected if the mother was less than six months pregnant and either has only one child under five who is malnourished or has several children, half of whom are malnourished.

Unlike the Guatemala study, no significant effects were found between the supplemented and unsupplemented group. But like the Guatemala study, their findings should be qualified because the study did not measure directly the amount of the supplement consumed by the mother and the infant. It also did not control for the effect of the supplement on the intrahousehold allocation of food. The supplement, which consisted of dry milk, bread and oil, was distributed weekly and provided to the entire family but was not consumed under observation. It is possible that the supplementation program may have induced the household to substitute household purchased food with the supplement, offsetting the effect of the supplement.

The evidence provided by correlational studies, such as those reviewed in Behrman (1993) and Pollitt (1990), are also not conclusive because they do not control for the endogeneity of nutritional status and nutrient intake or the effect of unobserved heterogeneity regarding child and household related factors. Moreover, estimates from studies that have used a bivariate correlational approach are liable to have omitted variable bias. Malnourished children, especially those in developing countries, are likely to be exposed to non-nutritional risk factors, such as, poverty and low levels of parental education, that also inhibit cognitive development (Pollitt, 1988; Grantham-McGregor, 1995). Poor households may not have access to resources that promote cognitive ability and parents with low levels of educational attainment may be unable to provide an intellectually stimulating environment for their children. In short, a poor environment magnifies the adverse effect of malnutrition on cognitive ability and failure to control for the former will bias estimates of the effect of the latter.

This study examines the relationship of nutrition with cognitive ability, while controlling for the effect of household environmental factors. It also addresses the econometric issues of endogeneity of nutritional status and nutrient intake and unobserved heterogeneity regarding child and household related factors. This was made possible by the wide range of variables contained in the data set, which included individual food intake, anthropometric measures, and household socioeconomic and demographic information. But the study is unable to address simultaneously the issues of endogeneity and unobserved heterogeneity because the data needed to do so is not available in the data set.

The dissertation is organized as follows. Chapter Two presents the model used by the study, which is based on the household production model, along with a discussion of the issues regarding its estimation. Chapter Three provides a brief background of the Egypt Nutrition CRSP and description of the data that they collected, which is relevant to the study. Chapter Four contains the empirical counterpart of the model presented in Chapter Two. Chapter Five presents the results of the estimation of the model. Chapter Six concludes the study with a discussion of the policy implications of the findings.

CHAPTER TWO
THEORETICAL MODEL AND ECONOMETRIC ISSUES

2.1 Introduction

The theoretical model that is used to examine the determinants of cognitive ability is based on the household production model, as formalized by Becker (1965), and the application of the model to examining the determinants of child quality by Willis (1973) and Becker and Tomes (1976). The theoretical model and the econometric issues surrounding its estimation, namely, endogeneity and unobserved heterogeneity, are presented in this chapter.

The chapter is divided into five sections. The first two sections of this chapter, contain a brief review of the household production model and the applications of the model that are pertinent to the study. The following two sections contain a description of the theoretical model used by the study and a discussion of the econometric issues involved in estimating the model. The final section summarizes the contents of the chapter.

2.2 The Household Production Model

The basic idea of the household production model is that households use their time to transform market goods into commodities that provide utility. The commodities are produced according to the household's production technology and the time and income available to the household. This model is relevant to the study, since it can account for a household's ability to affect the level of its children's cognitive ability, to a certain extent, by the quantity and quality of inputs it provides them, such as, parental care and intellectual environment. Although it is believed that heredity sets a limit on a child's potential or innate cognitive ability, it is the child's environment that enables that potential to be realized and determines how close the child's actual ability is to the potential (Sattler, 1988). In other words, the outcome is the product of the interaction between heredity and environment.

Formally, the household production model (Becker, 1965; Becker, 1981) postulates that a household maximizes the utility function,

$$U(Z_1,\ldots,Z_n), \tag{2.1}$$

where the Z_i 's are home produced commodities (for example, child quality) and are each produced according to the household's production technology,

$$Z_i = f_i(x_i, T_i; E_i), \qquad i=1,\ldots n, \tag{2.2}$$

where x_i and T_i are, respectively, the goods purchased in the market and the vector of time that are inputs into the household's production of the ith commodity, and E_i is a vector of variables representing the environment in which production of the ith commodity occurs, such as, the ability and human capital of the household. The utility function is maximized subject to the goods constraint,

$$\sum_{i=1}^{n} p_i x_i = I = V + wT_W, \tag{2.3}$$

and the time constraint,

$$T = T_w + \sum_{i=1}^{n} T_i, \tag{2.4}$$

where p_i is the vector of unit prices x_i, T_w is the vector of hours spent in the labor market, w is the vector of earnings per unit of T_w, and V is unearned income.

The income and time constraints can be collapsed into the household's full income constraint,

$$S = V + wT_w = \sum_{i=1}^{n}(wT_i + p_i x_i), \tag{2.5}$$

where S is the household's full income.

2.3 Extensions to the Household Production Model

The household production model has had many applications. It has been used to model the demand for children and the demand for health, the determinants of labor supply, investment in human capital, crime and marital choice. But the application of the model that is particularly relevant to examining the determinants of cognitive ability is the one that pertains to the determinants of child quality by Willis (1973) and Becker and Tomes (1976), since cognitive ability is one facet of child quality.

Willis extended the household production model to examine the relationship between the quantity and quality of children. He showed that the level of quality produced in each child is related to the number of children in the household. Likewise, the number of children parents decide to have is related to the level of quality that they desire each child to have. Becker and Tomes' extension of the model incorporated the interaction between quality and endowment of children. They showed that the amount parents invested in each child's quality might also be related to the child's endowment, and whether parents reinforce better endowments or compensate those with poorer endowments.

2.3.1 Willis Model

One of the reasons households may invest in the quality of their children is to raise their children's productivity. In developing countries, where formal capital markets are not readily accessible, children could be considered as assets that could be used to store value. For instance, children's income could supplement parental or household income or later provide for their parents' old age security (Hoddinott, 1992). As long as parents can capture at least a portion of their children's lifetime earnings, parents have an incentive to invest in improving the quality or human capital of their children, such as, their health, nutrition and education.

But the amount invested in each child may depend on the number of children in the household because the greater the number of children, the smaller is each child's potential share of household resources. Likewise, the number of children parents decide to have may depend on the desired level of quality they want each child to have. Thus, there may be a tradeoff between the quantity and quality of children. Willis (1973), using the household production model, provides a theoretical basis for this tradeoff.

Willis modeled the household with parents as the decision-makers as deriving utility from the quantity and quality of children and other goods unrelated to children. Formally, households maximize the utility function,

$$U(N, Q, S), \qquad (2.6)$$

where N is the number of children in the household, Q is the quality per child and S is the composite home produced commodity that is not associated with the quantity and quality of children and embodies all sources of satisfaction to parents other than those arising from their children. Willis assumed above that parents chose an equal level of quality per child in order to simplify the analysis, although he acknowledged that the level of quality need not be the same for each child.

Households maximize their utility function (2.6) subject to the full wealth (I) constraint,

$$I = \pi_c NQ + \pi_s S = \pi_c C + \pi_s S, \tag{2.7}$$

which is the sum of the shadow cost of total child quality or child services (C) and the shadow cost of the composite commodity (S), with the shadow prices for total child quality and the composite commodity being, π_c and π_S, respectively. The composite commodity (S) and total child quality or child services (C) are produced according to the following household production functions, which Willis assumed to be linearly homogeneous,

$$S = f(x_S, t_S) \tag{2.8}$$

$$C = NQ = f(x_C, t_C), \tag{2.9}$$

where t_s and x_s are the vectors of the total amount of time and goods devoted to the production of the composite commodity (S) and t_c and x_c are the vectors of the total amount of time and goods devoted to the production of their children's quality (C) during the parents' lifetime. Willis assumed that inputs to S do not jointly produce child quality. Likewise, there is also no joint production of child quality. Quality per child is produced according to the production function,

$$Q = f\left({}^{x_C}\!/_N, {}^{t_C}\!/_N\right), \tag{2.10}$$

where t_c/N and x_c/N are the amount of time and goods devoted each child's quality. The first order condition of the utility maximization problem,

$$\frac{U_N}{\pi_C Q} = \frac{U_Q}{\pi_C N} = \frac{U_S}{\pi_S}, \tag{2.11}$$

implies that the shadow price of N or the marginal cost of an additional child of given quality (P_N) is proportional to the level of quality per child and that the shadow price of Q or the marginal cost of raising the quality per child given the number of children (P_Q) is proportional to the number of children. That is,

$$P_N = \pi_C Q \tag{2.12}$$

$$P_Q = \pi_C N. \tag{2.13}$$

Thus, increasing the level of quality per child raises the cost of an additional child, and conversely, having an additional child increases the cost of raising the quality per child. In other words, the cost of increasing the level of quality per child is higher the more children there are in the household, since the increase in quality is applied to a larger number of children. Likewise, the cost of having another child is higher for households with a higher level of quality per child, since that level of quality has to be applied to the additional child.

2.3.2 Becker and Tomes Model

In Willis' model described above, parents invest an equal amount in the quality of every child in the household. But this may not hold when the amount parents invest in each child depends on the child's endowment, which may vary across the children within a household. For example, parents may prefer to maximize their return by investing more resources in children they observe to have a higher endowment because their future return from such an investment is likely to be greater. On the other hand, it may be optimal for parents to compensate children with a lower endowment by transferring more resources to those children in order to try to raise their future returns. Becker and Tomes (1976) constructed a theoretical basis for the interaction between child quality and innate endowments.

Unlike Willis, Becker and Tomes allowed the quality of each child to vary within a household. In their model, the utility function of each household with n children has the form,

$$U(y, w_1, \ldots, w_n), \tag{2.14}$$

where the w_i's represent the quality of each child in the household and y is the aggregate amount of all other commodities. In order to distinguish between the effect of differences in endowments from differences in preferences toward children, they assumed that the utility function has child neutral preferences. That is, the marginal utility to parents from changes in child quality is the same for children when their qualities are equal. Formally,

$$\begin{aligned} \frac{\delta U}{\delta w_i} \Big/ \frac{\delta U}{\delta w_j} &> 1 \qquad \text{if } w_i < w_j \\ &= 1 \qquad \text{if } w_i = w_j \\ &< 1 \qquad \text{if } w_i > w_j, \end{aligned} \tag{2.15}$$

where w_i is the quality of the ith child.

Each household produces child quality according to the following production function,

$$w_i = e_i + q_i, \qquad i=1,\ldots,n \tag{2.16}$$

where the quality of the ith child, w_i, is the sum of the household's contribution to the quality of that child, q_i, and that child's endowment, e_i, which are allowed to differ across the children within a household. The household maximizes their utility (2.14) subject to their income (I) contraint,

$$I = p_y y + \sum_{i=1}^{n} p_{q_i} q_i \,, \tag{2.17}$$

where p_y is the unit price of the composite commodity (y) and p_{q_i} is the cost of increasing the household's contribution to the quality of the ith child's (q_i) by one unit. Becker and Tomes noted that the form of the production technology above (2.16) can be derived from the more general form, $w = f(x, t; e)$, by first, assuming constant marginal product for the goods, x, and ignoring time inputs, t, which would reduce the general form to $w = a(e)x + b(e)e$. Then, assuming that the marginal product of parental expenditures on quality, a(e), is independent of endowment, e, the function would be further reduced to $w = ax + b(e)e = q + e$.

With the assumption of child neutral preferences (2.15), the first order condition of the utility maximization problem,

$$\frac{\delta U}{\delta w_i} \Big/ \frac{\delta U}{\delta w_j} = \frac{P_{q_i}}{P_{q_j}}, \tag{2.18}$$

implies that if the cost of adding quality to each child were the same, that is, $p_{q_i} = p_{q_j}$, even when children within a household have different endowments, all the children in the household would have the same level of quality. Parents would then be fully compensating children with less endowment by contributing more to their quality than to the quality of better-endowed children. Thus, the amount invested in a child would be perfectly negatively correlated with that child's endowment.

On the other hand, the cost of adding quality to each child may not be the same and may be negatively related to the child's endowment. For example, less able students or children with low endowments may be more likely to drop out of school or repeat a grade, which would raise their cost of education. The cost of raising their quality through educational achievement is thus higher than for more able students. In this case, the first order condition (2.18), along with child neutral preferences (2.15), would imply that the quality of children within a household will no longer be the same. Furthermore, the parental contribution to the quality of each child would be positively related to that child's endowment. Parents would invest more in better-endowed children and parental contributions would no longer fully compensate children with less endowment. Thus, parental contributions would reinforce differences in endowment.

Formally, this would be the case where the marginal product of expenditures on quality is not independent of the endowment. That is,

$$\delta w / \delta x = a(e) , \tag{2.19}$$

Then, the marginal cost of raising quality,

$$P_q = \frac{P_x}{\delta w/\delta x} = \frac{P_x}{a(e)} , \tag{2.20}$$

where P_x is the unit price of x, will be negatively related to the endowment.

2.4 Theoretical Model

The objective of the study is to examine the determinants of cognitive ability. The study focuses particularly on the nutritional status of children, since there are studies that have shown that inadequate nutrition may be detrimental to the cognitive growth and development of children. The theoretical model used by the study is based on the household production model and the variations of the model outlined above. Although the household is the unit of study, in this model, parents make the decisions regarding how household resources are allocated among the quality of their children, with child quality being measured by cognitive ability, and the consumption of other commodities unrelated to child quality.

Cognitive ability includes the individual's ability to adjust or adapt to the environment, the ability to learn, and the ability to perform abstract thinking (Sattler, 1988, pp. 44-45). It is modeled as a home produced commodity using household members' time and market goods. In other words, parents can determine, to a certain extent, the development and level of their children's cognitive ability by the quantity and quality of inputs such as, food and education, it provides them.

But the extent to which parents can affect the cognitive ability of their children may depend on child-related characteristics, such as, their nutritional status and innate cognitive ability. Better nourished children may have a greater capacity to interact more with their environment and to attract parental attention, which would stimulate their cognitive development. They may also take better advantage of the opportunities that parents provide in order to promote cognitive ability. It may also depend on the child's innate cognitive ability, which may limit the level of cognitive ability that the household can achieve. Although it is believed that heredity sets a limit on a child's potential abilities, it is the child's environment that enables that potential to be realized and determines how close actual ability is to the potential. In other words, the child's observed ability is the outcome of the interaction between heredity and environment, which may nurture or impede intellectual development (Sattler, 1988).

Parents' capacity to determine their children's cognitive ability may also depend on parental factors, such as, their level of educational achievement and income. More educated parents may be better at fostering the cognitive ability of their children, by being able to provide their children with a more stimulating home environment or choose inputs that are more effective in nurturing the cognitive development of a child. Parents with more income may have greater access to resources that promote the cognitive ability of their children, such as, schools with higher quality.

In the model, cognitive ability is allowed to differ among the children in the household. This may be due to differences in endowment among the children in the household. Children endowed with more innate ability should be observed to have a higher level of cognitive ability. The differences in observed ability among children in the household may also be due to the parent's experience in raising children. The parents' child rearing skills, for instance, may be improving over time or with each child. Experience gained from raising one child may improve skills in raising later born children. The difference in cognitive ability may also be due to changes in the household environment over time. Each child within a household might not be faced with the same household environment. Household income, for instance, may be rising over the parents' life cycle. Thus, parents may be able to provide children who were born later with more resources that enhance cognitive ability than their siblings who were born earlier.

Formally, each household with n children has a utility function with the following form,

$$U(q_1,\ldots,q_n,y) \tag{2.21}$$

where the q_i's are the cognitive ability of each child in the household and y is the vector of consumption of other goods in the household unrelated to the children's cognitive ability. The household produces cognitive ability according to the following production function,

$$q_i = q(F_i, NF_i; C_i, E_i) \qquad i=1,\ldots,n \qquad (2.22)$$

where F_i is the vector of nutritional inputs (for example, intake of energy, protein, iron, whether the child is breastfeeding), NF_i is the vector of non-nutritional inputs (for example, years of schooling, tutoring, the number of books in the house), C_i is the vector of observed and unobserved characteristics of the child that affect observed cognitive ability (for example, age, gender, birth order, personality, innate ability), and E_i is the vector of observed and unobserved characteristics of the household environment that affect observed cognitive ability (for example, parent's level of education, intellectual atmosphere, preferences regarding child quality, child rearing practices, birth spacing).

The household maximizes its utility (2.21) subject to the household's full income constraint,

$$I = p_y y + \sum_{i=1}^{n} p_i q_i \qquad (2.23)$$

where p_y is the vector of cognitive ability input prices and p_i is the vector of other consumption goods prices.

2.5 Econometric Issues

Estimating the relationship between nutritional status and a child's cognitive ability involves obtaining an unbiased estimate of equation (2.22), that is, the household production function for cognitive ability, $q_i = q(F_i, NF_i; C_i, E_i)$. But there are econometric issues, such as, endogeneity and unobserved heterogeneity, that need to be addressed in order to obtain an unbiased estimate of the production function's parameters.

One assumption of the classical linear regression model is that explanatory variables should not be correlated with the error term. That is, the effect of the explanatory variables on the dependent variable must be isolated from the effect of variables that are not included in the model. Otherwise, the ordinary least squares estimate (OLS) of the parameters of the model will be biased because the parameter estimates would also be capturing the effect of the variables that are not included in the model.

Endogeneity may be present because some of the explanatory variables in the model, such as, food intake, breastfeeding and the child's years of education, are variables whose level can be chosen by the individual and are likely to be determined simultaneously with the child's cognitive ability. For example, parents could choose to give more resources, such as, food and schooling, to children with more cognitive ability. Parents could also choose to prolong breastfeeding the children they observe to have less cognitive ability, and children with more cognitive ability may be able to attain a higher level of education. Consequently, these variables would be correlated with the error term and the OLS estimate of their parameters would be biased.

To eliminate endogeneity, the two-stage least squares (2SLS) procedure (Greene, 1997) will be used by the study. This procedure involves finding instrumental variables, which are variables that are highly correlated with the endogenous variable but are not correlated with the error term. The endogenous variable is first regressed on the instrumental variables, along with all the other exogenous variables in the model. The predicted or fitted value of the endogenous variable from this (first-stage) regression would then be purged of the correlation with the error term, and it would then be used to replace the endogenous explanatory variable in the (second-stage) regression of the model.

The difficulty with implementing this procedure is identifying suitable instrumental variables because variables that are highly correlated with the endogenous variable are likely to be correlated with the error term. Poor instruments are likely to lead to large standard errors and low t-ratios. Furthermore, for finite samples, Nelson and Startz (1990) showed that if the instrumental variables chosen are very weakly correlated with the endogenous explanatory variables, then the second stage least squares estimate of the coefficient of the predicted value of the endogenous variable will not only be biased but will also have t-statistics that are biased upwards. That is, one would be more likely to accept a significant relationship, when really none may exist. This is because with weakly correlated instruments, the instrumental variable estimate of the coefficient of the endogenous variable, the estimate of the standard error of the regression, and the t-ratio would be distributed around a value that is related to the correlation between the endogenous variable and the error term rather than around their respective true values.

Unobserved heterogeneity across households, which would be captured by the error term, may also bias OLS estimates, if it is related to any explanatory variables in the model, which is likely to be the case. For example, some parents, who have a greater preference for child quality over the consumption of other goods, are likely to provide their children with better nutrition and more education and prolong the interval between their births. If the preference for child quality were unobserved in the data, then it would be included in the error term and food intake, schooling and birth spacing would be correlated with the error term. Consequently, the OLS estimate of the coefficients of these variables would then be biased because it would include the effect of unobserved household preferences for child quality.

Unobserved heterogeneity across children may also bias OLS estimates. Some children, for example, may be more able to attract resources that promote their cognitive ability, such as, better nutrition and education. Some children may also be more effective than others in using resources that promote their cognitive ability. If these child specific factors were not observed in the data, then the level of those resources would be correlated with the error term and the OLS estimate of their coefficients would be biased.

To eliminate unobserved heterogeneity bias, a child fixed effects model will be used by the study, using the panel data for a subset of the children in the sample. This would eliminate the bias from unobserved heterogeneity, assuming that the effect of the unobserved heterogeneity is fixed within the child over time (Hsiao, 1986). If that assumption holds, then the unobserved heterogeneity can be represented as a child specific time invariant dummy variable. Taking the difference across the two observations for any child i,

$$q_{i,t+1} - q_{i,t} = q(F_{i,t+1} - F_{i,t}, NF_{i,t+1} - NF_{i,t}; C_{i,t+1} - C_{i,t}, E_{i,t+1} - E_{i,t}) \quad t = 1,2 \quad (2.24)$$

would eliminate the unobserved heterogeneity, since the dummy variable that represent the unobserved heterogeneity are fixed over the two periods.

The sibling or family fixed effects procedure, that is, the procedure where one takes the difference across siblings rather than across two observations on an individual, has also been used in other studies to eliminate biases from unobserved heterogeneity (Behrman and Lavy, 1994; Horton, 1988). But this procedure would only remove all the observed and unobserved individual, household and community effects that are common across siblings.

Biases from unobserved heterogeneity that are not common across siblings would still remain. But the disadvantage with fixed effects estimators is that one may be interested in some of the effects of time invariant variables, such as, gender and parental education. In addition, it does not eliminate time persistent heterogeneity and fixed effects estimators worsen biases from measurement errors (Strauss and Thomas, 1995).

What would be ideal for the study is to use an estimation procedure that controls for both endogeneity and the effect of unobserved heterogeneity. The instrumental variables approach would eliminate the bias resulting from endogeneity but not the bias from unobserved heterogeneity. Likewise, the fixed effects procedure would eliminate the bias from unobserved heterogeneity but not the bias from endogeneity. But to control for both would require a fixed effects procedure with instrumental variables (or two-stage least squares fixed effects). This procedure would require instruments that are correlated with individual-specific differences over time. But it could not be carried out because such instruments are not available in the data set used in the analysis.

2.6 Summary

The model used by the study to examine the determinants of cognitive ability and particularly, the relationship of nutrition to cognitive ability was presented in this chapter. It is based on the household production model and its extensions to modeling the determinants of child quality. The model is relevant to the study, since it can account for a household's ability to affect to a certain extent the level of its children's cognitive ability by the quantity and quality of inputs it provides them.

Estimating the determinants of cognitive ability involves obtaining an unbiased estimate of the household's production function for cognitive ability. The econometric issues that will be addressed in order to obtain an unbiased estimate are endogeneity and unobserved heterogeneity. The two stage least squares estimation procedure will be used to eliminate the bias from endogeneity, while child fixed effects estimator will be used to eliminate the bias from unobserved heterogeneity. The econometric specification of the household production function for cognitive ability will be presented in Chapter 4, which follows the description of the data set used in the analysis in Chapter 3.

CHAPTER THREE
EGYPT NUTRITION COLLABORATIVE RESEARCH SUPPORT PROGRAM

3.1 Introduction

The data used by the study are a portion of the data set collected by the Nutrition Collaborative Research Support Program (Nutrition CRSP) in Kalama, Egypt. The following three sections of the chapter give a brief description of the origin of the Nutrition CRSP, the research design of the Nutrition CRSP in Egypt and the data that were collected and the method of collecting the data that are relevant to the study.

3.2 Background of the Nutrition Collaborative Research Support Program

The Nutrition Collaborative Research Support Program was sponsored by the U.S. Agency for International Development (USAID) to investigate the effect of mild-to-moderate undernutrition on human functional outcomes (Egypt Project Final Report, 1987). The call for this line of research originated from the World Food and Nutrition Study of the National Academy of Sciences (National Academy of Sciences, 1977a,b), which pointed out the urgent need to determine the consequence of low levels of nutrition for human function:

> The number of people who suffer from moderate malnutrition and who do not display the clinical symptoms of severe malnutrition is immensely larger than the number of people visibly affected. We need to know the implications of the lesser grades of undernutrition and overnutrition. If this question is not addressed, we are blindly accepting unnecessary risks about the kind of world we will have a generation or two hence. (National Academy of Sciences, 1977b, p. 15)

Following the World Food and Nutrition Study, the Committee on International Nutrition Programs of the Food and Nutrition Board of the National Research Council, with support from the USAID, convened a workshop which identified the five areas of human function whose relationship to marginal food intake should be investigated. These areas were disease response, reproductive capacity, work output/physical activity, cognitive development, and social competence.

In 1978, a series of workshops, which were funded by a USAID planning grant awarded to the University of California, Berkeley, further developed the issues and developed guidelines for research in each of those five areas. These guidelines were subsequently used to evaluate research proposals submitted for this topic and included the following: the unit of study should be the household and the focal point the mother-child dyad; food intake would be the major independent variable and should be represented by a range of energy intakes from habitually mild to moderately restricted; the design of the research should be naturalistic rather than intervention; and the findings should be generalizable to nutrition problems in developing countries and should have potential policy and program implications (Egypt Project Final Report, 1987, p.1). In 1980, a research program was approved and funding for the Nutrition CRSP was awarded by the USAID the following year.

Field studies were conducted in Egypt, Kenya and Mexico from 1982-1987. Each project addressed the same critical questions and all shared common design elements. This was done in order to enable researchers to compare their results across projects (Cattle, 1989, pp. 106-107). There were, however, differences in the methods of data collection and, more importantly, in the actual data collected due to field conditions in each project that may limit comparison across projects. The Final Report of the Management Entity (1988) contains a detailed description of the extent to which the data collected across the projects are comparable.

The field study was carried out in three phases. Phase I activities (1982-1983) included: selection of the study site; preliminary ethnographic study of the community; establishment of the magnitude of inter- and intra-individual variation in usual intake of food energy; characterization of the usual cyclical patterns of food intake; description of the distribution of nutritional status in the community, primarily using anthropometric data; description of the mortality, fertility and morbidity characteristics of the community; and pilot testing of the methodologies projected for use in the next phase. In Phase II, the selection and recruitment of households and collection of data were carried out (1983-1985). Phase III (1986-1987) was the data analysis phase but, due to insufficient time and funds, only a partial analysis of the data were completed during this phase (Egypt Project Final Report, 1987, pp. 23-30). Analysis of the data were completed between 1989-1992 using additional funding from the USAID (Kirksey et al., pp.1-3).

The principal research hypotheses which the Nutrition CRSP were designed to test were:

- Maternal food intake during pregnancy and lactation influences the infant's endowment at birth and development during the first six month of breastfeeding and maternal infant care and sanitation practices;

- Food intake of the toddler between 18 and 30 months affects the toddler's morbidity, anthropometry, and psychological development, while maternal food intake during this period influences maternal toddler care and sanitation practices;

- Food intake of the child between 7 and 9 years affects the child's morbidity and behavior, while parental intake during this period influences their behavior towards the child;

- **Food intake of adults affects their morbidity, responsiveness and performance of usual responsibilities, which, in turn, affects the morbidity and performance of other household members;**

- **Household food intake affects household morbidity.**

This study used a portion of the data collected by the Egypt Nutrition CRSP to examine the relationship between nutrition and the cognitive ability of children.

3.3 Egypt Nutrition CRSP: Household Selection

The chosen site of the Egyptian study, Kalama, is a peri-urban village on the Nile Delta located 25 km north of Cairo. There were around 1470 households in Kalama, out of which 312 households were selected for the study; and out of the 312 households selected, 258 completed the study. Household selection was primarily based on the presence of any one of the following pre-defined target classes of individuals. These individuals were:

- an adult female, between 15 and 45 years of age, in the first trimester of pregnancy, with mate present (who would become the target male), or likely to become pregnant, such as, newlyweds who did not yet have children and mothers whose youngest child was more than one year of age, and whose infant would be 6 months of age before completion of the second year of study;

- a toddler, that is, a child who will be 18 months of age during the first year of study;

- a schooler, that is, a child who will be 7-9 years of age during the first year of study.

Infants born to the study households were also included as target subjects until they reached six months of age, if their mothers had participated in the study from their third month of pregnancy until the infant's birth. Eligible households were enrolled in the study if its members were willing to participate after careful explanation of the study and what it would entail for them (Egypt Project Final Report, 1987, pp. 25, 132).

Households remained in the study for 12 months for target toddlers or schoolers, or until the target infants reached six months of age. The presence of more than one target individual in a household sometimes resulted in that household being followed for a longer period of time. For example, if the mother of a target toddler or schooler were to become pregnant and the infant was eligible to be included as a target subject, then the household would be followed through the birth of the infant and the infant's first six months of life.

Target individuals who completed the study included 153 toddlers, 121 schoolers and 121 mother-infant pairs. Although recruitment of households was spread geographically over the entire village to obtain the necessary variation in socioeconomic status, there was no attempt to sample on a randomized or stratified random basis (Kirksey et al., 1992, p. 6). As a result, there may be a slight difference between the characteristics of the Nutrition CRSP sample and the Kalama village as a whole. The sampling procedure used was not documented in any of the Nutrition CRSP publications. Tables 3.1-3.5 compare some of the demographic characteristics of the Egypt Nutrition CRSP sample with the Kalama village population. Information on the village population was taken from the 1982 village census, whose sampling procedure was also not documented by the Nutrition CRSP investigators.

From Table 3.1, one can compare the population structure of the village with the Egypt Project sample (NCRSP). Table 3.1 indicates that the NCRSP sample is slightly younger than the village population. About 86% of the NCRSP sample is under 40 compared to 81% in the village as a whole. This is consistent with the NCRSP's sample selection criteria, which was weighted towards households with young children and married women in

Table 3.1 Population structure: Percent of total population and sex ratio (male/female) by age, Kalama village and Egypt Nutrition CRSP sample, 1982

	Percent of Total Population		Sex Ratio (male/female)	
Age (years)	Kalama	NCRSP	Kalama	NCRSP
<1	3.7	3.4	1.1	1.0
1-4	15.5	19.0	1.0	1.0
5-9	14.4	15.8	1.0	0.9
10-14	10.8	10.9	1.1	0.8
15-19	10.1	9.0	1.2	1.2
20-24	7.4	6.3	0.9	0.8
25-29	7.5	7.7	0.8	1.0
30-34	6.5	7.3	1.0	1.0
35-39	5.5	6.7	1.3	1.5
40-44	4.0	3.2	1.0	2.1
45-49	3.0	1.9	0.9	1.8
50-54	3.3	1.7	0.7	0.5
55-59	2.4	1.8	1.0	0.5
60-64	2.6	2.6	0.9	1.2
65-69	1.5	1.0	0.7	0.5
70-74	0.9	1.0	1.0	1.0
>74	0.8	0.9	1.4	0.7
All ages	100.0	100.0		
Number of Individuals	8,544	2,188		

Source: Ricci (1992)

their childbearing years. As a result, there are slightly more toddlers (19% versus 15.5%), pre-adolescent children (26.7% versus 25.2%) and young adults (28% versus 26.9%) in the NCRSP sample than in the village as a whole.

Table 3.2 compares the distribution of the village households with the NCRSP sample by size. It shows that NCRSP households are larger than households in the whole village.

Table 3.2 Household size: Percent distribution of households by number of individuals claimed as members, Kalama and Egypt Nutrition CRSP sample, 1982

Household Size	Kalama	NCRSP
1-2 individuals	9.9	1.0
3-4 individuals	22.2	13.1
5-6 individuals	33.5	33.0
7-8 individuals	20.2	30.1
9-10 individuals	9.2	14.8
11-12 individuals	3.2	4.5
13-14 individuals	1.1	1.0
15-16 individuals	0.6	1.3
>16 individuals	0.3	1.2
All households	100.0	100.0
Number of Households	1,470	312

Source: Ricci (1992)

Approximately 78% of the NCRSP households versus 63% of the households in the village had 5-10 individuals. The average household in the NCRSP sample had seven individuals whereas the average household in the village has 5-6 individuals.

Households in both samples were predominantly nuclear families, as can be seen from Table 3.3. Type I extended families or simple extended families were also more common in both samples than Type II extended families or joint extended families. But there were more extended families of both types in the NCRSP sample than the village population. This is consistent with the households in the NCRSP sample being larger households than the households in the village population.

Table 3.3 **Household Structure: Percent distribution of households by household structure, Kalama and Egypt Nutrition CRSP sample, 1982**

Household structure	Kalama	NCRSP
Nuclear family	68.5	58.5
Extended family, Type I[a]	26.1	33.8
Extended family, Type II[b]	5.4	7.7
All households	100.0	100.0

[a]A multi-generation family consisting of a senior couple, a married son, his wife, and the young couple's unmarried children.

[b]A multi-generation family consisting of a senior couple, married sons, their wives, and the young couples' unmarried children.

Source: Ricci (1992)

Tables 3.4-3.5 compare school attendance by gender in the village sample with the NCRSP sample. In both samples, more females than males had never attended school. The average years of education for males 17 years old and older was 4.9 years (± 5 years), while for females, the average was only 1.1 years (± 2.8 years) (Ricci, 1992). Tables 3.4-3.5 also show that the proportion of the population who had never attended school increased with age for either gender. This may have been due to the social reforms put in place during the mid-1950 that included universal access to primary education and increasing educational achievement. The increase, however, was sharper for females than for males. Nearly all of the females over 40 had never attended school and 80-90% of females between the ages of 20-39 had never attended school versus 40-50% of males.

Table 3.4 School attendance by gender: Percent of males, six years of age or older, who have *never* attended school by age, Kalama village and Egypt Nutrition CRSP sample

	Kalama		NCRSP	
Age (years)	Percent	Frequency	Percent	Frequency
6-9	4.7	492	0.8	126
10-19	18.4	962	12.0	209
20-29	40.5	607	29.8	141
30-39	53.4	554	35.6	160
40-49	66.4	301	61.1	72
50-59	85.8	225	75.0	24
60-69	85.3	163	69.4	25
>69	88.6	79	77.8	18

Source: Ricci (1992)

Table 3.5 School attendance by gender: Percent of females, six years of age or older, who have *never* attended school by age, Kalama village and Egypt NCRSP sample

	Kalama		NCRSP	
Age (years)	Percent	Frequency	Percent	Frequency
6-9	15.2	427	12.6	135
10-19	51.8	800	47.8	224
20-29	83.0	646	72.6	157
30-39	88.6	466	84.3	134
40-49	95.6	293	97.1	35
50-59	97.3	257	100.0	48
60-69	98.4	182	100.0	39
>69	96.9	65	100.0	21

Source: Ricci (1992)

3.4 Egypt Nutrition CRSP: Data Collection

The data collection phase took place from November 1983 to December 1985. The data collected included: individual food intake; anthropometric measurements of target individuals; cognitive evaluation of target individuals; and household socioeconomic data. Table 3.6 summarizes the data collection schedules for principal variables that were used by this study.

Table 3.6 Collection schedule for principal variables

Variable	Subjects	
	Toddler	Schooler
Food Intake	2 consecutive days per month for 12 months	
Height or Length	Monthly	Monthly
Cognitive Evaluation	18,24,30 month (Bayley Mental Scale)	twice (WISC-R)
Socioeconomic Data	One baseline survey at the beginning of the study, which was updated at the end of the study; Updates of the baseline information on the CRSP households were attempted every six months	

Source: Egypt Project Final Report (1987)

3.4.1 Food Intake

The general approach to collecting individual food intake data combined self-reporting and sample weighing of prepared food. On each day of the 2-day recording period, the target female was asked to report on the dietary and mixed dishes consumed by household members the previous day. Information was requested by eating event, in sequence, including a record of each individual present for each eating event. For mixed dishes prepared in the home, the amount of each ingredient in the recipe was obtained, the weight being recorded in the pre-preparation state. If the mixed dish had been purchased ready-to-eat, the amount of recipe ingredients was estimated from a file of commercial recipes from the village market. Portions of mixed food consumed communally were estimated by the target female herself and for others as a proportion of her own intake (Egypt Project Final Report, 1987, p. 41).

Target males and target schoolers were interviewed personally when available. When they were not available, target females would be interviewed to determine their within-household food intake. Information on the target toddler was obtained from the child's caretaker(s), usually the target female. Other individuals, such as, an older sister, grandmother or other caretaker, were also interviewed for information on the toddler's food intake (Egypt Project Final Report, 1987, p. 42).

The nutrient content of food intakes was determined using an international food composition database, called the INT Minilist. Initially, the focus of the study was primarily on intakes of macronutrients: energy, protein, fat, and carbohydrate. But because preliminary results indicated potential relationships between dietary quality and functional outcomes, interest grew in obtaining information for a wider variety of nutrients in the diets. The INT

Minilist was developed expressly for Egypt, Kenya and Mexico but could be expanded to other countries if the need arose. The INT Minilist is an abbreviated food composition Table in which foods of like nutrient content are represented by a single entry. For example, the nutrient content of apples, which is included in the Table, would be used to approximate the nutrient content of pears or of other similar foods, which are not included in the Table. Thus, the number of food items in the INT Minilist is fewer than conventional food Tables but there are more nutrients documented for each food item entered in it (Calloway et al., 1992, p. 9).

3.4.2 Calculation of Derived Nutrient Intake Variable: Available Protein

Dietary quality was further assessed by estimating the availability of some of the nutrients. Protein intake was expressed in terms of utilizable protein by adjusting observed protein intake for its amino acid composition and digestibility (Calloway et al.,1992 and the Egypt Data Codebook). To adjust for its amino acid composition, observed protein intake needed to be adjusted for the availability of the most limiting essential amino acid[1], which is determined to be the amino acid with the lowest amino acid score. The amino acid score is the proportion of the amino acid requirement for the relevant age group that is met by the individual's amino acid intake per gram of protein. That is, for amino acid AA1,

$$\text{Amino Acid Score AA1} = \frac{\text{Estimated Intake of AA1/g dietary protein}}{\text{Reference Pattern for AA1}}. \qquad (3.1)$$

[1] Essential amino acids are amino acids that are needed by the body but cannot be synthesized in the body. As a result, they must be in the diet in sufficient quantity in order to maintain health. They are lysine, tryptophan, threonine, methionine, phenylalanine, isoleucine, leucine and valine. Computation of the amino acid score for methionine and phenylalanine takes into account the amount of amino acids, cystine and tyrosine, respectively, since the latter can substitute to some extent for the former.

The reference amino acid patterns proposed in FAO/WHO/UNU (1985) for the relevant age group were used to compute the amino acid score.

The FAO/WHO/UNU (1985) report recommended that digestibility of protein intake be estimated by weighted summation of digestibility of individual sources. As the INT Minilist does not include protein digestibilities of individual foods, many of which are unknown, a digestibility factor was imputed for the Nutrition CRSP analysis. An empirical association between dietary fiber and protein digestibility was developed using regression models, based on reported data for maize, polished rice, whole wheat, refined wheat, oatmeal, millet, mature peas, peanut butter, soyflour and dry beans. The prediction equation derived was

$$\text{Digestibility} = 1-(0.1*\text{Dietary Fiber/Dietary Protein}). \qquad (3.2)$$

While it is known that characteristics other than dietary fiber affect protein digestibility, the above empirical relationship yielded estimates for toddler diets that fell within the reported range of estimated digestibilities of mixed food diets (Calloway et al., 1992, pp. 10-11). Thus,

$$\text{Utilizable Protein} = \text{Observed Intake*Lowest Amino Acid Score*Digestibility}. \qquad (3.3)$$

3.4.3 Calculation of Derived Nutrient Intake Variable: Available Iron

Iron intakes were expressed in terms of availability by adjusting observed intakes for the iron composition of the diet and the intake of nutrients that affect availability (Murphy et al., 1992; and the Egypt Data Codebook). The amount of iron available from the diet depends on the iron composition (that is, heme versus nonheme iron) and other nutrients consumed in the diet. Heme iron is considered to be more readily available than non-heme iron but availability of non-heme iron depends on the presence of factors in the diet which may enhance or reduce its availability.

Heme iron, which was estimated to be 40% of the iron from meat, fish and poultry, was assumed to have an average availability of 25%. To estimate availability of nonheme iron (=total iron intake - heme iron intake), observed nonheme iron intake was adjusted for the amount of ascorbic acid, protein from meat, fish, and poultry, and tea in the diet. Protein from meat, fish and poultry and ascorbic acid interact to enhance nonheme iron absorption. Table 3.7 shows the estimated availability of nonheme iron based on the amount of ascorbic acid and heme iron consumed in the diet. Thus, for an individual consuming 9 g/1000 kcal of protein from meat, fish and poultry and 35 mg/1000 kcal of ascorbic acid, the percent availability of nonheme iron intake is 15%.

On the other hand, tannins in tea inhibit non-heme iron absorption. To compute the effect of tea consumption on non-heme iron absorption, it was assumed that a 200-250 ml

Table 3.7 Estimated percent availability of nonheme iron (at basal requirement level)

Ascorbic Acid (mg/1000 kcal)	Meat, fish and poultry protein (g/1000 kcal) <9	9-27	>27
	%		
<35	5	10	15
35-105	10	15	15
>105	15	15	15

Source: Murphy et al. (1992)

cup of tea reduces absorption by approximately 60% and that the effect is proportional to the quantity of tea consumed. The tea factor ranges from 0.4 (which translates to tea at every meal, that is, 600mL of tea per day) to 1.0 (no tea consumed). That is,

$$\text{Tea Factor} = \begin{cases} 1-((\text{ml of tea}/600)*0.6) \\ 0.4 \quad \text{if } 1-((\text{ml of tea}/600)*0.6) < 0.4 \end{cases} \tag{3.4}$$

Average tea consumption by both schoolers and toddlers was quite high and was at about the same level as the average consumption of the adults. Table 3.8 compares average tea consumption of children with the adults' consumption. Thus,

$$\text{Available Iron} = \text{Heme Iron}*0.25 + (\text{Nonheme Iron}*\text{Percent Availability}*\text{Tea Factor}). \tag{3.5}$$

Table 3.8 Tea consumption of adults and children (mean ± standard deviation)

	Tea, dry gm/day	Tea, liquid ml/day	Tea Factor
Schoolers, boys	3.16±2.82	157.9±141.2	0.84±0.14
Schoolers, girls	3.44±8.12	172.1±405.8	0.83±0.41
Toddlers, weaned	2.81±5.49	140.3±274.5	0.86±0.27
Toddlers, not weaned	1.80±2.01	89.8±100.3	0.91±0.10
Adult men	2.09±4.00	104.7±203.1	0.90±0.20
Adult women:			
Nonpregnant and Nonlactating women	3.27±3.57	163.5±178.4	0.84±0.18
Pregnant women	3.11±6.66	155.3±333.0	0.85±0.33
Lactating women	3.08±6.35	154.1±317.6	0.85±0.32

Source: Kirksey et al. (1992)

3.4.4 Anthropometry

Anthropometric protocols were designed to emphasize quality control, since the rates of change expected in many of the variables were small compared to the inherent error of measurement due to equipment, observer, and subject. Length was measured, rather than (standing) height, for children under the age of 30 months in order not to change methods midway through the study. Most subjects were measured in their homes, although some data on school children were collected during visits to the school. The data collected from the anthropometric module were supplemented by anthropometric measures taken for adults and schoolers at the time of the resting metabolic rate (RMR) measurements (Egypt Project Final Report, 1987, p. 57-59).

3.4.5 Cognitive Evaluation

The evaluation of cognitive functions was assessed through cognitive measures and testing. Toddlers were administered the Bayley Scales of Infant Development (Bayley, 1969), a measure of general infant intelligence, at 18, 24 and 30 months, along with subscales from the Infant Psychological Development Scale (Uzgiris and Hunt, 1975) to measure specific mental abilities, namely, memory (Object Permanence subscale), ability to use objects as tools (Means subscale), and ability to anticipate consequences (Foresight subscale), at 18 and 24 months. Schooler's cognitive abilities were evaluated using six subtests (Vocabulary, Similarities, Block Design, Picture Completion, Coding and Digit Span) from the Egyptian translation of the Wechsler Intelligence Scale for Children--Revised (Wechsler, 1974) and the Egyptian translation of the Raven's Coloured Progressive Matrices (Raven, 1956). The Egypt Nutrition CRSP data archive contains only a raw score for the

Bayley Mental Scale and the normalized standard score for each of the six subtests of the Wechsler Intelligence Scale for Children--Revised.

3.4.6 Socioeconomic Indicators

The initial socio-demographic survey on all village households, including the Nutrition CRSP study households, was conducted from October 1983 to February 1984. The survey yielded data on: household demographic structure; housing characteristics and domestic assets; durable household equipment; household agricultural activities and farm assets; household expenditure pattern; household resource base; and brief reproductive histories of adult females residing in households.

Updates of the baseline information on Nutrition CRSP study households were conducted from August 1984 to September 1985 and from October 1985 to February 1986. The latter survey included an update of the whole village. An attempt was made to obtain "update data" every six months on each study household (Egypt Project Final Report, 1987, p. 119). Principal respondents were: household head or target male; or the wife of the household head or the target male. Although questions were directed to these specific adults, it was customary for all or most adults present during the interview to respond. This practice was not discouraged and was regarded as a form of built-in quality control of household data (Egypt Project Final Report, 1987, p. 119).

Respondents were unwilling to report their income for various reasons. In order to gauge a household's income level, a socioeconomic status index was constructed instead. The index is composed of three sub-indices: a demographic index; a household material assets index; and a farm assets index. The demographic index captured the father's years of education and occupational rank. Mother's years of education was not used because most had not attended school.

For the household material assets index, nine assets were chosen that would distinguish those households in the lower socioeconomic level from those in the high and intermediate socioeconomic level. The assets included household durable goods and indicators of housing quality. Households were then ranked by how many of these assets the household owned. The farm assets index was used to rank agricultural and mixed subsistence households. The index ranked households according to the amount of land owned and leased and the number of livestock owned and shared with other households. For a more detailed description of the components and calculation of the index, see the Egypt Project Final Report (1987).

3.5 Summary

The data used by the study to examine the relationship between nutrition and the cognitive ability of children is a part of the longitudinal data collected by the Nutrition Collaborative Research Support Program in Egypt, which examined the relationship between mild-to-moderate malnutrition and human functional performance. The data on the target toddlers and target schoolers, who were given cognitive tests, were selected for the study. In addition to the cognitive tests, the data used by the study included: individual food intake; anthropometric measurements of target individuals; and household demographic structure and socioeconomic data. The derivation of the actual data that will be used by the analysis will be presented in the next chapter.

CHAPTER FOUR
SPECIFICATION OF THE MODEL

4.1 Introduction

To determine the relationship between nutrition and the cognitive ability of children, one would need to obtain an unbiased estimate of the household production function for cognitive ability,

$$q_i = q(F_i, NF_i; C_i, E_i) . \tag{4.1}$$

where F_i is the vector of nutritional inputs, NF_i is the vector of non-nutritional inputs, C_i is the vector of observed and unobserved characteristics of the child that affect observed cognitive ability, and E_i is the vector of observed and unobserved characteristics of the household environment that affect observed cognitive ability. The estimation of the model, whose results are presented in the next chapter, uses data on toddlers and schoolers collected by the Egypt Nutrition CRSP.

This chapter presents the empirical specification of the variables that enter directly and indirectly in the household production function for cognitive ability. The variable definitions and the descriptive statistics of the variables, along with the variables that enter indirectly into the cognitive ability production function, are presented in Tables 4.1-4.3. As shown in Table 4.1, several binary (0,1) variables were created to represent household environment and physical attributes of housing. Tables 4.2 and 4.3 provide descriptive statistics for the toddler and schooler sample, respectively, for variables defined in Table 4.1 and others in the data set.

Table 4.1 Variable definitions

Variable	Definition
Available protein to energy ratio	Percentage of energy from protein intake, adjusted for the amino acid composition and digestibility of protein source
Available iron intake	Iron intake in mg/day, adjusted for the proportion of intake that is heme and nonheme iron and the presence of dietary factors (that is, ascorbic acid and tea) that affect availability of nonheme iron
Child was breastfed	Child was breastfed on the day food intake was recorded (0,1)
Child's height-for-age in z-score	Child's height expressed as the number of standard deviations from the age- and sex-specific median height
Child's years of education	Years of education completed
Birth spacing	Number of children/(mother's age-16)
Child is female	Child is female (0,1)
Birth order	Age rank of child relative to siblings living in the household
Child is female*Birth order	Interaction between sex and birth order of the child
Child is female*Age	Interaction between sex and age of the child
Child's height is missing	Data on height was not available (0,1)
Month test was taken	Month cognitive test was taken (1=January, 2=February, and so forth)
Month during school year test was taken	Month during school year cognitive test was taken (1=January, 2=February, and so forth)
Father's/Mother's years of education	Years of education completed by each parent
Father completed primary school	Father completed primary school (0,1)
Mother had some education	Mother had attended school (0,1)
Father's/Mother's height	Height of each parent measured in centimeters
Father's/Mother's height is missing	Data on height was not available (0,1)
Household owned no land	Household did not own land (0,1)
Amount of land owned	Land owned measured in qarats
Index of socioeconomic status	Four-point scale ranking households into one of four groups (1=low, 2=intermediate low, 3=intermediate high, 4=high)
Primary water supply was in house	Household's primary water supply was in house (0,1)
Primary water supplied by private pump	Household's primary water supply was from a private pump (0,1)
House had room for receiving visitors	House had a special room for receiving visitors (0,1)

Table 4.2 Descriptive statistics of variables: toddler sample

Variable	N	Mean	S.D.
Endogenous Variables			
Mental Development Index based on the Mental Scale of the Bayley Scales of Infant Development	97	86.11	13.97
Available protein to energy ratio	97	10.61	3.98
Available iron intake (mg/day)	97	0.44	0.35
Child was breastfed	97	0.22	0.41
Child's height-for-age in z-score	97	-1.87	0.99
Birth spacing	97	0.31	0.11
Predetermined Child Characteristics			
Age of child in years	97	1.92	0.36
Age of child squared	97	3.82	1.42
Child is female	97	0.48	0.50
Birth order or age rank of child relative to siblings in the household	97	3.87	1.55
Child is female*Birth order	97	1.79	2.17
Child is female*Age	97	0.97	1.03
Predetermined Household Environment			
Father's years of education	97	4.20	4.28
Father completed primary school	97	0.21	0.41
Father's age in years	97	35.21	7.65
Father's height in centimeters	97	124.92	74.22
Father's height missing	97	0.26	0.44
Mother's years of education	97	1.03	2.10
Mother had some education	97	0.21	0.41
Mother's age in years	97	29.61	5.93
Mother's height in centimeters	97	147.64	34.94
Mother's height missing	97	0.05	0.22
Household owned no land	97	0.68	0.47
Amount of land owned in qarats	97	6.72	14.55
Index of socioeconomic status (1=low, 2=intermediate low, 3=intermediate high, 4=high)	97	2.16	0.93
House had glass windows	97	0.34	0.48
Number of rooms in the house	97	3.66	1.83
House had a separate kitchen	97	0.18	0.38
Primary water supply was in house	97	0.20	0.40
Primary water supplied by private pump	97	0.13	0.34
House had room for receiving visitors	97	0.29	0.46

Note: For those with nonmissing or nonzero values, mean father's height is 168.30, mean mother's height is 155.66, mean father's years of education is 7.14, mean mother's years of education is 5.00, and mean land owned is 21.03.

Table 4.3 Descriptive statistics of variables: schooler sample

Variable	N	Mean	S.D.
Endogenous Variables			
Wechsler Intelligence Scale for Children—Revised Full Scale IQ	111	69.17	13.46
Available protein to energy ratio	111	11.47	2.68
Available iron intake (mg/day)	111	0.82	1.03
Child's height-for-age in z-score	111	-1.01	0.96
Child's height-for-age in z-score squared	111	1.93	2.47
Child's years of education	111	2.18	0.95
Birth spacing	111	0.31	0.09
Predetermined Child Characteristics			
Age of child in years	111	7.92	0.72
Age of child squared	111	63.23	11.74
Child is female	111	0.54	0.50
Birth order or age rank of child relative to siblings in the household	111	2.43	1.27
Child is female*Birth order	111	1.35	1.55
Child is female*Age	111	4.29	4.00
Child's height missing	111	0.06	0.24
Month during the school year that test was taken	111	5.03	3.18
Month test was taken	111	7.11	3.96
Predetermined Household Environment			
Father's years of education	111	4.77	4.66
Father completed primary school	111	0.51	0.50
Father's age in years	111	38.14	6.00
Father's height in centimeters	111	135.22	65.83
Father's height missing	111	0.19	0.39
Mother's years of education	111	1.13	2.39
Mother had some education	111	0.20	0.40
Mother's age in years	111	31.93	4.85
Mother's height in centimeters	111	143.07	42.95
Mother's height missing	111	0.08	0.27
Household owned no land	111	0.77	0.43
Amount of land owned in qarats	111	4.88	12.69
Index of socioeconomic status (1=low, 2=intermediate low, 3=intermediate high, 4=high)	111	2.12	0.89
House has glass windows	111	0.40	0.49
Number of rooms in the house	111	3.55	1.59
House had a separate kitchen	111	0.22	0.41
Primary water supply was in house	111	0.19	0.39
Primary water supplied by private pump	111	0.09	0.29
House had room for receiving visitors	111	0.40	0.49

Note: For those with nonmissing or nonzero values, mean father's height is 166.90, mean mother's height is 155.80, mean father's years of education is 7.78, mean mother's years of education is 5.68 and mean land owned is 23.66.

The chapter is organized as follows. The first section of the chapter deals with the specification of the dependent variable, that is, cognitive ability, while the following two sections deal with the specification of the nutritional and non-nutritional explanatory variables. The final section summarizes the material in the chapter.

4.2 Specification of the Dependent Variable: Cognitive Ability

Cognitive ability corresponds with the individual's ability to adjust or adapt to the environment, the ability to learn, and the ability to perform abstract thinking (Sattler, 1988, pp. 44-45). Cognitive ability of the children was measured using cognitive or intelligence tests. Test scores from the Bayley Scales for Infant Development (Bayley, 1969) were used to evaluate the cognitive ability of toddlers, while test scores from the Wechsler Intelligence Scale for Children—Revised or WISC-R (Wechlser, 1974) were used to evaluate the cognitive ability of schoolers.

Intelligence tests such as these do not measure innate intelligence or potential nor do they measure the entire spectrum of abilities related to intellectual behavior. These tests provide only an estimate of an individual's (observed) ability and information about the individual's current repertoire of (observed) cognitive skills and knowledge (Sattler, 1988, p. 79). Moreover, intelligence tests are not achievement tests. Although both test aptitude and learning, intelligence tests are broader in coverage, sample from a wider range of experiences, and assess learning that occurs in a wider variety of life experiences. Achievement tests are more dependent on formal learning and sample more specific skills. Intelligence tests stress the ability to apply information in new and different ways, whereas achievement tests stress mastery of factual information (Sattler, 1988, p. 73).

4.2.1 Bayley Scales of Infant Development

The cognitive ability of toddlers was evaluated using the Mental Scale of the Bayley Scales of Infant Development (Bayley, 1969). This can be used to measure infant development of children from 2 months to 2 ½ years of age. According to Sattler (1988), the Bayley Scales are currently by far the best measure of infant development and provide valuable information about patterns of early mental development. The Mental Scale contains 163 items which involve shape discrimination, sustained attention, purposeful manipulation of objects, imitation and comprehension, vocalization, memory, problem solving and naming objects (Sattler, 1988, pp. 317-321).

The Egypt Nutrition CRSP data archive contains only raw scores from the Mental Scale. A raw score, however, does not give a meaningful assessment of the child's performance because it does not permit a direct comparison of the child's performance with the performance of other children. The raw scores were then converted to the Mental Development Index (MDI) within the child's own age group, which is a normalized standard score[1] with mean of 100 and standard deviation of 16. That is, the MDI is a Deviation IQ with mean of 100 and standard deviation of 16. This was carried out using the conversion table in the manual of the Bayley Scales of Infant Development (Table 15 in Bayley, 1969, pp. 107-124).

[1] Standard scores are raw scores that have been transformed to have a given mean and standard deviation. The Deviation IQ is one example of a standard score which has a mean of 100 and a standard deviation of 15 or 16 (Sattler, p. 22).

4.2.2 Wechsler Intelligence Scale for Children—Revised

The schoolers' cognitive ability were evaluated using the Egyptian translation of the Wechsler Intelligence Scale for Children--Revised or WISC-R (Wechsler, 1974), which is used to test children from 6 years to 16 years and 11 months of age. The test consists of 12 subtests. Six of the subtests form the Verbal Scale (Information, Similarities, Arithmetic, Vocabulary, Comprehension and Digit Span) and the other six subtests form the Perfomance Scale (Picture Completion, Picture Arrangement, Block Design, Object Assembly, Coding and Mazes) (Sattler, 1988, p. 121). Six out of the 12 subtests were administered to the Egyptian schoolers. Three of these subtests were from the group of subtests that form the Verbal Scale (Vocabulary, Similarities, and Digit Span). The other three subtests were from the group of subtests that forms the Performance Scale (Picture Completion, Coding, and Block Design).

Generally, the Full Scale IQ is computed by, first, converting the raw scores earned on the ten subtests into normalized standard scores (or scaled scores) with a mean of 10 and a standard deviation of 3 within the child's own age group. Digit Span and Mazes are excluded from the calculation of the Full Scale IQ even when it has been administered (Sattler, 1988, p. 121). The scaled scores of the subtests are then added and converted into the Full Scale IQ, which is a Deviation IQ with a mean of 100 and a standard deviation of 15. But since only five of the ten subtests were administered to the Egyptian schoolers, the Full Scale IQ then had to be estimated using the short form procedure taken directly from Sattler (1988, p. 138) and is described below.

The following formula was used to estimate the Deviation IQ of the Egyptian schoolers in the sample:

$$\text{Deviation Quotient} = \left(\frac{15}{S_C}\right)(X_C - M_C) + 100 \tag{4.2}$$

where $S_C = S_S\sqrt{n + 2\sum r_{jk}}$ (standard deviation of the composite score)

X_C = composite score (sum of subtest scaled scores in the short form)

M_C = normative mean which is equal to 10n

S_S = subtest standard deviation which is equal to 3

n = number of component subtest

$\sum r_{jk}$ = sum of the correlations between component subtests

This equation accounts for the number of subtests in the short form (which, in the study, was equal to five), the correlations between the subtests, and the total scaled-score points obtained on the short form. The correlations between component subtests can be obtained from the correlation tables located in the WISC-R manual for the group closest in age to the examinee (Wechsler, 1974, pp. 36-46). Hence, with five subtests in the short form, ten correlations were required (Sattler, 1988, p. 138). The short form used by the study, which consisted of Vocabulary, Similarities, Picture Completion, Coding, and Block Design, is considered to be one of the ten best combinations of five WISC-R subtests, in terms of reliability and validity (Sattler, 1988, p. 820).

4.3 Specification of the Explanatory Variables: Nutritional Factors

The study is focused particularly on the relationship of nutritional factors with the cognitive ability of children. Inadequate nutrition may have a detrimental effect on biological and behavioral factors related to the cognitive growth and development of a child. Early malnutrition may result in alterations or damage to the structures of the brain and central nervous system that may not be fully reversible. In addition, malnutrition weakens the immune system causing a child to be more susceptible to infections. A higher incidence of illness would lead to fewer social interactions with the environment, resulting in loss in learning time and opportunities. Consequently, malnutrition may hinder normal cognitive growth and development and hence prevent children from achieving their cognitive potential.

Both nutrient intake and anthropometry were used to represent nutritional factors that may determine the cognitive ability of children. Individual nutrient intake was used to capture current nutrition, while the child's height-for-age expressed in z-score was used to capture past or long-term nutritional status. Both are expected to be positively related to cognitive ability.

4.3.1 Nutrient Intake

Although data were collected for a wide range of nutrients, the analysis focuses mainly on the protein to energy ratio and iron intake. Both have been shown to have a positive correlation with cognitive ability in previous studies (Pollitt, 1990). The protein to energy ratio was used instead of entering protein and energy separately in the model because of the high correlation among energy, protein, and iron. The correlation matrix can be found in Table A.5-A.6 in the appendix. Nutrient intakes were computed from the food intake closest to the cognitive test date. But nutrient intakes alone, however, do not reflect their bioavailability, that is, the proportion of the nutrients in food that is absorbed and utilized (O'Dell, 1984, p. 301). Not accounting for the bioavailability of intakes may lead to an incorrect assessment of the nutrient quality of an individual's diet. Thus, protein and iron intakes were expressed in terms of bioavailability using the algorithm outlined in Calloway et al. (1992), Murphy et al. (1992) and the Egypt data codebook[1].

Bioavailability is affected by both extrinsic and intrinsic factors. Extrinsic factors are related to dietary factors and include, the nutrient content or composition of the diet, interactions among the dietary components, and factors related to the digestibility of nutrients in the diet. Intrinsic factors are factors related to the individual's physiological capacity for absorbing and utilizing nutrients in the diet. These include the individual's general level of health, adequacy of nutrient stores, and gastrointestinal efficiency. Since very little information was collected on intrinsic factors, the procedure used to estimate availability only accounts for extrinsic factors.

The amount of available protein depends on the amino acid composition of the protein in the diet and the digestibility of the source of protein. To obtain available protein, observed protein intakes were first adjusted for the availability of the first limiting essential amino acid, which is the essential amino acid for which the individual had the lowest intake. Then, it was adjusted for digestibility, using the digestibility factor estimated by the Egypt project investigators. The estimated available protein was then used to compute the available protein to energy ratio.

Availability from iron intake depends on the proportion of iron intake that is heme versus nonheme iron. Heme iron is considered to be more readily available than nonheme iron but the availability of nonheme iron depends on the presence of dietary factors, namely, ascorbic acid and tea, that may enhance or reduce its availability. Ascorbic acid has been

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[1] The estimates of the household production function for cognitive ability without adjusting for availability, along with their descriptive statistics, can be found in Tables A.1-A.4 and A.7-A.14.

found to enhance absorption whereas tannins in tea inhibit absorption. Thus, to obtain available iron, observed iron intakes were adjusted for the iron composition and the amount of ascorbic acid and tea consumed with it.

4.3.2 Breastfeeding

In addition to the protein to energy ratio and iron intake, a dummy variable capturing whether a toddler was being breastfed at the time the food intake was recorded was included in the toddler model. The variable is equal to 1 if the toddler was breastfed on the day the food intake was recorded and is zero otherwise. One reason for including this variable is that breastfeeding toddlers tend to have a lower food intake than non-breastfeeding toddlers. Another reason is that weaning may be associated with changes in the composition of food intake and child feeding patterns among the toddlers in the study.

For children living in developing countries, the weaning period is a particularly vulnerable period. It is associated with growth faltering and an increase in morbidity. One reason for this is that weaning foods given to toddlers typically consist of adult dietary staples, which may not be able to meet the daily nutritional requirements of the child, even though it may be sufficient to satisfy the dietary requirements of adults. This is because adult dietary staples, such as bread, rice and potatoes, tend to have low nutrient density and are often too bulky to eat in quantities large enough to satisfy their daily nutritional requirements. Another reason is that weaning foods may be contaminated due to inadequate sanitation, lack of clean water, and poor hygiene practices. Unlike that of adults, the immune system of young children may not be mature enough to cope with infections caused by eating contaminated food as well as an adult. So, what would be a minor infection to an adult could turn out to be a major infection for a toddler or a child (Huffman and Steel, 1995; Martorell, 1995).

In the case of the toddlers in the study, the Egypt Nutrition CRSP investigators found evidence that the quality of food eaten prior to complete weaning (that is, the child is still partially breastfeeding) was significantly different from food eaten after complete weaning. Prior to complete weaning, toddlers received more than 20% of additional calories from dairy products, primarily homemade cheese, and 10% from poultry, primarily home-grown chicken, and only 5% of calories came from the adult dietary staple, whole wheat flat bread. After complete weaning, 31% of calories were from bread, 1% came from dairy products and none from poultry, although calories from meat rose from 1% to 8% (Kirksey et al., 1992, pp. 48-49). As a result, there is a major shift to bread providing most of the toddlers' energy, protein and mineral intake at complete weaning. Tables A.15-A.17 in the appendix compare toddler diets before and after complete weaning.

Table 4.4 below shows that average energy, available protein and available iron intake were lower for breastfeeding toddlers than for non-breastfeeding toddlers. But the average protein to energy ratio was not significantly different between breastfeeding and non-breastfeeding toddlers. Consistent with the shift to bread as the dietary staple following complete weaning, intake of dietary fiber was lower for breastfeeding toddlers. But the shift in the composition of the diet may have had an adverse effect on their long-term nutritional status.

More boys than girls (30% versus 13%) were still breastfeeding and a higher proportion of mothers with education had stopped breastfeeding (90% versus 75% of mothers

Table 4.4 **Comparison of the mean characteristics of breastfeeding toddlers with non-breastfeeding toddlers on the day their food intake was recorded**

Variable	Breastfed N=21	Non-Breastfed N=76
Energy	707.33	1175.38
Available protein	20.55	31.42
Available protein to energy ratio	10.19	10.73
Available iron	0.28	0.48
Dietary fiber	10.86	15.32
Height-for-age z-score	-1.77	-1.90
Child is female	0.29	0.54
Mother had some education	0.10	0.24
Socioeconomic status index	1.90	2.22

with no education). In Egypt, the traditional and religiously sanctioned period of breastfeeding is two years, although the actual age at weaning varies somewhere between 18-24 months (Kirksey et al., 1992, p. 48). It is likely that mothers with no education may be more likely to follow closely traditional and religiously sanctioned modes of child rearing than mothers with education.

In the sample used in the analysis, all children had been weaned completely by about age 24 months. For toddlers in the sample who were in their 18th month, about half were still breastfeeding. Table 4.5 below compares the mean characteristics of 18-month old toddlers who were still breastfeeding with 18-month old toddlers who were not. Unlike the toddler sample as a whole, there does not appear to be a gender differential in breastfeeding status at 18 months of age. About half the boys and girls were still being breastfed. On the other hand, there was still a higher proportion of mothers with education who had stopped breastfeeding (66% of mothers with education versus 45% of mothers with no education) [1].

But like the toddler sample as a whole breastfeeding toddlers in their 18th month, on average, consumed less energy, protein, iron and fiber, but their protein to energy ratio were slightly higher than non-breastfeeding toddlers' protein to energy ratio. Furthermore, their long-term nutritional status was also better than non-breastfeeding toddlers. Thus, weaning could be negatively related (and conversely, breastfeeding could be positively related) to cognitive ability if nutritional factors were positively related to cognitive ability.

Table 4.5 Comparison of the mean characteristics of 18-month old breastfeeding toddlers with 18-month old non-breastfeeding toddlers on the day their food intake was recorded

Variable	Breastfed at 18 months N=20	Non-Breastfed at 18 months N=19
Energy	720.20	1100.32
Available protein	21.12	26.77
Available protein to energy ratio	10.29	9.64
Available iron	0.29	0.41
Dietary fiber	10.95	14.26
Height-for-age z-score	-1.77	-1.97
Child is female	0.30	0.32
Mother had some education	0.10	0.21
Socioeconomic status index	1.95	2.00

[1] In order to have a better understanding of the factors associated with breastfeeding, a probit model was estimated for the toddler sample. The estimate of the probit model for breastfeeding can be found in Tables A.18-A.21 in Appendix A. The probit model for the entire toddler sample can be seen in Table A.18. Since only age appears to be a significant influence on breastfeeding for the entire sample, an alternative specification was estimated using only the sub-sample of toddlers in their 18th month. The probit model for the sub-sample can be seen in Table A.20. No other variables were statistically significant for this sub-sample.

For the fixed effect estimates, a dummy variable indicating whether a child was weaned during the study, that is, the child stopped breastfeeding during the study, was used instead of the difference in the breastfeeding status variable. This would give a more meaningful interpretation of the child's breastfeeding pattern during the period of observation by indicating one of the critical periods in child development that is weaning. But the former can be derived from the latter in the following manner.

Let

$$BF = \begin{cases} -1 & \text{if a child was breastfed on the day the food intake was recorded} \\ 0 & \text{otherwise} \end{cases}$$

Then, the difference in the breastfeeding status (ΔBF) can take on any of the following values:

$\Delta BF = 0$, $\Delta BF = 1$, or $\Delta BF = -1$,

where

$$\Delta BF = BF_{t+1} - BF_t .$$

Case 1: $\Delta BF = 0$

When $\Delta BF = 0$,

$\Delta BF = BF_{t+1} - BF_t = 0 - 0$ = not breastfeeding in either period or

$\Delta BF = BF_{t+1} - BF_t = -1-(-1)$ = breastfeeding in both periods of observation.

There were no cases of breastfeeding in both periods. In this sample, all the toddlers stopped breastfeeding on or before their 24th month, which is the traditional and religiously sanctioned weaning age. Due to the timing of the administration of the test, there were no toddlers tested between the 19th and 23rd month of age. Consequently, the case of breastfeeding in both periods was not captured in the data. Thus, when ΔBF=0, the child was not being breastfed in either period. In other words, the child completely stopped breastfeeding prior to the study.

Case 2: $\Delta BF = 1$

When $\Delta BF = 1$,

$$\Delta BF = BF_{t+1} - BF_t = 0 - (-1).$$

That is, the child stopped breastfeeding by the second period of the observation. In other words, the child was being weaned during the study.

Case 3: $\Delta BF = -1$

When $\Delta BF = -1$,

$$\Delta BF = BF_{t+1} - BF_t = -1 - 0.$$

That is, the child resumed breastfeeding in the second period of observation. There were no cases of this in the sample. For most of the children in the sample, once they had stopped breastfeeding, they were not observed to be breastfeeding in a later period.

Thus, only the cases when

$$\Delta BF = BF_{t+1} - BF_t = 0 - 0 = \text{child was weaned prior to the study or}$$

$$\Delta BF = BF_{t+1} - BF_t = 0 - (-1) = \text{child was weaned during the study}$$

were observed in the sample. That is, the toddler had either been weaned prior to the periods or was newly weaned during the two periods. Thus, the dummy variable is equal to one if the child was weaned during the period of observation and is equal to zero if the child was weaned prior to the period of observation study[1].

4.3.3 Height-for-Age Z-Score

The child's height-for-age was used to represent past nutritional status and is thus expected to have positive influence on cognitive ability. This is the measure that is commonly used in the nutrition literature and is being used increasingly in the economics literature (Strauss and Thomas, 1998) because height does not decrease with acute malnutrition and increases very slowly in pre-adolescent children (Jelliffe and Jelliffe, 1989, pp. 107-108). In other words, height is not sensitive to temporary or short-run changes in nutrient intake.

There are three ways of expressing height-for-age and the other anthropometric indices, which are, weight-for-age and weight-for-height. These are percent of median, percentile, and the z-score. The method currently recommended by those in the nutrition community, which is used here, is to use the z-score because it has several advantages over the percent of median and the percentile. One of the more important advantages the z-score has over the percent of median, for instance, is that it can be used to establish a criterion or a cut-off point for those at risk that is uniform across age. Unlike z-scores, a child could be classified as severely undernourished or mildly undernourished depending on the child's age

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[1] Note that in the ordinary least squares and two-stage least squares estimate, the breastfeeding variable BF is equal to 1 if the child was breastfeeding on the day the food intake was recorded and is zero otherwise. If this form of the breastfeeding variable had been retained for the fixed effects estimate, then the difference in the breastfeeding status ΔBF would be equal to -1 if the child was weaned during the study and is equal to zero if the child was weaned prior to the study. Reversing the sign of the breastfeeding variable BF makes the fixed effects estimate for breastfeeding (that is, the weaning variable) easier to interpret.

for a given percent of median. Moreover, unlike percentiles, one can calculate summary statistics for a group of z-scores (World Health Organization, 1995).

Height-for-age z-score compares the height of a child of a certain age and sex with the median height of the reference population of that age and sex group. It expresses the child's height as the number of standard deviations from the median height in the child's sex and age group. The height-for-age z-score (HAZ) is computed as follows:

$$\text{HAZ} = \frac{\text{Height of the child} - \text{Median height of reference population}}{\text{Standard deviation of reference population}} \qquad (4.3)$$

The intuition behind this measure is that the farther a child's height is from the median height, the greater the probability of that child's height being abnormal or substandard (Jelliffe and Jelliffe, 1989, p. 123).

The unreferenced height of the children recorded in the Egypt Nutrition CRSP data set were converted to height-for-age z-scores using the EPINUT program on Epi Info, which is an epidemiological software developed by the Centers for Disease Control (CDC) and the World Health Organization (WHO) (Dean et al., 1996). The reference curves used in the software were developed by the National Center for Health Statistics (NCHS) and the CDC using data from the Fels Research Institute and the US Health Examination Surveys (Dean, 1996).

4.4 Specification of the Explanatory Variables: Non-Nutritional Factors

Although the study is focused particularly on the relationship between the child's nutritional status and cognitive ability, other variables, which have been shown in previous studies to be related to the cognitive ability of a child, were also included as explanatory variables in the model. These variables are the child's gender and years of education, parental educational achievement, birth spacing, birth order, and an index of the household's socioeconomic status.

4.4.1 Gender

Although intelligence tests are designed to be gender neutral, studies conducted previously have shown that girls may do better than boys on particular tests and vice versa. There is substantial evidence that girls have greater verbal ability than boys and that boys excel in visual-spatial ability and mathematical ability during adolescence (Sattler, 1988, p. 70). Thus, gender could be associated with performance on intelligence tests but the association could go in either direction.

On the other hand, gender determines the kinds of tasks assigned to boys and girls in many traditional cultures, and these, in turn, influences the kinds of experience children have. Given evidence that aspects of children's daily life are associated with the development of cognitive abilities and that in many cultures the tasks of daily life are prescribed by sex role, gender should be included as one of the factors influencing cognitive development (Engle and Levin, 1984, p. 399-400).

In this village, boys are given more opportunities to be exposed to a broader range of experiences than girls. Girls are expected to assist with, if not take over the domestic work of women from an early age, whereas boys are allowed to spend a greater proportion of their time during the school year on school-related activities (Galal et al., 1987, p. 16). This restriction on the activities of girls may have a negative influence on their cognitive development. Thus, the influence of gender on cognitive ability may be positive or negative depending on which factor above is predominant.

4.4.2 Child's Years of Education

Although intelligence tests are designed to measure more than formally acquired abilities, children who are enrolled in school may be exposed to a broader range of experiences, which would promote the acquisition of new skills, and consequently, enable them to perform better on an intelligence test. Thus, the child's years of education is expected to have a positive influence on their cognitive ability.

For the schooler model only, an additional variable was included to capture the point during the school year at which the test was taken. This was added in order to control for the advantage schoolers enrolled in school, who had taken the test further into the school year, might have over those who had taken the test during the earlier part of the school year. Those who had taken the test later in the school year would be expected to perform better on the cognitive tests, since they would have had more schooling. The variable takes on a value between one to twelve. The variable is equal to one if the schooler had taken the test in October, since school begins around late September or early October. The variable is equal to two if the schooler had taken the test in November, and so forth.

4.4.3 Parent's Level of Educational Achievement

The parent's level of educational achievement should have a positive influence on their children's cognitive ability. Mothers with more education may provide their children with a more intellectually stimulating home environment and may also employ better child rearing practices. In addition, the father's level of educational achievement is generally correlated with the household's income level or socioeconomic status and could be an indication of the household's access to resources that enhance the cognitive ability of children, such as, books and schools with better quality.

The father's years of education and a dummy variable indicating whether the mother has had some schooling were included in the model. Mother's years of education was not used because nearly all the mothers in the sample either had zero years of education or between 4-6 years of education. Thus, the variability in mother's education did not come from the number of years a mother spent in school but came from mothers who had attended school and those who had not.

4.4.4 Birth Spacing

Birth spacing is included in the model as a way to control for the number of children in the household. Shorter interval of births in a household is likely to be associated with a larger number of children in the household. This would mean that a lower level of resources, that can enhance cognitive ability, such as, parental time and goods, would be available for each child. Furthermore, shorter birth intervals in a household is usually associated with a child having low weight at birth and being weaned earlier on average (Haaga, 1995). Consequently, shorter birth intervals may be associated with a child having lower endowments and a higher incidence of morbidity, which could lead to learning problems and loss in learning opportunities. Thus, a longer interval between births should be positively related to cognitive ability.

4.4.5 Birth Order

Like birth spacing, birth order, which was computed to be the age rank of the child relative to the siblings living in the household, can capture the difference in the household environment that each child faces (Horton, 1988). The rationale is that the birth of a sibling changes the household environment of children presently in the household. Likewise, the household environment the newly born child faces is different from the one the siblings faced. A child with a higher birth order has more siblings and implies a greater level of crowding in the household and a lower level of resources available per child. Lower order children may have an advantage over higher order siblings because they would have had access to more parental care and attention, at least when they were young, while higher order children may be more likely to be cared for by older siblings. Thus, birth order should be negatively related to cognitive ability.

But the effect of birth order may also be nonlinear (Horton, 1988; Hanushek, 1992). The last-born child may have the same advantage as the first-born child, while the middle-born children would be the worst off. This is because the last-born child would have no younger siblings to compete with and may benefit from a higher level of household income when older children leave home or begin to earn income, whereas middle-born children would be crowded out.

4.4.6 Socioeconomic Status

For various reasons, household members were unwilling to report their income. In order to gauge a household's income level, an index of socioeconomic status was constructed by the Nutrition CRSP investigators instead by assessing visible farm and household assets.

The index ranked households into four groups (1=low, 2=intermediate low, 3=intermediate high, and 4=high) by the father's occupational rank, household material assets and farm assets. The socioeconomic status of the household is expected to have a positive influence on cognitive ability, since it is an indicator of the household's access to resources that enhance the cognitive ability of children.

4.4.7 Instrumental Variables

Other variables listed in Tables 4.2-4.3 enter only indirectly into the household cognitive ability production function through the endogenous variables in the model: nutrient intakes, whether the toddler was breastfed, height, birth spacing and the schooler's years of education. These other variables, along with all the exogenous or predetermined variables that enter directly in the model, constitute the set of instrumental variables that will be used to predict the endogenous variables that enter into the household cognitive ability production function.

The instrumental variables used include proxies of assets and wealth, such as, land ownership and indicators of housing quality, predetermined family characteristics, such as, parental education, height, and age, and predetermined child characteristics, such as, age, sex, and birth order. Household assets and wealth are associated with the household's capacity to purchase food and to provide their children with education, while family and child characteristics are likely to be associated with child feeding patterns, spacing of births, and education of children. These variables are thus likely to be correlated with the child's food and nutrient intake and nutritional status (as captured by the child's height), the household's breastfeeding pattern and spacing of births, and the amount of education a child is likely to receive and would be suitable as instruments.

4.5 Summary

This chapter presented the empirical specification of the household production model for cognitive ability, which corresponds with the individual's ability to adjust or adapt to the environment, the ability to learn, and the ability to perform abstract thinking. Intelligence tests will be used to proxy cognitive ability. These tests provide an estimate of an individual's (observed) ability and information about the individual's current repertoire of cognitive skills and knowledge.

Explanatory variables of the model include nutritional and non-nutritional variables. Nutritional variables include available protein to energy ratio, available iron intake, height, and the toddler's breastfeeding status. Those expected to have a positive influence on cognitive ability are the available protein to energy ratio, available iron intake and height. Breastfeeding could also have a positive influence on cognitive ability, since breastfeeding for the toddlers in the sample is associated with a diet that is not as rich in bread. Conversely, weaning could have a negative influence on cognitive ability.

Non-nutritional variables include the child's gender, schooler's years of education, parental education, birth spacing, birth order, and index of socioeconomic status. Those expected to have a positive influence on cognitive ability are the child's years of education, parental education and socioeconomic status. Those expected to have a negative influence are the closer spacing of births and higher birth order, since these factors are associated with a greater level of crowding in the household. The direction of the influence of gender is not clear. Although cognitive tests are designed to be gender neutral, girls have been shown to do better than boys on particular tests and vice versa. On the other hand, girls in this village are given fewer opportunities to be exposed to a broad range of experiences, which could have a negative influence on their cognitive development. Thus, the expected influence of gender may be positive or negative depending on which of those factors are predominant.

CHAPTER FIVE
RESULTS OF THE ESTIMATION OF THE MODEL

5.1 Introduction

The results of the estimation of the production function for cognitive ability using data on toddlers and schoolers are presented in this chapter. Table 5.1 gives a concise description of the variables that enter directly into the production function for cognitive ability,

$$q_i = q(F_i, NF_i; C_i, E_i). \qquad (5.1)$$

where F_i is the vector of nutritional inputs, NF_i is the vector of non-nutritional inputs, C_i is the vector of observed and unobserved characteristics of the child that affect observed cognitive ability, and E_i is the vector of observed and unobserved characteristics of the

Table 5.1 Specification of the household production function for cognitive ability

Variable	Model Counterpart
Bayley Mental Development Index (toddlers only)	Cognitive ability
Wechsler Full Scale IQ (schoolers only)	Cognitive ability
Available protein to energy ratio	Nutritional input
Available iron intake	Nutritional input
Child was breastfeeding (toddlers only)	Nutritional input
Child's years of education (schoolers only)	Non-nutritional input
Child is female	Child characteristic
Height-for-age z-score	Child characteristic/ Past nutritional input
Father years of education	Household environment
Mother had some education	Household environment
Birth spacing/Birth order	Household environment
Index of socioeconomic status	Household environment

household environment that affect observed cognitive ability.

The chapter is organized as follows. The results of the estimation of the model for the toddlers are presented in the next section, followed by the results for the schoolers. The final section summarizes the results.

5.2 Results of the Estimation: Toddler Sample

The model was estimated, first, using ordinary least squares (OLS), then re-estimated using two-stage least squares (2SLS) to control for endogeneity of breastfeeding, current nutrient intake (that is, the protein to energy ratio and iron intake), past nutrient intake (as proxied by the toddler's height) and birth spacing. Finally, the model was estimated using child fixed effects to eliminate the bias from unobserved heterogeneity[1].

5.2.1 Result of the OLS Estimation of the Model

The results from the OLS estimation of the model are presented in Table 5.2. In all four specifications of the model, the indicators of both current nutrition and past or cumulative nutrition are significantly related to cognitive ability. Breastfeeding and the child's height were both positive and statistically significant at the 0.01 level. As was discussed in the preceding chapter, the nutrient quality of food given to breastfed toddlers was significantly different from those given to toddlers who have stopped breastfeeding. For breastfeeding toddlers, dairy products and poultry were the major non-breast milk source of energy, protein, vitamin and mineral intake. After breastfeeding had stopped completely, the

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[1] The estimates of the household production function for cognitive ability for the toddler sample *without adjusting for protein and iron availability* can be found in Tables A.7-A.10 in Appendix A. For more details, see Chapter 4, Section 4.3.1.

Table 5.2 Ordinary least squares (OLS) estimate of the household production function for cognitive ability, toddler sample

	OLS (1)	OLS (2)	OLS (3)	OLS (4)
Intercept	85.32	84.99	92.68	92.55
	(12.24)[a]	(12.00)[a]	(13.37)[a]	(13.19)[a]
Child is female	-1.90	-1.90	-2.36	-2.36
	(-0.76)	(-0.75)	(-0.95)	(-0.95)
Child was breastfeeding	9.62	9.42	9.13	9.03
	(3.11)[a]	(2.97)[a]	(2.99)[a]	(2.88)[a]
Available protein to energy ratio	0.34	0.40	0.38	0.41
	(1.10)	(1.08)	(1.25)	(1.12)
Available iron intake	-------	-1.35	-------	-0.66
		(-0.31)		(-0.16)
Height-for-age z-score	5.85	5.85	6.21	6.21
	(4.69)[a]	(4.67)[a]	(4.95)[a]	(4.92)[a]
Father's years of education	0.46	0.46	0.43	0.43
	(1.47)	(1.47)	(1.40)	(1.40)
Mother had some education	2.51	2.48	3.26	3.25
	(0.77)	(0.76)	(1.01)	(1.00)
Index of socioeconomic status	1.32	1.38	0.99	1.02
	(0.95)	(0.98)	(0.72)	(0.73)
Birth spacing	5.42	5.88	-------	-------
	(0.49)	(0.53)		
Birth order	-------	-------	-1.16	-1.15
			(-1.42)	(-1.40)
R-squared	0.34	0.34	0.35	0.35
N	97	97	97	97
F-tests for significance of coefficients				
Test: socioeconomic effect=0	3.30[d]	3.36[d]	2.52[d]	2.51[d]
Test: father's ed=mother's ed=index of socioeconomic status=0	2.04[d]	2.05[d]	1.99[d]	1.97[d]

Note: t-statistics are in parenthesis
[a]-statistically significant at the 0.01 level
[d]-cannot be rejected at the 0.05 level

toddlers' major source of energy, protein, vitamin and mineral intake shifted to bread, which may be too bulky to eat in quantities large enough to satisfy their nutritional requirements. But measures of nutrient intake, protein to energy ratio and iron intake, were statistically insignificant, while the addition of iron into the estimation did not improve the explanatory power of the model.

The estimated coefficient of gender was negative but not statistically significant. Variables that represent the quality of the household environment were also not statistically significant. Both the father's years of education and whether the mother had some education had a positive but statistically insignificant influence on cognitive ability. Their insignificance is counterintuitive, since more educated parents are more likely to be able to provide their children with better care and a more intellectually stimulating environment. But, on the other hand, parents might not need a lot of education to foster a toddler's cognitive development. While parents with more education should be more effective in promoting the cognitive ability of their children, the effect of parental education may not be evident until later in the child's life.

The household's index of socioeconomic status was also not statistically significant. The lack of significance may be because indexing reduces the variation of socioeconomic status across households. Further tests were run to test the role of socioeconomic status. The first test tested the role of the socioeconomic effect, where the socioeconomic effect was defined as follows,

$$\text{Socioeconomic effect} = b_{\text{father's ed}}\text{*mean father's education} + b_{\text{mother's ed}}\text{* mean mother's education} + b_{SES}\text{*mean index of socioeconomic status,}$$

where $b_{father's\ ed}$, $b_{mother's\ ed}$, and b_{SES} is the OLS estimate of the coefficient for father's years of education, whether the mother had some education, and the index of socioeconomic status, respectively. The second test tested the joint statistical significance of parental education and the index of socioeconomic status. Both tests show that these factors do not have a statistically significant influence on the cognitive ability of toddlers.

Birth spacing and birth order were not statistically significant. One explanation for this may be that childcare provided by older siblings and members of the extended family is an adequate substitute for parental care and may, thus, be mitigating the effect of shorter birth intervals and having a higher birth order. In Egypt, extended households are not uncommon and female members of the extended family typically share in the care of children. Also, older children, particularly girls, are expected to help with and eventually take over the domestic work.

5.2.2 Result of the 2SLS Estimation of the Model

The model was also estimated using the 2SLS procedure in order to control for the endogeneity of some of the explanatory variables of the model, namely, breastfeeding status, the protein to energy ratio, iron intake, height-for-age z-score and birth spacing. The results from the first-stage regression for breastfeeding, protein to energy ratio, iron intake, and height-for-age z-score can be found in Tables B.1-B.6 in Appendix B. The predicted value for breastfeeding, protein to energy ratio, iron intake, height-for-age z-score, and birth spacing from the first-stage regression was used to estimate the second-stage regression of the model. The results from the 2SLS estimation of the model are presented in Table 5.3.

Table 5.3 **Two-stage least squares (2SLS) estimate of the household production function for cognitive ability, toddler sample**

	2SLS (1)	2SLS (2)	2SLS (3)	2SLS (4)
Intercept	101.94	100.99	108.43	108.33
	(5.95)[a]	(5.56)[a]	(7.00)[a]	(6.88)[a]
Child is female	-1.72	-1.68	-2.08	-2.07
	(-0.58)	(-0.56)	(-0.72)	(-0.71)
Child was breastfeeding	13.47	13.26	12.55	12.48
	(2.24)[b]	(2.15)[b]	(2.19)[b]	(2.05)[b]
Available protein to energy ratio	-0.89	-0.78	-0.86	-0.83
	(-1.04)	(-0.69)	(-1.03)	(-0.81)
Available iron intake	-------	-1.64	-------	-0.38
		(-0.16)		(-0.04)
Height-for-age z-score	7.39	7.41	8.16	8.17
	(2.80)[a]	(2.80)[a]	(3.05)[a]	(3.03)[a]
Father's years of education	0.53	0.53	0.50	0.50
	(1.53)	(1.53)	(1.43)	(1.43)
Mother had some education	2.08	2.05	2.52	2.52
	(0.56)	(0.55)	(0.68)	(0.67)
Index of socioeconomic status	0.91	1.00	0.62	0.64
	(0.56)	(0.58)	(0.38)	(0.38)
Birth spacing	2.47	3.43	-------	-------
	(0.17)	(0.22)		
Birth order	-------	-------	-0.94	-0.93
			(-0.99)	(-0.98)
R-squared	0.19	0.20	0.20	0.20
N	97	97	97	97

Note: t-statistics are in parenthesis
[a]-statistically significant at the 0.01 level
[b]-statistically significant at the 0.05 level

The 2SLS estimates are quite similar qualitatively to the OLS estimates. There is also very little difference in the results obtained from different specifications of the model. The estimate of the coefficients was also less efficient with the inclusion of iron intake. In all four cases of the model, current and past nutritional status remained statistically significant after controlling for endogeneity. Breastfeeding was significant at the 0.05 level and height remained statistically significant at the 0.01 level. Moreover, it appears that endogeneity biases the estimate of their coefficients downward.

The estimated coefficient of the child's gender remained statistically insignificant. The variables included in the model to capture the quality of the household environment, that is, parental education, the index of socioeconomic status, birth order and birth spacing also remained statistically insignificant.

5.2.3 Results of the Fixed Effects Estimation of the Model

The model was also estimated using a child fixed effects procedure in order to eliminate the bias from unobserved heterogeneity. This procedure can eliminate the bias from unobserved heterogeneity provided one could assume that the bias is invariant or constant over time. The descriptive statistics of the variables used in the fixed effects estimation can be found in Tables 5.4-5.5.

The results from estimating the model using fixed effects are presented in Table 5.6-5.7. The results show that weaning had a negative and statistically significant influence on cognitive development. This finding is consistent with previously conducted studies that have found weaning to be negatively associated with other child outcomes, such as, morbidity and growth.

Table 5.4: Descriptive statistics of the variables used in the fixed effects estimation of the model with birth spacing: toddler sample

Variable	N	Mean	S.D.
Mental Scale of the Bayley Scales of Infant Development			
Mental Development Index	42	-7.69	15.78
Available protein to energy ratio	42	0.02	5.36
Available iron intake (mg/day)	42	0.02	0.41
Child was newly weaned (weanling)	42	0.29	0.46
Child's height-for-age in z-score	42	0.13	0.46
Birth spacing	42	-0.31	0.13
Index of socioeconomic status	42	0.14	0.47
Index of socioeconomic status missing	42	0.05	0.22

Table 5.5: Descriptive statistics of the variables used in the fixed effects estimation of the model without birth spacing: toddler sample

Variable	N	Mean	S.D.
Mental Scale of the Bayley Scales of Infant Development			
Mental Development Index	43	-8.05	15.76
Available protein to energy ratio	43	0.03	5.30
Available iron intake (mg/day)	43	0.02	0.40
Child was newly weaned (weanling)	43	0.30	0.46
Child's height-for-age in z-score	43	0.13	0.45
Index of socioeconomic status	43	0.14	0.47
Index of socioeconomic status missing	43	0.07	0.26

Table 5.6 **Individual fixed effects (FE) estimate of the household production function for cognitive ability (without birth spacing), toddler sample**

	FE (1)	FE (2)	FE (3)	FE (4)
Intercept	-7.23	-7.08	-6.90	-6.91
	(-2.66)[a]	(-2.48)[b]	(-2.45)[b]	(-2.43)[b]
Child was newly weaned (weanling)	-10.11	-10.12	-9.54	-9.48
	(-1.97)[c]	(-1.95)[c]	(1.85)[c]	(-1.83)[c]
Available protein to energy ratio	-------	-------	0.62	0.65
			(1.43)	(1.48)
Available iron intake	-------	-------	-------	-3.43
				(-0.59)
Height-for-age z-score	-------	-0.97	-1.14	-1.41
		(-0.19)	(-0.23)	(-0.28)
Index of socioeconomic status	16.09	15.95	14.39	14.80
	(3.14)[a]	(3.04)[a]	(2.72)[a]	(2.75)[a]
Index of socioeconomic status missing	-0.07	-0.10	-1.95	-1.33
	(-0.01)	(-0.01)	(-0.22)	(-0.15)
R-squared	0.22	0.22	0.26	0.27
F	3.60[b]	2.64[b]	2.58[b]	2.17[c]
N	43	43	43	43

Note: t-statistics are in parenthesis
[a]-statistically significant at the 0.01 level
[b]-statistically significant at the 0.05 level
[c]-statistically significant at the 0.10 level

Table 5.7 Individual fixed effects (FE) estimate of the household production function for cognitive ability (with birth spacing), toddler sample

	FE (1)	FE (2)	FE (3)	FE (4)
Intercept	0.82	1.45	1.97	2.51
	(0.13)	(0.22)	(0.30)	(0.37)
Child was newly weaned (weanling)	-10.73	-10.81	-10.40	-10.36
	(-1.97)[c]	(-1.96)[c]	(-1.91)[c]	(-1.90)[c]
Available protein to energy ratio	-------	-------	0.63	0.68
			(1.46)	(1.54)
Available iron intake	-------	-------	-------	-4.63
				(-0.80)
Height-for-age z-score	-------	-1.99	-2.20	-2.62
		(-0.39)	(-0.44)	(-0.52)
Index of socioeconomic status	14.99	14.67	13.09	13.56
	(2.90)[a]	(2.77)[a]	(2.46)[b]	(2.52)[b]
Index of socioeconomic status missing	2.33	2.27	-0.16	0.87
	(0.22)	(0.21)	(0.02)	(0.08)
Birth spacing	24.83	25.81	26.70	23.39
	(1.40)	(1.42)	(1.50)	(1.57)
R-squared	0.24	0.25	0.29	0.30
F	2.99[b]	2.37[c]	2.39[b]	2.12[c]
N	42	42	42	42

Note: t-statistics are in parenthesis
[a]-statistically significant at the 0.01 level
[b]-statistically significant at the 0.05 level
[c]-statistically significant at the 0.10 level

But the fixed effects estimate of the coefficient for height was no longer statistically significantly related to cognitive ability and nutrient intake was still statistically insignificant. It is likely that the weaning variable captured most of the variation in nutrition related variables. Like the OLS and 2SLS estimates, the coefficient estimates were less efficient with the inclusion of iron intake. The fixed effects estimate of the coefficient for the index of socioeconomic status was statistically significant at the 0.01 level. But the fixed effects estimate of the coefficient for birth spacing was still statistically insignificant.

5.3 Results of the Estimation: Schooler Sample

Like to the toddler sample, the model was estimated for the schooler sample, first using ordinary least squares (OLS). It was then re-estimated using two-stage least squares to control for the endogeneity of current nutrient intake (that is, the protein to energy ratio and iron intake), past nutrient intake as proxied by the schooler's height-for-age z-score, schooler's years of education, and birth spacing. Finally, the model was estimated using child fixed effects to eliminate the bias from unobserved heterogeneity[1].

5.3.1 Result of the OLS Estimation of the Model

The results from the OLS estimation of the model are presented in Table 5.8. In column (1) and (3), only past nutrition was statistically significantly related to cognitive ability. The coefficient estimate for height was significant at the 0.10 level. Like to the OLS estimates of the model for the toddler sample, the addition of iron intake to the model

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[1] The estimates of the household production function for cognitive ability for the schooler sample *without adjusting for protein and iron availability* can be found in Tables A.11-A.14 in Appendix A. For more details, see Chapter 4, Section 4.3.1.

Table 5.8 Ordinary least squares (OLS) estimate of the household production function for cognitive ability, schooler sample

	OLS (1)	OLS (2)	OLS (3)	OLS (4)
Intercept	65.59	65.56	64.29	64.20
	(8.72)[a]	(8.66)[a]	(8.53)[a]	(8.38)[a]
Child is female	-3.90	-3.91	-3.90	-3.91
	(-1.68)[c]	(-1.67)[c]	(-1.68)[c]	(-1.67)[c]
Available protein to energy ratio	0.32	0.33	0.31	0.32
	(0.69)	(0.68)	(0.67)	(0.66)
Available iron intake	--------	-0.10	--------	-0.10
		(-0.08)		(-0.08)
Height z-score	4.12	4.12	4.12	4.12
	(1.64)[c]	(1.63)	(1.64)[c]	(1.63)
Height z-score squared	1.51	1.51	1.51	1.51
	(1.60)	(1.59)	(1.60)	(1.60)
Height missing	-1.31	-1.30	-1.41	-1.40
	(-0.26)	(-0.26)	(-0.28)	(-0.28)
Child's years of education	2.40	2.39	2.48	2.48
	(1.86)[c]	(1.84)[c]	(1.91)[c]	(1.89)[c]
Month during school year test was taken	-1.17	-1.17	-1.17	-1.17
	(-3.09)[a]	(-3.07)[a]	(-3.08)[a]	(-3.06)[a]
Father's years of education	0.92	0.92	0.91	0.92
	(3.24)[a]	(3.21)[a]	(3.24)[a]	(3.21)[a]
Mother had some education	5.21	5.25	5.25	5.29
	(1.66)[c]	(1.65)[c]	(1.68)[c]	(1.66)[c]
Index of socioeconomic status	-0.23	-0.22	-0.19	-0.18
	(-0.16)	(-0.16)	(-0.13)	(-0.13)
Birth spacing	-2.97	-3.06	--------	--------
	(-0.22)	(-0.22)		
Birth order	--------	--------	0.12	0.13
			(0.12)	(0.13)
R-squared	0.30	0.30	0.30	0.30
N	111	111	111	111
F-tests for significance of coefficients				
Test: socioeconomic effect=0	2.88[d]	2.85[d]	2.85[d]	2.81[d]
Test: father's ed=mother's ed=index of socioeconomic status=0	5.41	5.20	5.39	5.17

Note: t-statistics are in parenthesis
[a]-statistically significant at the 0.01 level
[c]-statistically significant at the 0.10 level
[d]-cannot be rejected at the 0.05 level

did not raise significantly the explanatory power of the model and may even have caused the coefficient estimates to be less efficient. When iron intake was included in the model, the coefficient estimate for height became statistically insignificant.

The schooler's years of education was also statistically significant at the 0.01 level and girls did not appear to do as well as boys, even though intelligence tests are not designed to favor one gender over the other. But as mentioned in the preceding chapter, gender is also related to the kind of experiences a child would have had. In this village, the range of experience of girls was more restricted than that of boys, and this may have had a negative influence on the cognitive development of girls. The month during the school year the test was taken was statistically significant and negative at the 0.01 level. This result is counterintuitive, but there is not enough information to be able to explain this result.

The child's household environment seemed to have a positive influence on cognitive ability. Both the father's years of schooling and whether the mother had some education were statistically significant at the 0.01 and 0.10, respectively. An additional year of schooling for the father would raise the test score by 1 point, and children whose mother had some education would earn 5 points more than children whose mother has no education.

But the other aspects of the quality of the household environment were not statistically significantly related to cognitive ability. The coefficient estimate of the household's index of socioeconomic status was not only statistically significant but also had the wrong sign. The reason for the latter result was not evident from the data. The lack of correlation may be because father's education, which is correlated with the household's socioeconomic status index, may be capturing the effect of socioeconomic status on cognitive.

The test of the joint significance of parental education and the index of socioeconomic status show that these variables jointly have a statistically significant influence on cognitive ability at least at the 0.05 level. An additional test was run to test the role of the socioeconomic effect, where the socioeconomic effect was defined as follows,

$$\text{Socioeconomic effect} = b_{\text{father's ed}}\text{*mean father's education} + b_{\text{mother's ed}}\text{* mean mother's education} + b_{SES}\text{*mean index of socioeconomic status,}$$

where $b_{\text{father's ed}}$, $b_{\text{mother's ed}}$, and b_{SES} is the OLS estimate of the coefficient for father's years of education, whether the mother had some education, and the index of socioeconomic status, respectively. The test showed that the socioeconomic effect was not statistically significant at the 0.05 level.

Birth spacing and birth order were also not statistically significant, although the sign of the coefficient for birth order was counterintuitive. These findings were similar (with the signs of the coefficients reversed) to the ones obtained from the OLS estimate of the model for the toddler sample.

5.3.2 Result of the 2SLS Estimation of the Model

The results of the estimation of the model using the 2SLS procedure to control for the endogeneity of protein to energy ratio, iron intake, height-for-age z-score, height-for-age z-score squared, child's years of education and birth spacing, are presented in Table 5.9. The result from the first-stage regression for protein to energy ratio, iron intake, height-for-age z-score, height-for-age z-score squared, and child's years of education can be found in Tables B.7-B.13 in Appendix B. The predicted value of nutrient intakes, height-for-age z-score, height-for-age z-score squared, child's years of education, and birth spacing from the first-

Table 5.9 Two-stage least squares estimate (2SLS) of the household production function for cognitive ability, schooler sample

	2SLS (1)	2SLS (2)	2SLS (3)	2SLS (4)
Intercept	64.40	64.72	62.73	63.75
	(5.39)[a]	(5.06)[a]	(4.95)[a]	(4.43)[a]
Child is female	-3.12	-3.06	-3.09	-2.98
	(-1.15)	(-1.08)	(-1.15)	(-1.05)
Available protein to energy ratio	1.26	1.19	1.11	0.98
	(1.02)	(0.78)	(0.93)	(0.67)
Available iron intake	-------	0.29	-------	0.61
		(0.08)		(0.15)
Height-for-age z-score	12.97	13.01	13.09	13.17
	(2.15)[b]	(2.13)[b]	(2.18)[b]	(2.16)[b]
Height-for-age z-score squared	5.41	5.44	5.43	5.49
	(2.23)[b]	(2.19)[b]	(2.23)[b]	(2.21)[b]
Height missing	-2.44	-2.41	-2.55	-2.46
	(-0.39)	(-0.38)	(-0.41)	(-0.39)
Child's years of education	-0.09	-0.05	0.10	0.15
	(-0.04)	(-0.02)	(0.05)	(0.07)
Month during school year test was taken	-1.31	-1.30	-1.30	-1.29
	(-2.92)[a]	(-2.88)[a]	(-2.90)[a]	(-2.87)[a]
Father's years of education	0.99	0.99	0.99	0.99
	(2.53)[a]	(2.51)[a]	(2.54)[a]	(2.51)[a]
Mother had some education	6.80	6.68	6.98	6.73
	(1.87)[c]	(1.68)[c]	(1.93)[c]	(1.69)[c]
Index of socioeconomic status	-0.87	-0.88	-0.78	-0.82
	(-0.55)	(-0.55)	(-0.49)	(-0.50)
Birth spacing	-8.49	-8.20	--------	--------
	(-0.47)	(-0.44)		
Birth order	--------	--------	0.09	0.04
			(0.08)	(0.03)
R-squared	0.14	0.13	0.14	0.14
N	111	111	111	111

Note: t-statistics are in parenthesis
[a]-statistically significant at the 0.01 level
[b]-statistically significant at the 0.05 level
[c]-statistically significant at the 0.10 level

stage regression was used to estimate the second-stage regression of the model.

Like the OLS estimates above, there was little difference among the results from estimating various specifications of the model. There was also very little gained in explanatory power from the addition of iron intake. In all four cases, the coefficient estimate for past nutritional status was statistically significant at the 0.05 level, while current nutrition still had a statistically insignificant influence on cognitive ability. This finding suggests that it is long-term exposure to malnutrition rather than current intakes that has a negative influence on the cognitive ability of school-aged children.

Variables that capture the quality of the household environment remained statistically significant. Both father's years of education and whether the mother had some schooling were statistically significant at the 0.01 and 0.10 level, respectively. The marginal effect of having a mother with education had risen to seven points, while the marginal effect of an additional year of education for the father remained at about one point. But the index of socioeconomic status, birth spacing and birth order were still statistically insignificant. The schooler's years of education and gender were no longer statistically significant, although the month during the school year the test was taken remained statistically significant at the 0.01 level and still had the wrong sign.

5.3.3 Result of the Fixed Effects Estimation of the Model

The descriptive statistics of the variables used in the fixed effects procedure can be seen in Table 5.10 and the results from the fixed effects estimation are presented in Table 5.11. Unlike the fixed effects estimation of the model for the toddler sample presented in the previous section, none of the variables included in the schooler model are individually or

Table 5.10: Descriptive statistics of the variables used in the fixed effects estimation of the model with and without birth spacing: schooler sample

Variable	N	Mean	S.D.
Wechsler Intelligence Scale for Children—Revised			
Full Scale IQ	49	5.40	11.22
Available protein to energy ratio	49	0.30	4.66
Available iron intake (mg/day)	49	0.11	0.59
Child's height-for-age in z-score	49	-0.00	0.17
Child's height missing	49	0.08	0.28
Birth spacing	49	-0.29	0.08
Child's years of education	49	0.90	0.31
Index of socioeconomic status	49	0.16	0.47

Table 5.11 Individual fixed effects (FE) estimate of the household production function for cognitive ability (with and without birth spacing), schooler sample

	FE (1)	FE (2)	FE (3)	FE (4)
Intercept	-0.03	-0.51	5.83	5.68
	(-0.00)	(-0.05)	(1.10)	(1.06)
Available protein to energy ratio	-0.13	-0.19	-0.13	-0.17
	(-0.35)	(-0.45)	(-0.35)	(-0.41)
Available iron intake	--------	1.00	--------	0.72
		(0.31)		(0.22)
Height z-score	-7.83	-8.48	-7.75	-8.21
	(-0.79)	(-0.83)	(-0.79)	(-0.81)
Height missing	-9.37	-9.58	-9.55	-9.71
	(-1.54)	(-1.54)	(-1.58)	(-1.58)
Child's years of education	2.10	2.56	0.84	0.92
	(0.37)	(0.39)	(0.16)	(0.17)
Index of socioeconomic status	-2.64	-2.47	-2.48	-2.34
	(-0.75)	(-0.68)	(-0.71)	(-0.65)
Birth spacing	-16.42	-17.22	--------	--------
	(-0.73)	(-0.75)		
R-squared	0.10	0.10	0.08	0.09
F	0.75	0.64	0.80	0.66
N	49	49	49	49

Note: t-statistics in parenthesis

jointly significant statistically. One explanation could be that there were no significant variation in the explanatory variables over the two periods of observation.

Another explanation could be that the measure of the household environment included in the model, namely, the index of socioeconomic status, did not capture the relevant factors in the schoolers' household environment that affect their cognitive ability. Moreover, schoolers are not as restricted to the home as the toddlers and it is likely that the measure of the household environment included in the fixed effects model may not account for a significant proportion of the total environment that they face. For example, schoolers who are enrolled in school are likely to spend a greater proportion of their day outside the home and in school. But measures of the school environment were not available in the data. Thus, it is likely that the model has not included enough variables relevant to the schoolers' cognitive ability.

5.4 Summary

The purpose of the study was to examine whether the nutritional status of young children affects their cognitive ability because cognitive ability may be one pathway through which malnutrition diminishes educational achievement. The findings of the study support the hypothesis that nutritional status affects cognitive ability. For toddlers, both long-term nutritional status and current intakes had a statistically significant influence on their cognitive ability. In addition to the height-for-age z-score, breastfeeding had a positive influence on toddlers' cognitive ability, while weaning had a negative influence on their cognitive ability.

For children in developing countries, weaning is a particularly vulnerable period. One reason is that the weaning foods given to toddlers typically consist of adult dietary staples, which are often too bulky for toddlers to eat in quantities large enough to meet their nutritional requirements. For the toddlers in this village, complete weaning was associated with a significant shift in the composition of dietary intake. Prior to complete weaning, homemade dairy products and home-grown poultry were a significant source of nutrient intake for toddlers, while only a small proportion came from bread, the adult dietary staple. But following complete weaning, bread became the toddlers' significant source of nutrient intake.

The protein to energy ratio and iron intake, however, had a statistically insignificant influence on toddler's cognitive ability. These findings are similar to those found by Bhargava (1996), who had used data on Kenyan school-aged children and had subsequently dropped nutrient intake from the final analysis. The addition of iron also had not improved the explanatory power of the model. One reason for this is that there may be a large variation in within individual nutrient intake relative to across individual nutrient intake, which would bias the effect of nutrient intake downwards (Torres et al., 1990). Another reason could be that the effect of micronutrient deficiencies on cognitive ability may not be evident in the short-term unless the level of deficiency is severe. The body may be able to maintain the nutritional requirements of the brain at a more moderate level of malnutrition than at a more severe level, at least over the short-term. There is some evidence that when the body is faced with an inadequate intake of energy, vital organs, such as, the brain, heart and lungs, would not be the first to be compromised (Waterlow, 1990).

For schoolers, on the other hand, long-term nutritional status seemed to be more important than current intakes in determining cognitive ability. Their height-for-age z-score had a statistically significant influence on cognitive ability, and, like the toddlers, nutrient intakes did not. It is likely that cumulative deficits were more important than current deficits for the cognitive ability of schoolers than for the cognitive ability of toddlers because schoolers would have experienced the effects of malnutrition longer than toddlers.

The effect of parental education on the cognitive ability of children did not seem to be the same throughout the child's life. Parental education seemed to have a statistically significant influence on the cognitive ability of schoolers but not for the cognitive ability toddlers, at least for this sample. It may be that parents do not need to have a lot of formal education in order to stimulate a toddler's cognitive ability. Parents with more education should be more effective in promoting the cognitive development of their children, but the effect of parental education on cognitive ability may not be evident until later in the child's life.

The OLS estimate of the effect of gender on cognitive ability was statistically significant for the schoolers but not for the toddlers. Because older children have greater mobility, the potential range of experience is broader for older children than for younger children. Toddlers of either gender are likely to be restricted to the home. On the other hand, male schoolers in this village were allowed greater freedom to explore their environment, whereas female schoolers, like the toddlers, were more restricted to the home and to domestic activities. Given that richness of experience is associated positively with cognitive development, it is not unlikely that male schoolers may do better than female schoolers on cognitive evaluations. But like the child's years of education, gender did not remain statistically significant once endogeneity was taken into account.

The OLS estimate of the child's years of education was statistically significantly related to cognitive ability. But it did not remain so once endogeneity and unobserved heterogeneity were taken into account. The index of socioeconomic status was statistically significant only for toddlers. It is possible, however, that father's education in the schooler model may be capturing the effect of the household socioeconomic status, since father's education is correlated with the household's socioeconomic status. On the other hand, birth spacing and birth order were not statistically significant for either toddlers or schoolers.

CHAPTER SIX
IMPLICATIONS OF THE STUDY

Education makes up a significant proportion of government expenditure in developing countries. But the effectiveness of expenditure in education may be constrained by the level of investment in child nutrition. Malnutrition may diminish children's ability to learn and hence limit their educational achievement. This study found that malnutrition does indeed have a negative effect on the cognitive ability of children, suggesting that programs aimed at ensuring the nutritional needs of the child are also necessary for improving educational achievement. Furthermore, nutrition programs that promote the nutritional status of children over the long-term may be more effective than programs that promote children's nutritional status over the short-term.

For the toddlers in the sample, both current intake and long-term nutritional status were significantly associated with their cognitive ability. Food intake during the weaning period, in particular, seemed critical to their cognitive development and thus, should be monitored closely in order to ensure that their daily nutritional requirements are met during this period. Programs, for example, that educate mothers about how to enrich weaning foods given to toddlers and how to keep track of their toddler's growth in terms of their weight and height may be effective in preventing toddlers from becoming malnourished following complete weaning.

Moreover, it seems that food programs aimed at adults may not necessarily translate into an improvement in toddler's nutritional outcomes. Bread, which is the adult dietary staple in Egypt, is one of the food items heavily subsidized by the Egyptian government. Although bread may be able to meet the nutritional requirements of adults, it appears that the shift to bread as the major source of calories, protein, vitamin and mineral intake for toddlers following complete weaning has an adverse effect on their cognitive development. This may be because toddlers, unlike adults, are unable to eat bread in an amount large enough to satisfy their dietary requirements. Thus, a nutrition program designed specifically for toddlers may be needed.

For schoolers on the other hand, long-term nutritional status had a significant influence on their cognitive ability, but current intakes did not. In contrast to the toddlers, cumulative nutritional deficits were more important than current nutritional deficits for the cognitive ability of schoolers. This may be because schoolers would have experienced the effects of malnutrition longer than the toddlers. This finding further supports the need for early nutrition programs. Because there is no information in the data set regarding the early years of schoolers, it is difficult to pinpoint when nutrition intervention would be beneficial for them. But the toddler findings does suggest at least one period, that is, the weaning period, when nutrition programs may be particularly beneficial to promoting their cognitive development.

But the findings of the study have to be interpreted with caution. The size of the sample used by the study was not very large and was further reduced in the fixed effects estimation, which lowers the precision of the estimates. Further study using other data sets may be needed to confirm these results.

APPENDIX A: ADDITIONAL RESULTS

Table A.1 Descriptive statistics and definition of variables: toddler sample

Variable	N	Mean	S.D.
Endogenous Variables			
Bayley Mental Scale Mental Development Index	97	86.11	13.97
Protein to energy ratio	97	12.03	3.40
Iron intake (mg/day)	97	5.67	3.14
Child was breastfeeding (1=breastfeeding, 0=not breastfeeding)	97	0.22	0.41
Child's height-for-age in z-score	97	-1.87	0.99
Birth spacing (=number of children/(mother's age-16))	97	0.31	0.11
Predetermined Child Characteristics			
Age of child in years	97	1.92	0.36
Age of child squared	97	3.82	1.42
Child is female (1=female, 0=male)	97	0.48	0.50
Birth order or age rank of child relative to siblings in the household	97	3.87	1.55
Child is female*Birth order	97	1.79	2.17
Child is female*Age	97	0.97	1.03
Predetermined Household Environment			
Father's years of education	97	4.20	4.28
Father completed primary school (1=yes, 0=no)	97	0.21	0.41
Father's age in years	97	35.21	7.65
Father's height in centimeters	97	124.92	74.22
Father's height missing (1=yes, 0=no)	97	0.26	0.44
Mother's years of education	97	1.03	2.10
Mother had some education (1=yes, 0=no)	97	0.21	0.41
Mother's age in years	97	29.61	5.93
Mother's height in centimeters	97	147.64	34.94
Mother's height missing (1=yes, 0=no)	97	0.05	0.22
Household owned no land (1=yes, 0=no)	97	0.68	0.47
Amount of land owned in qarats	97	6.72	14.55
Index of socioeconomic status (1=low, 2=intermediate low, 3=intermediate high, 4=high)	97	2.16	0.93
House had glass windows (1=yes, 0=no)	97	0.34	0.48
Number of rooms in the house	97	3.66	1.83
House had a separate kitchen (1=yes, 0=no)	97	0.18	0.38
House had its own water supply (1=yes, 0=no)	97	0.20	0.40
Primary water supplied by private pump (1=yes, 0=no)	97	0.13	0.34
House had room for receiving visitors (1=yes, 0=no)	97	0.29	0.46

Note: For those with nonmissing or nonzero values, mean father's height was 168.30, mean mother's height was 155.66, mean father's years of education was 7.14, mean mother's years of education was 5.00, and mean land owned was 21.03.

Table A.2 Descriptive statistics and definition of variables: schooler sample

Variable	N	Mean	S.D.
Endogenous Variables			
Wechsler Intelligence Scale for Children—Revised Full Scale IQ	111	69.17	13.46
Protein to energy ratio	111	12.48	2.36
Iron intake (mg/day)	111	11.30	6.28
Child's height-for-age in z-score	111	-1.01	0.96
Child's height-for-age in z-score squared	111	1.93	2.47
Child's years of education	111	2.18	0.95
Birth spacing (=number of children/(mother's age-16))	111	0.31	0.09
Predetermined Child Characteristics			
Age of child in years	111	7.92	0.72
Age of child squared	111	63.23	11.74
Child is female (1=female, 0=male)	111	0.54	0.50
Birth order or age rank of child relative to siblings in the household	111	2.43	1.27
Child is female*Birth order	111	1.35	1.55
Child is female*Age	111	4.29	4.00
Child's height missing (1=yes, 0=no)	111	0.06	0.24
Month during the school year that test was taken (1=October, etc.)	111	5.03	3.18
Month test was taken (1=January, etc.)	111	7.11	3.96
Predetermined Household Environment			
Father's years of education	111	4.77	4.66
Father completed primary school (1=yes, 0=no)	111	0.51	0.50
Father's age in years	111	38.14	6.00
Father's height in centimeters	111	135.22	65.83
Father's height missing (1=yes, 0=no)	111	0.19	0.39
Mother's years of education	111	1.13	2.39
Mother had some education (1=yes, 0=no)	111	0.20	0.40
Mother's age in years	111	31.93	4.85
Mother's height in centimeters	111	143.07	42.95
Mother's height missing (1=yes, 0=no)	111	0.08	0.27
Household owned no land (1=yes, 0=no)	111	0.77	0.43
Amount of land owned in qarats	111	4.88	12.69
Index of socioeconomic status (1=low, 2=intermediate low, 3=intermediate high, 4=high)	111	2.12	0.89
House had glass windows (1=yes, 0=no)	111	0.40	0.49
Number of rooms in the house	111	3.55	1.59
House had a separate kitchen (1=yes, 0=no)	111	0.22	0.41
House had its own water supply (1=yes, 0=no)	111	0.19	0.39
Primary water supplied by private pump (1=yes, 0=no)	111	0.09	0.29
House had room for receiving visitors (1=yes, 0=no)	111	0.40	0.49

Note: For those with nonmissing or nonzero values, mean father's height was 166.90, mean mother's height was 155.80, mean father's years of education was 7.78, mean mother's years of education was 5.68 and mean land owned was 23.66.

Table A.3 Descriptive statistics and definition of variables used in fixed effects estimation, toddler sample

Variable	N	Mean	S.D.
Bayley Mental Scale Mental Development Index	43	-8.05	15.76
Protein to energy ratio	43	0.13	4.46
Iron intake (mg/day)	43	1.86	3.55
Child was newly weaned (weanling)	43	0.30	0.46
Child's height-for-age in z-score	43	0.13	0.45
Birth spacing	42	-0.31	0.13
Index of socioeconomic status	43	0.14	0.47
Index of socioeconomic status missing	43	0.07	0.26

Table A.4 Descriptive statistics and definition of variables used in fixed effects estimation, schooler sample

Variable	N	Mean	S.D.
Wechsler Full Scale IQ	49	5.40	11.22
Protein to energy ratio	49	0.27	4.26
Iron intake (mg/day)	49	-0.13	5.12
Child's height-for-age in z-score	49	-0.00	0.17
Child's height missing	49	0.08	0.28
Child's years of education	49	0.90	0.31
Birth spacing	49	-0.29	0.08
Index of socioeconomic status	49	0.16	0.47

Table A.5 Nutrient intake correlation matrix, toddler sample

	Energy	Protein	Protein to energy ratio	Iron
Energy		0.85[a]	0.08[ns]	0.86[a]
Protein			0.54[a]	0.87[a]
Protein to energy ratio				0.30[a]
Iron				

Note: [ns]-not significant
[a]-significant at the 0.01 level

Table A.6 Nutrient intake correlation matrix, schooler sample

	Energy	Protein	Protein to energy ratio	Iron
Energy		0.86[a]	0.10[ns]	0.62[a]
Protein			0.56[a]	0.69[a]
Protein to energy ratio				0.32[a]
Iron				

Note: [ns]-not significant
[a]-significant at the 0.01 level

Table A.7 **Ordinary least squares (OLS) estimate of the household production function for cognitive ability, toddler sample**

	OLS (1)	OLS (2)	OLS (3)	OLS (4)
Intercept	84.49	84.72	91.47	91.49
	(11.04)[a]	(11.01)[a]	(12.24)[a]	(12.17)[a]
Child is female	-1.86	-1.84	-2.30	-2.29
	(-0.74)	(-0.73)	(-0.93)	(-0.92)
Child was breastfeeding	9.58	9.07	9.10	8.98
	(3.09)[a]	(2.79)[a]	(2.99)[a]	(2.80)[a]
Protein to energy ratio	0.37	0.44	0.45	0.47
	(1.02)	(1.14)	(1.24)	(1.22)
Iron intake	--------	-0.24	--------	-0.06
		(-0.55)		(-0.13)
Height-for-age z-score	5.86	5.92	6.23	6.24
	(4.70)[a]	(4.71)[a]	(4.97)[a]	(4.94)[a]
Father's years of education	0.45	0.46	0.42	0.42
	(1.44)	(1.46)	(1.36)	(1.35)
Mother had some education	2.61	2.53	3.42	3.39
	(0.80)	(0.77)	(1.05)	(1.04)
Index of socioeconomic status	1.33	1.47	1.01	1.05
	(0.96)	(1.04)	(0.73)	(0.73)
Birth spacing	5.25	6.07	--------	--------
	(0.48)	(0.55)		
Birth order	--------	--------	-1.20	-1.17
			(-1.46)	(-1.38)
R-squared	0.34	0.34	0.35	0.35
N	97	97	97	97
F-tests for significance of coefficients				
Test: socioeconomic effect=0	3.30[d]	3.54[d]	2.54[d]	2.47[d]
Test: father's ed=mother's ed=index of socioeconomic status=0	2.04[d]	2.11[d]	2.00[d]	1.97[d]

Note: t-statistics are in parenthesis
[a]-statistically significant at the 0.01 level
[d]-cannot be rejected at the 0.05 level

Table A.8 Two-stage least squares (2SLS) estimate of the household production function for cognitive ability, toddler sample

	2SLS (1)	2SLS (2)	2SLS (3)	2SLS (4)
Intercept	108.63	108.09	112.48	109.47
	(5.21)[a]	(5.10)[a]	(6.15)[a]	(5.75)[a]
Child is female	-2.09	-2.08	-2.29	-2.15
	(-0.68)	(-0.67)	(-0.77)	(-0.72)
Child was breastfeeding	12.83	13.56	12.32	14.82
	(2.07)[b]	(1.89)[c]	(2.12)[b]	(2.07)[b]
Protein to energy ratio	-1.22	-1.28	-1.10	-1.14
	(-1.17)	(-1.18)	(-1.08)	(-1.11)
Iron intake	--------	0.21	--------	0.61
		(0.21)		(0.61)
Height-for-age z-score	7.66	7.47	8.20	7.68
	(2.82)[a]	(2.59)[a]	(3.06)[a]	(2.71)[a]
Father's years of education	0.57	0.56	0.53	0.51
	(1.59)	(1.57)	(1.50)	(1.42)
Mother had some education	1.54	1.67	2.05	2.59
	(0.39)	(0.42)	(0.53)	(0.65)
Index of socioeconomic status	0.73	0.63	0.53	0.24
	(0.43)	(0.36)	(0.32)	(0.14)
Birth spacing	1.71	0.62	--------	--------
	(0.11)	(0.04)		
Birth order	--------	--------	-0.83	-1.07
			(-0.86)	(-1.02)
R-squared	0.16	0.16	0.19	0.18
N	97	97	97	97

Note: t-statistics are in parenthesis
[a]-statistically significant at the 0.01 level
[b]-statistically significant at the 0.05 level

Table A.9 **Individual fixed effects (FE) estimate of the household production function for cognitive ability, toddler sample**

	FE (1)	FE (2)	FE (3)	FE (4)
Intercept	-7.23	-7.08	-7.03	-6.72
	(-2.66)[a]	(-2.48)[b]	(-2.48)[b]	(-2.29)[b]
Child was newly weaned (weanling)	-10.11	-10.12	-9.63	-8.38
	(-1.97)[c]	(-1.95)[c]	(-1.86)[c]	(-1.46)
Protein to energy ratio	-------	-------	0.66	0.64
			(1.27)	(1.22)
Iron intake	-------	-------	-------	-0.37
				(-0.51)
Height-for-age z-score	-------	-0.97	-0.81	-0.68
		(-0.19)	(-0.16)	(-0.13)
Index of socioeconomic status	16.09	15.95	14.56	14.10
	(3.14)[a]	(3.04)[a]	(2.74)[a]	(2.59)[a]
Index of socioeconomic status missing	-0.07	-0.09	-1.74	-1.19
	(-0.01)	(-0.01)	(-0.20)	(-0.13)
R-squared	0.22	0.22	0.25	0.26
Adjusted R-squared	0.16	0.14	0.15	0.13
F	3.60[b]	2.64[b]	2.47[b]	2.06[c]
N	43	43	43	43

Note: t-statistics are in parenthesis
[a]-statistically significant at the 0.01 level
[b]-statistically significant at the 0.05 level
[c]-statistically significant at the 0.10 level

Table A.10 Individual fixed effects (FE) estimate of the household production function for cognitive ability, toddler sample

	FE (1)	FE (2)	FE (3)	FE (4)
Intercept	0.82	1.45	1.38	1.38
	(0.13)	(0.22)	(0.21)	(0.20)
Child was newly weaned (weanling)	-10.73	-10.81	-10.29	-9.08
	(-1.97)[c]	(-1.96)[c]	(-1.88)[c]	(-1.47)
Protein to energy ratio	-------	-------	0.65	0.63
			(1.25)	(1.21)
Iron intake	-------	-------	-------	-0.32
				(-0.44)
Height-for-age z-score	-------	-1.99	-1.82	-1.68
		(-0.39)	(-0.36)	(-0.33)
Index of socioeconomic status	14.99	14.67	13.31	12.90
	(2.90)[a]	(2.77)[a]	(2.48)[b]	(2.34)[b]
Index of socioeconomic status missing	2.33	2.27	0.70	1.52
	(0.22)	(0.21)	(0.07)	(0.14)
Birth spacing	24.83	25.81	25.46	24.68
	(1.40)	(1.42)	(1.42)	(1.35)
R-squared	0.24	0.25	0.28	0.28
Adjusted R-squared	0.16	0.14	0.16	0.14
F	2.99[b]	2.37[c]	2.27[c]	1.93[c]
N	42	42	42	42

Note: t-statistics are in parenthesis
[a]-statistically significant at the 0.01 level
[b]-statistically significant at the 0.05 level
[c]-statistically significant at the 0.10 level

Table A.11 Ordinary least squares (OLS) estimate of the household production function for cognitive ability, schooler sample

	OLS (1)	OLS (2)	OLS (3)	OLS (4)
Intercept	66.93	67.48	66.03	66.20
	(8.14)[a]	(8.15)[a]	(7.92)[a]	(7.92)[a]
Child is female	-3.86	-4.06	-3.86	-4.06
	(-1.66)[c]	(-1.73)[c]	(-1.66)[c]	(-1.73)[c]
Protein to energy ratio	0.12	0.22	0.11	0.21
	(0.22)	(0.41)	(0.21)	(0.39)
Iron intake	--------	-0.14	--------	-0.14
		(-0.73)		(-0.72)
Height-for-age z-score	4.04	4.13	4.04	4.12
	(1.60)	(1.63)	(1.60)	(1.63)
Height-for-age z-score squared	1.51	1.58	1.51	1.58
	(1.60)	(1.66)[c]	(1.60)	(1.66)[c]
Height missing	-0.93	-0.99	-1.00	-1.09
	(-0.18)	(-0.20)	(-0.20)	(-0.21)
Child's years of education	2.44	2.37	2.50	2.46
	(1.88)[c]	(1.82)[c]	(1.91)[c]	(1.88)[c]
Month during school year test was taken	-1.17	-1.15	-1.16	-1.14
	(-3.06)[a]	(-3.00)[a]	(-3.06)[a]	(-2.99)[a]
Father's years of education	0.95	0.97	0.95	0.96
	(3.33)[a]	(3.37)[a]	(3.33)[a]	(3.37)[a]
Mother had some education	5.28	5.44	5.30	5.47
	(1.68)[c]	(1.72)[c]	(1.69)[c]	(1.73)[c]
Index of socioeconomic status	-0.16	-0.17	-0.13	-0.13
	(-0.12)	(-0.12)	(-0.09)	(-0.09)
Birth spacing	-1.96	-2.79	--------	--------
	(-0.14)	(-0.20)	0.09	0.13
Birth order	--------	--------	(0.10)	(0.14)
R-squared	0.30	0.30	0.30	0.30
N	111	111	111	111
F-tests for significance of coefficients				
Test: socioeconomic effect=0	3.20	3.32	3.26	3.36
Test: father's ed=mother's ed=index of socioeconomic status=0	5.78[d]	5.91[d]	5.80[d]	5.94[d]

Note: t-statistics are in parenthesis
[a]-statistically significant at the 0.01 level
[c]-statistically significant at the 0.10 level
[d]-cannot be rejected at the 0.05 level

Table A.12 Two-stage least squares (2SLS) estimate of the household production function for cognitive ability, schooler sample

	2SLS (1)	2SLS (2)	2SLS (3)	2SLS (4)
Intercept	61.10	61.66	59.89	61.07
	(4.16)[a]	(4.06)[a]	(3.92)[a]	(3.80)[a]
Child is female	-2.88	-2.38	-2.89	-2.26
	(-1.06)	(-0.75)	(-1.06)	(-0.71)
Protein to energy ratio	1.44	1.06	1.28	0.84
	(1.00)	(0.57)	(0.92)	(0.48)
Iron intake	-------	0.27	-------	0.33
		(0.34)		(0.44)
Height-for-age z-score	13.47	13.88	13.52	14.01
	(2.20)[b]	(2.17)[b]	(2.22)[b]	(2.18)[b]
Height-for-age z-score squared	5.55	5.79	5.55	5.84
	(2.27)[b]	(2.22)[b]	(2.27)[b]	(2.23)[b]
Height missing	-2.51	-2.07	-2.62	-2.03
	(-0.39)	(-0.31)	(-0.41)	(-0.30)
Child's years of education	-0.27	-0.07	-0.08	0.10
	(-0.13)	(-0.03)	(0.04)	(0.04)
Month during school year test was taken	-1.33	-1.34	-1.32	-1.33
	(-2.89)[a]	(-2.83)[a]	(-2.88)[a]	(-2.80)[a]
Father's years of education	0.98	0.99	0.98	0.99
	(2.43)[b]	(2.38)[b]	(2.44)[b]	(2.37)[b]
Mother had some education	7.40	7.06	7.51	7.07
	(1.98)[b]	(1.79)[c]	(2.02)[b]	(1.78)[c]
Index of socioeconomic status	-0.79	-0.80	-0.72	-0.77
	(-0.49)	(-0.49)	(-0.45)	(-0.46)
Birth spacing	-8.10	-6.34	-------	-------
	(-0.44)	(-0.33)		
Birth order	-------	-------	0.07	0.01
			(0.06)	(0.01)
R-squared	0.11	0.07	0.12	0.06
N	111	111	111	111

Note: t-statistics are in parenthesis
[a]-statistically significant at the 0.01 level
[b]-statistically significant at the 0.05 level
[c]-statistically significant at the 0.10 level

Table A.13 **Individual fixed effects (FE) estimate of the household production function for cognitive ability, schooler sample**

	FE (1)	FE (2)	FE (3)
Intercept	6.58	6.53	5.87
	(3.75)[a]	(3.68)[a]	(1.10)
Protein to energy ratio	-0.22	-0.20	-0.21
	(-0.57)	(-0.50)	(-0.51)
Iron intake	-------	-0.12	-0.11
		(-0.35)	(-0.33)
Height-for-age z-score	-7.97	-7.08	-7.20
	(-0.82)	(-0.70)	(-0.70)
Height missing	-9.70	-9.38	-9.29
	(-1.65)	(-1.56)	(-1.52)
Child's years of education	-------	-------	0.73
			(0.13)
Index of socioeconomic status	-2.26	-2.22	-2.21
	(-0.65)	(-0.63)	(-0.62)
R-squared	0.09	0.09	0.09
Adjusted R-squared	0.01	-0.01	-0.04
F	1.07	0.86	0.71
N	49	49	49

Note: t-statistics are in parenthesis
[a]-significant at the 0.01 level

Table A.14 Individual fixed effects (FE) estimate of the household production function for cognitive ability, schooler sample

	FE (1)	FE (2)	FE (3)
Intercept	2.63	2.42	-0.02
	(0.42)	(0.38)	(-0.00)
Protein to energy ratio	-0.21	-0.19	-0.20
	(-0.54)	(-0.47)	(-0.50)
Iron	--------	-0.13	-0.12
		(-0.39)	(-0.35)
Height-for-age z-score	-7.92	-6.91	-7.20
	(-0.81)	(-0.68)	(-0.70)
Height missing	-9.69	-9.33	-9.07
	(-1.64)	(-1.54)	(-1.47)
Child's years of education	--------	--------	-1.97
			(0.34)
Index of socioeconomic status	-2.43	-2.40	-2.38
	(-0.69)	(-0.67)	(-0.66)
Birth spacing	-13.75	-14.32	-16.57
	(-0.65)	(-0.67)	(-0.73)
R-squared	0.10	0.10	0.10
Adjusted R-square	-0.01	-0.03	-0.05
F	0.93	0.78	0.68
N	49	49	49

Note: t-statistics are in parenthesis

Table A.15 Comparison of toddler diets before and after complete weaning (mean percent of non-breast milk dietary energy from food groups)

Food group	Before weaning (N=443 child days)	After weaning (N=2319 child days)
Traditional bread	5.5	31.3
"French" bread	4.9	0.6
Dairy products	21.6	1.2
Eggs	3.2	0.4
Poultry	11.2	0.0
Meat	0.9	7.9
Fish	2.6	0.0
Vegetables	5.0	10.5
Fruits and juices	6.7	4.5
Legumes	1.5	5.1
Fats and oils	3.4	9.5
Sweets	4.0	15.2
Beverages (non-dairy)	0.8	0.2
Nuts	1.2	----

Source: Kirksey, et al. (1992)

Table A.16 Dietary quality for toddlers before and after complete weaning (mean percent of non-breast milk vitamin intake from food groups)

	Before weaning (N=443 child days)	After weaning (N=2319 child days)
From traditional bread		
Iron	10.0	47.2
Zinc	8.0	37.0
Calcium	0.9	15.1
Copper	9.9	33.4
Magnesium	11.5	51.4
From meat, fish, poultry, egg		
Iron	26.3	11.6
Zinc	26.6	32.1
Calcium	7.3	6.5
Copper	13.3	2.9
Magnesium	16.8	3.2
From dairy products		
Iron	6.2	0.3
Zinc	26.7	1.5
Calcium	64.3	10.5
Copper	11.2	0.4
Magnesium	14.3	0.5

Source: Kirksey, et al. (1992)

Table A.17 **Dietary quality for toddlers before and after complete weaning (mean percent of non-breast milk mineral intake from food groups)**

	Before weaning (N=443 child days)	After weaning (N=2319 child days)
From traditional bread		
Vitamin A	38.0	2.7
Vitamin C	1.9	0.5
Thiamin	9.8	2.7
Riboflavin	33.7	14.6
Niacin	4.7	2.6
Vitamin B-6	38.7	7.0
Pantothenic acid	37.5	7.3
Folate	10.8	2.4
From meat, fish, poultry, egg		
Vitamin A	19.4	74.7
Vitamin C	53.9	65.2
Thiamin	23.3	30.9
Riboflavin	11.8	20.1
Niacin	8.8	27.4
Vitamin B-6	20.6	46.3
Pantothenic acid	9.8	33.7
Folate	37.4	25.7
From dairy products		
Vitamin A	31.3	0.0
Vitamin C	1.2	0.0
Thiamin	10.1	0.6
Riboflavin	0.9	6.4
Niacin	1.7	0.2
Vitamin B-6	7.1	1.4
Pantothenic acid	19.3	1.6
Folate	8.6	1.2

Source: Kirksey, et al. (1992)

Table A.18 Probit for breastfeeding, toddler sample

	Parameter Estimate	Asymptotic t-statistic
Intercept	6.38	2.85
Age	-4.69	-3.77[a]
Female	-0.38	-0.86
Child has birth order equal to one	1.53	1.43
Number of older siblings	-0.19	-0.90
Height-for-age z-score	0.26	1.03
Mother's age	0.08	1.63
Mother's years of education	-0.60	-0.95
Father's years of education	0.01	0.28
Index of socioeconomic status	-0.14	-0.66
N	97	
Number of right predictions	82.0	
Percentage of right predictions	0.85	

Note: [a]-statistically significant at the 0.01 level

Table A.19 Prediction success table

		Actual	
		0	1
	0	69	8
Predicted	1	7	13

Table A.20 Probit for breastfeeding, 18 month old toddlers only

	Parameter Estimate	Asymptotic t-statistic
Intercept	-0.34	-0.25
Female	-0.18	-0.38
Child has birth order equal to one	6.16	0.01
Number of older siblings	-0.06	-0.28
Height-for-age z-score	0.27	1.05
Mother's age	0.04	0.73
Mother's years of education	-0.57	-0.88
Father's years of education	-0.03	-0.58
Index of socioeconomic status	0.09	0.39
N	39	
Number of right predictions	26	
Percentage of right predictions	0.67	

Table A.21 Prediction success table

		Actual	
		0	1
	0	13	7
Predicted	1	6	13

APPENDIX B: FIRST-STAGE REGRESSIONS

Table B.1 First-stage regression for breastfeeding, toddler sample

	Parameter Estimate	t-statistic
Intercept	6.05	3.01[a]
Age	-3.76	-2.73[a]
Age squared	0.78	2.26[b]
Child is female	-0.26	-0.56
Birth order	-0.02	-0.40
Child is female*Birth order	-0.01	-0.13
Child is female*Age	0.13	0.58
Father's years of education	-0.00	-0.07
Father completed primary	0.06	0.40
Father's age	-0.00	-0.62
Father's height	-0.01	-1.05
Mother's height missing	-0.37	-0.29
Mother had some education	-0.06	-0.15
Mother's years of education	0.00	0.02
Mother's age	0.01	1.03
Mother's height	-0.00	-0.25
Father's height missing	1.40	-1.21
Household owned no land	0.09	0.75
Amount of land owned	0.00	0.05
House had glass windows	-0.07	-0.74
House had its own water supply	-0.00	-0.02
Primary water supplied by private pump	-0.04	-0.29
House had room for visitors	-0.04	-0.37
Number of rooms in house	-0.04	-1.38
House had separate kitchen	0.02	0.16
Index of socioeconomic status	0.01	0.20
R-squared	0.49	
F-statistic	2.74[a]	
N	97	

Note: [a]-statistically significant at the 0.01 level
[b]-statistically significant at the 0.05 level

Table B.2 First-stage regression for *available* protein to energy ratio, toddler sample

	Parameter Estimate	t-statistic
Intercept	0.25	0.01
Age	-13.51	-0.85
Age squared	4.39	1.09
Child is female	-3.24	-0.61
Birth order	-0.42	-0.75
Child is female*Birth order	0.72	1.22
Child is female*Age	-0.03	-0.01
Father's years of education	-0.00	-0.01
Father completed primary	-0.23	-0.13
Father's age	0.06	0.67
Father's height	0.07	0.90
Mother's height missing	7.40	0.50
Mother had some education	-1.64	-0.34
Mother's years of education	-0.05	-0.06
Mother's age	-0.02	-0.15
Mother's height	0.06	0.64
Father's height missing	10.84	0.81
Household owned no land	-0.00	-0.00
Amount of land owned	-0.01	-0.29
House had glass windows	1.39	1.19
House had its own water supply	-0.46	-0.36
Primary water supplied by private pump	0.83	0.52
House had room for visitors	1.27	0.99
Number of rooms in house	-0.06	-0.19
House had separate kitchen	-0.00	-0.00
Index of socioeconomic status	-0.57	-0.99
R-squared	0.26	
F-statistic	1.00	
N	97	

Table B.3 First-stage regression for protein to energy ratio, toddler sample

	Parameter Estimate	t-statistic
Intercept	0.12	0.01
Age	-12.28	-0.91
Age squared	3.88	1.14
Child is female	-2.32	-0.52
Birth order	-0.26	-0.54
Child is female*Birth order	0.47	0.93
Child is female*Age	-0.03	-0.01
Father's years of education	-0.01	-0.04
Father completed primary	0.14	0.09
Father's age	0.06	0.80
Father's height	0.06	0.86
Mother's height missing	11.21	0.90
Mother had some education	-3.31	-0.82
Mother's years of education	0.30	0.40
Mother's age	-0.02	-0.17
Mother's height	0.08	0.97
Father's height missing	9.20	0.81
Household owned no land	-0.58	-0.48
Amount of land owned	-0.03	-0.72
House had glass windows	1.40	1.42
House had its own water supply	-0.47	-0.44
Primary water supplied by private pump	0.60	0.44
House had room for visitors	1.00	0.92
Number of rooms in house	0.01	0.04
House had separate kitchen	0.18	0.16
Index of socioeconomic status	-0.54	-1.09
R-squared	0.27	
F-statistic	1.05	
N	97	

Table B.4 First-stage regression for available iron, toddler sample

	Parameter Estimate	t-statistic
Intercept	-4.25	-2.21[b]
Age	1.34	1.01
Age squared	-0.22	-0.67
Child is female	-0.13	-0.29
Birth order	-0.05	-1.15
Child is female*Birth order	0.10	2.02[b]
Child is female*Age	-0.15	-0.70
Father's years of education	0.00	0.02
Father completed primary	-0.02	-0.16
Father's age	0.02	2.38[b]
Father's height	0.01	1.54
Mother's height missing	0.71	0.59
Mother had some education	0.27	0.69
Mother's years of education	-0.06	-0.85
Mother's age	-0.01	-1.42
Mother's height	0.01	0.82
Father's height missing	1.64	1.45
Household owned no land	0.21	1.74[c]
Amount of land owned	0.01	1.89[c]
House had glass windows	0.16	1.69[c]
House had its own water supply	-0.14	-1.30
Primary water supplied by private pump	-0.19	-1.41
House had room for visitors	-0.11	-1.00
Number of rooms in house	0.03	1.17
House had separate kitchen	0.10	0.87
Index of socioeconomic status	0.04	0.80
R-squared	0.36	
F-statistic	1.61[c]	
N	97	

Note: [b]-statistically significant at the 0.05 level
[c]-statistically significant at the 0.10 level

Table B.5 First-stage regression for iron, toddler sample

	Parameter Estimate	t-statistic
Intercept	-51.26	-3.21[a]
Age	28.65	2.62[a]
Age squared	-6.48	-2.36[b]
Child is female	-2.52	-0.69
Birth order	-0.06	-0.15
Child is female*Birth order	1.32	3.27[a]
Child is female*Age	-1.38	-0.80
Father's years of education	0.11	0.90
Father completed primary	-1.19	-0.97
Father's age	0.04	0.65
Father's height	0.06	1.13
Mother's height missing	13.09	1.30
Mother had some education	-1.65	-0.51
Mother's years of education	0.19	0.32
Mother's age	-0.07	-0.75
Mother's height	0.10	1.54
Father's height missing	10.25	1.11
Household owned no land	0.01	0.01
Amount of land owned	0.04	1.30
House had glass windows	1.20	1.50
House had its own water supply	-0.75	-0.86
Primary water supplied by private pump	-1.11	-1.01
House had room for visitors	-0.86	-0.98
Number of rooms in house	0.14	0.66
House had separate kitchen	0.69	0.74
Index of socioeconomic status	0.50	1.26
R-squared	0.44	
F-statistic	2.25[a]	
N	97	

Note: [a]-statistically significant at the 0.01 level
[b]-statistically significant at the 0.05 level

Table B.6 First-stage regression for height-for-age z-score, toddler sample

	Parameter Estimate	t-statistic
Intercept	-16.39	-3.11[a]
Age	4.01	1.11
Age squared	-1.12	-1.23
Child is female	-2.15	-1.80[c]
Birth order	-0.04	-0.29
Child is female*Birth order	0.18	1.37
Child is female*Age	0.73	1.27
Father's years of education	0.01	0.34
Father completed primary	0.15	0.38
Father's age	0.04	1.76[c]
Father's height	-0.00	-0.14
Mother's height missing	10.05	3.03[a]
Mother had some education	-0.48	-0.45
Mother's years of education	0.01	0.04
Mother's age	-0.03	-0.97
Mother's height	0.07	3.23[a]
Father's height missing	-0.84	-0.28
Household owned no land	0.28	0.87
Amount of land owned	-0.02	-1.44
House had glass windows	-0.09	-0.33
House had its own water supply	-0.03	-0.09
Primary water supplied by private pump	0.10	0.28
House had room for visitors	0.35	1.21
Number of rooms in house	-0.02	-0.31
House had separate kitchen	0.00	0.00
Index of socioeconomic status	0.27	2.07[b]
R-squared	0.39	
F-statistic	1.78[b]	
N	97	

Note: [a]-statistically significant at the 0.01 level
[b]-statistically significant at the 0.05 level
[c]-statistically significant at the 0.10 level

Table B.7 First-stage regression for *available* protein to energy ratio, schooler sample

	Parameter Estimate	t-statistic
Intercept	21.11	0.73
Age	0.18	0.03
Age squared	0.03	0.07
Child is female	-0.51	-0.08
Birth order	0.47	1.15
Child is female*Birth order	0.14	0.31
Child is female*Age	-0.06	-0.08
Father's years of education	0.19	1.49
Father completed primary	-0.37	-0.37
Father's age	-0.09	-1.60
Father's height	-0.05	-1.04
Mother's height missing	7.57	0.80
Mother had some education	-2.70	-1.16
Mother's years of education	0.54	1.40
Mother's age	-0.10	-1.21
Mother's height	0.04	0.61
Father's height missing	-10.38	-1.20
Household owned no land	-2.23	-2.43[b]
Amount of land owned	-0.01	-0.41
House had glass windows	0.40	0.58
House had its own water supply	1.22	1.52
Primary water supplied by private pump	1.00	0.92
House had room for visitors	-0.59	-0.81
Number of rooms in house	-0.59	-2.63[a]
House had separate kitchen	1.01	1.35
Child's height missing	0.35	0.31
Index of socioeconomic status	-0.13	-0.35
Month during school year test was taken	-0.03	-0.31
Month test was taken	-0.07	-0.90
R-squared	0.32	
F-statistic	1.41	
N	111	

Note: [a]-statistically significant at the 0.01 level
[b]-statistically significant at the 0.05 level

Table B.8 First-stage regression for protein to energy ratio, schooler sample

	Parameter Estimate	t-statistic
Intercept	23.15	0.92
Age	0.22	0.04
Age squared	0.02	0.07
Child is female	-0.77	-0.14
Birth order	0.49	1.35
Child is female*Birth order	0.03	0.08
Child is female*Age	-0.00	-0.01
Father's years of education	0.17	1.57
Father completed primary	-0.15	-0.17
Father's age	-0.08	-1.64
Father's height	-0.05	-1.19
Mother's height missing	4.96	0.60
Mother has education	-2.26	-1.11
Mother's years of education	0.42	1.23
Mother's age	-0.09	-1.23
Mother's height	0.02	0.45
Father's height missing	-10.08	-1.33
Household owns no land	-1.99	-2.48[b]
Amount of land owned	-0.01	-0.36
House had glass windows	0.31	0.51
House had its own water supply	0.93	1.32
Primary water supplied by private pump	0.83	0.87
House had room for visitors	-0.47	-0.73
Number of rooms in house	-0.55	-2.84[a]
House had separate kitchen	0.62	0.94
Child's height missing	0.31	0.31
Index of socioeconomic status	-0.13	-0.41
Month during school year test was taken	-0.03	-0.41
Month test was taken	-0.06	-0.98
R-squared	0.34	
F-statistic	1.48[c]	
N	111	

Note: [a]-statistically significant at the 0.01 level
[b]-statistically significant at the 0.05 level
[c]-statistically significant at the 0.10 level

Table B.9 First-stage regression for *available* iron, schooler sample

	Parameter Estimate	t-statistic
Intercept	4.05	0.35
Age	-0.47	-0.18
Age squared	0.03	0.18
Child is female	-0.91	-0.36
Birth order	0.07	0.44
Child is female*Birth order	0.04	0.21
Child is female*Age	0.08	0.27
Father's years of education	0.07	1.42
Father completed primary	-0.47	-1.16
Father's age	-0.03	-1.14
Father's height	-0.04	-1.80[c]
Mother's height missing	6.01	1.56
Mother had some education	0.40	0.42
Mother's years of education	-0.03	-0.17
Mother's age	0.03	0.94
Mother's height	0.04	1.44
Father's height missing	-6.54	-1.86[c]
Household owned no land	-0.40	-1.06
Amount of land owned	-0.01	-0.85
House had glass windows	0.31	1.09
House had its own water supply	0.47	1.43
Primary water supplied by private pump	0.32	0.73
House had room for visitors	-0.28	-0.92
Number of rooms in house	-0.09	-0.96
House had separate kitchen	0.39	1.30
Child's height missing	-0.17	-0.37
Index of socioeconomic status	0.05	0.36
Month during school year test was taken	-0.01	-0.31
Month test was taken	-0.05	-1.61
R-squared	0.25	
F-statistic	0.99	
N	111	

Note: [c]-statistically significant at the 0.10 level

Table B.10 First-stage regression for iron, schooler sample

	Parameter Estimate	t-statistic
Intercept	38.10	0.52
Age	-5.72	-0.34
Age squared	0.34	0.33
Child is female	-9.81	-0.61
Birth order	0.03	0.03
Child is female*Birth order	0.24	0.21
Child is female*Age	0.92	0.47
Father's years of education	0.28	0.86
Father completed primary	-1.31	-0.51
Father's age	-0.12	-0.85
Father's height	-0.20	-1.48
Mother's height missing	37.54	1.54
Mother had some education	3.77	0.63
Mother's years of education	-0.54	-0.54
Mother's age	0.19	0.86
Mother's height	0.23	1.47
Father's height missing	-33.85	-1.53
Household owned no land	-3.56	-1.51
Amount of land owned	-0.05	-0.65
House had glass windows	2.37	1.33
House had its own water supply	2.65	1.29
Primary water supplied by private pump	1.06	0.38
House had room for visitors	-1.05	-0.56
Number of rooms in house	-0.64	-1.12
House had separate kitchen	1.06	0.56
Child's height missing	-1.58	-0.54
Index of socioeconomic status	-0.22	-0.23
Month during school year test was taken	-0.03	-0.13
Month test was taken	-0.26	-1.40
R-squared	0.19	
F-statistic	0.70	
N	111	

Table B.11 First-stage regression for height-for-age z-score, schooler sample

	Parameter Estimate	t-statistic
Intercept	-12.17	-1.23
Age	-1.04	-0.48
Age squared	0.05	0.41
Child is female	-0.42	-0.20
Birth order	-0.04	-0.28
Child is female*Birth order	-0.07	-0.49
Child is female*Age	0.07	0.30
Father's years of education	-0.09	-2.24[b]
Father completed primary	0.56	1.69[c]
Father's age	-0.01	-0.76
Father's height	0.04	2.40[b]
Mother's height missing	8.04	2.57[a]
Mother had some education	-0.86	-1.12
Mother's years of education	0.09	0.69
Mother's age	0.04	1.31
Mother's height	0.05	2.59[a]
Father's height missing	6.81	2.38[b]
Household owned no land	0.36	1.20
Amount of land owned	0.00	0.03
House had glass windows	-0.19	-0.84
House had its own water supply	-0.08	-0.30
Primary water supplied by private pump	-0.21	-0.60
House had room for visitors	0.51	2.11[b]
Number of rooms in house	-0.01	-0.17
House had separate kitchen	0.27	1.08
Child's height missing	1.05	2.80[a]
Index of socioeconomic status	-0.06	-0.47
Month during school year test was taken	0.05	1.60
Month test was taken	0.01	0.56
R-squared	0.42	
F-statistic	2.14[a]	
N	111	

Note: [a]-statistically significant at the 0.01 level
[b]-statistically significant at the 0.05 level
[c]-statistically significant at the 0.10 level

Table B.12 First-stage regression for height-for-age z-score squared, schooler sample

	Parameter Estimate	t-statistic
Intercept	39.07	1.50
Age	-0.61	-0.10
Age squared	0.08	0.23
Child is female	4.42	0.78
Birth order	0.08	0.22
Child is female*Birth order	0.17	0.44
Child is female*Age	-0.65	-0.95
Father's years of education	0.16	1.43
Father completed primary	1.44	-1.59
Father's age	0.06	1.20
Father's height	-0.12	-2.57[a]
Mother's height missing	-15.06	-1.76[c]
Mother had some education	1.09	0.52
Mother's years of education	-0.09	-0.26
Mother's age	-0.13	-1.64
Mother's height	-0.10	-1.74[c]
Father's height missing	-20.31	-2.60[a]
Household owned no land	-0.81	-0.98
Amount of land owned	0.01	0.37
House had glass windows	0.02	0.04
House had its own water supply	-0.21	-0.29
Primary water supplied by private pump	0.38	0.39
House had room for visitors	-1.01	-1.52
Number of rooms in house	-0.05	-0.27
House had separate kitchen	0.18	0.27
Child's height missing	-2.06	-2.01[b]
Index of socioeconomic status	0.21	0.64
Month during school year test was taken	-0.10	-1.19
Month test was taken	0.04	0.61
R-squared	0.36	
F-statistic	1.62[b]	
N	111	

Note: [a]-statistically significant at the 0.01 level
[b]-statistically significant at the 0.05 level
[c]-statistically significant at the 0.10 level

Table B.13 First-stage regression for child's years of education, schooler sample

	Parameter Estimate	t-statistic
Intercept	-15.63	-1.99[b]
Age	3.59	2.01[b]
Age squared	-0.17	-1.52
Child is female	1.69	0.98
Birth order	0.03	0.23
Child is female*Birth order	-0.10	-0.84
Child is female*Age	-0.22	-1.06
Father's years of education	0.02	0.62
Father completed primary	0.00	0.01
Father's age	-0.00	-0.18
Father's height	-0.06	-0.40
Mother's height missing	1.62	0.63
Mother had some education	-0.03	-0.04
Mother's years of education	0.03	0.30
Mother's age	-0.01	-0.51
Mother's height	0.01	0.82
Father's height missing	-0.99	-0.42
Household owned no land	-0.34	-1.34
Amount of land owned	-0.01	-1.50
House had glass windows	-0.29	-1.54
House had its own water supply	0.46	2.09[b]
Primary water supplied by private pump	0.17	0.58
House had room for visitors	0.06	0.31
Number of rooms in house	-0.07	-1.11
House had separate kitchen	-0.06	-0.27
Child's height missing	0.54	1.74[c]
Index of socioeconomic status	0.10	0.94
Month during school year test was taken	-0.07	-2.85[a]
Month test was taken	-0.02	-1.21
R-squared	0.60	
F-statistic	4.35[a]	
N	111	

Note: [a]-statistically significant at the 0.01 level
[b]-statistically significant at the 0.05 level
[c]-statistically significant at the 0.10 level

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