Económica, La Plata, Vol. LIV, Nro. 1-2, 2008

HIGH QUALITY NUTRITION IN CHILDHOOD, BODY SIZE AND WAGES IN EARLY ADULTHOOD: EVIDENCE FROM GUATEMALAN WORKERS

MARIA CECILIA CALDERON

RESUMEN

Clasificación JEL: J24, I12

Causalidad entre salud y productividad no resulta directa de establecer. Por un lado, mayores ingresos pueden trasladarse en una dieta de mejor calidad. Por el otro, es probable que un trabajador saludable sea más productivo. Este trabajo analiza el efecto del tamaño corporal, altura e índice de masa corporal como indicadores de nutrición, en salarios. Los datos provienen del estudio longitudinal realizado en Guatemala entre 1969-77 y 2002-04. Estimaciones sugieren que la elasticidad tamaño del cuerpo en relación al salario aumenta cuando la heterogeneidad no observable es considerada, sin embargo, los resultados son más robustos para los hombres. Adicionalmente, la elasticidad estimada presenta algún grado de disparidad entre quantiles de la distribución condicional del salario.

Palabras clave: Salud, Altura, BMI, Salarios, Guatemala, Quantil.

ABSTRACT

JEL Classification: J24, I12

Establishing a causal relationship between health and productivity is not straightforward. On one hand, as income grows, people invest in better diets. On the other, a healthier worker is likely to be more productive. This paper focuses on the effect of body size, height and body mass index as indicators of nutrition, upon wages. Data comes from a longitudinal study conducted in Guatemala during 1969-77 and followed-up in 2002-04. Body size elasticity increases when unobserved heterogeneity is considered although evidence is stronger for males. Additionally, estimated elasticity shows some degree of heterogeneity at different quantiles of the conditional wage distribution.

Keywords: Health, Height, BMI, Wages, Guatemala, Quantile.

HIGH QUALITY NUTRITION IN CHILDHOOD, BODY SIZE AND WAGES IN EARLY ADULTHOOD: EVIDENCE FROM GUATEMALAN WORKERS

MARIA CECILIA CALDERON[1]

I. Introduction

Guatemala is the only country in Latin America and the Caribbean region that shows an underweight prevalence of more then 20% and the largest stunting rate, 46.4%. Vitamin A deficiency, iron deficiency anemia and iodine deficiency disorders are also a serious concern, with prevalence rates of 21%, 34% and 16%, respectively (World Bank, 2006). However, stunted children and over-weight mothers coexist.

This research attempts to explore the link between nutrition and productivity within the context of a developing country, Guatemala. The aim is to establish the causal effect of adult body size, in the form of height and body mass index[2] (BMI) elasticity, upon current wage rates and annual earnings using data collected in four poor Guatemalan villages, settings where returns to physical strength and energy may be substantial.

It is intuitively appealing to believe that better nourished individuals are more productive. Furthermore, the structure of employment in lower income economies is such that work often relies more heavily on physical

[1] Maria Cecilia Calderon, Population Studies Center, University of Pennsylvania, Philadelphia, PA. E-mail: cmaria@sas.upenn.edu. Paper presented at the Annual Meeting of the Population Association of America, March 29-31, 2007, New York, NY. This paper has benefited from the valuable comments of Jere Behrman, Sebastian Galiani, John Hoddinott, Hans-Peter Kohler, Scott McNiven, John Maluccio, Reynaldo Martorell, Manuel Ramirez, Erica Soler-Hampejsek, and Aryeh Stein. The usual disclaimers apply. This research was conducted with support from the NIH/Fogarty grant TW-05598 on "Early Nutrition, Human Capital and Economic Productivity," NSF/Economics grants SES 0136616 and SES 0211404 on "Collaborative Research: Nutritional Investments in Children, Adult Human Capital and Adult Productivities," NIH grant HD046125 on "Education and Health over the Life Course in Guatemala," R01 HD045627-01 grant on "Resource Flows Among Three Generations in Guatemala," NIH/NIA grant P30 AG12836 to PARC at the University of Pennsylvania, the Boettner Center for Pensions and Retirement Security at the University of Pennsylvania and the Mellon Foundation grant to the Population Studies Center of the University of Pennsylvania.

[2] BMI is defined as the ratio between weight (in kilograms) and height (in meters) squared.

characteristics such as strength and stamina, and therefore, on good health. However, the nutrition-productivity link is complex to establish. Although it is natural to assume that improved nutritional status leads to increased productivity; it is equally plausible that increased productivity leads to higher income which, in turn, improves nutritional status. This feedback between nutrition and productivity suggests that the labor market consequences of poor health are likely to be more serious for the poor who are more likely to suffer from severe health problems and to be working in jobs for which strength has a payoff.

The relationship between health and market outcomes has been controversial and much less explored in comparison with returns to schooling. Although the link between nutrition and labor productivity has played a key role in theories of economic development through the idea of efficiency wages, former empirical studies on this subject have typically concluded that there is little reliable evidence. Thomas and Strauss (1997) pointed out that this lack of reliability emerges from two causes: (1) the small number of studies on the matter reflects the fact that health indicators have rarely been collected in surveys that contain measures of wages or productivity; and (2) there is a non-trivial interpretation of correlations between health and labor outcomes; early studies have paid little or no attention to the direction of causality. Thus, these studies ignored the fact that any component of income, such as wages and labor supply, may affect current behavior which, in turn, affects health through the consumption of an improved quality diet, and vice versa.

Moreover, Leibenstein (1957) hypothesizes that, relative to poorly nourished workers, those who consume more calories are more productive, and that at very low levels of intake, better nutrition is associated with increasingly higher productivity. As well, Strauss and Thomas (1998) argue that such non-concavities lie at the heart of the efficiency wage models. Employers have an incentive to raise wages above the minimum supply price of labor excluding those workers in poorest health from the labor market because they are too costly to hire.

Hoddinott et al. (2008), using data from Guatemalan individuals (aged 25-42 years), seem to be the first ones in assessing the direct effect of an improved nutrition in early childhood on adult incomes, in contrast to the substantial but indirect evidence on this topic. They find that an improved nutrition before, but not after, age 3 years is associated with higher hourly wages, but only for men. For instance, improved nutrition from 0 to 2 years increases hourly wages in US$0.67, which means a 46% increase in average wages. There is a non-significant tendency for hours worked to be reduced and for annual incomes to be greater.

This research attempts to find empirical validation for the positive effect of health, measured by height and BMI, upon labor market outcomes. Furthermore, the main objective is to establish a causal relationship between adult height and BMI and current wage rates and annual earnings using information collected in four poor Guatemalan villages, settings where returns to physical strength and energy may be substantial. Data comes from "The Human Capital 2002-04 Study in Guatemala: A follow up to the INCAP[3] Longitudinal Study 1969-77" in which a cohort of young men and women, who participated as young children in a randomized community trial of nutrition supplementation, were resurveyed 35 years later. In the original study, two randomly selected villages received a nutritional supplement and two other villages received a control drink. The follow-up study conducted during 2002-04 collects current data from the former participants.

Formally, this paper focuses upon the following question: Does improved nutrition during childhood affect adult body size and, subsequently, economic productivity? In other words, how can this research exploit the experiment in the four Guatemalan villages to deal with the endogeneity bias and estimate the causal effect of height and BMI on wage rates and annual earnings? Moreover, returns to body size are estimated at different quantiles of the conditional wage distribution.

The examination of this question in Hoddinott et al. (2008), where the same data is analyzed, differs from the approach in this paper in some ways: Hoddinott et al. (2008) estimate the direct effect of childhood nutrition upon adult labor outcomes using reduced form equations and, thus, linear regressions seem appropriate; alternatively, this paper attempts to estimate the indirect impact of an improved childhood nutrition upon adult body size and the subsequent effect of body size upon adult labor outcomes applying an instrumental variable and quantile regression approach. Due to missing

[3] Institute of Nutrition for Central America and Panama.

information in anthropometric variables, the sample of male and female Guatemalan workers included in this paper is slightly smaller.

Previously, some researchers have been trying to understand the intricate interrelation between health, nutrition and economic productivity dealing with the potential endogeneity issue. Many of the studies in economics have dealt with this bias of simultaneous effects by developing models that predict the nutrition input variables based on exogenous factors such as prices and household demographic variables, in instrumental variable estimates. For instance, Immink and Viteri (1981a, 1981b) find for sugarcane cutters in Guatemala that it was the leisure time that appeared to be most affected by inadequate energy consumption. Men with low energy consumption decreased the energy intensity of their leisure time activities but not the amount of energy expended at work. When the energy intake increased, the men did not increase the supply of units of work but rather become more active in their leisure time. Another example is found in Immink, Viteri and Helms (1982) again for Guatemalan sugarcane cutters.

Additionally, Strauss (1986), using data from Sierra Leone, uses the predicted household energy intake per capita to explain household farm production. The results suggest that household energy consumption was a positive, significant determinant of farm productivity. A similar approach is used by Sahn and Alderman (1988) with data from Sri Lanka. This study employs predicted household energy consumption per capita as the measure of nutritional status and relates it to wage earnings. Surprisingly, household energy per capita appears as a significant, positive determinant of men's but not of women's wages. This differential result between men's and women's productivity is a finding in almost all studies linking nutrition to productivity. Both the Strauss (1986) and Sahn and Alderman (1988) analysis are limited to the use of household energy values as the only measure of individual nutritional condition.

Clearly, a measure of individual nutrient consumption and more importantly an indicator of an individual's nutritional status would have strengthened the analysis. Among other measures of individual nutrition, height and BMI have been widely analyzed in previous research. The best-documented fact in observational studies is that taller people tend to enjoy greater success in labor markets. At the micro level, many studies have demonstrated a positive association of height with hourly earnings. Seminal work by Fogel (1994) has documented secular increases in height which parallel economic growth in the historical literature.

For instance, Deolalikar (1988) explains wage earnings and farm outputs with measures of both individual energy intake and BMI using data from India. The author finds that even though energy intake is not a significant determinant of wages, BMI appears relevant. Also, BMI, but not energy consumption, has a significant, positive effect on farm output.

Furthermore, Thomas and Strauss (1992, 1997) examine the nutrition-productivity link using wage earnings of both employees and the self-employed in urban Brazil. They use four indicators of nutrition as explanatory variables: height, BMI, per capita calorie consumption and per capita protein intakes. Their findings indicate that height is a significant determinant of the wages in urban Brazil: taller men and women earn more even after controlling for education and other dimensions of health. However, BMI is a positive and significant predictor of males' but not for females' wages. These authors suggest that BMI is probably correlated with strength since its effects are largest among the least educated men who are more likely to do manual labor and very physical demanding activities. Also, this research suggests that per capita calorie and protein intake are significantly related to wages but the positive effect of calories disappears rapidly indicating that it may only be the very malnourished for whom energy is a limiting factor for wage earnings. Interestingly, after controlling for height and BMI, calorie intake has diminishing returns; but when protein consumption is added to the model, protein intake has an increasingly effect in wages reflecting the impact of an improved quality diet (measured by the fraction of calories from protein sources). The authors conclude that health (through improved nutrition) provides an important return to labor in Brazil. In addition, Strauss and Thomas (1998) conclude that the positive link between height, BMI and wages is also significant in the US: men who are taller and heavier (given height) earn higher wages.

Moreover, Thomas and Frankenberg (2002a) indicate that even though BMI had no effect on earnings, BMI affected the wages of time-rate workers but not piece-rate workers for adult Indonesian males. They argue that health is difficult to observe and employers use the BMI as a marker for health. As well, these authors find that a 1% increase in height was associated with a 5% increase in earnings, suggesting that taller people are probably stronger, an attribute that is probably highly rewarded in lower-income settings. Also, they argue that height is a proxy for more than just strength and suggest that part of height is influenced by genotype and reflects family backgrounds. Hence, height is largely determined in early childhood and reflects health and human capital investments made by the parents. Therefore, correlation between height and wages will diminish as the model includes other dimensions of human capital: controlling for age and education cuts the elasticity of wages with respect to height in half for Indonesian males.

Recent work by Thomas et al. (2005) provides unambiguous evidence in support of the hypothesis that health has a causal effect on economic prosperity of males during middle and older ages. The research consists of a random assignment design intervention in which Indonesian adults receive a treatment of iron every week for a year. The findings reveals that males who were iron deficient increase their physical and psycho-social health and economic productivity after the treatment. Also, they appear more likely to be working, sleep less, lose less work time to illness and more able to conduct physically arduous activities. Although benefits for women are in the same direction, the effects are more muted.

The evidence reviewed from earlier studies provides mixed results to explain the nutrition-productivity link. In all of them, height is treated as an indicator of long-term nutritional status and appears to be the variable most often associated with productivity. In addition, in most of these studies, height is treated as an exogenous variable. Furthermore, many of the previous studies that explore the nutrition-productivity link are limited to males. And when data is separated by gender, the specific impact of nutrition upon economic output differs among sexes. Consequently, the empirical evidence does not suggest a clear answer for causality in this relationship, particularly in low income countries where attention has been focused on low levels of BMI. However, although obesity is a central concern in some developed countries, certain concerns with obesity are emerging in poor economies.

The next sections are organized as follows. Section II describes the conceptual framework and formally establishes the central purpose of this research. The econometric model is presented in Section III and the experimental data is discussed in IV. The main body of evidence is presented in Section V where structural equations are estimated and also nonparametric relations are presented. Section VI summarizes the findings and discusses what conclusions can be made from this work. It also explains limitations to the analysis and some possible further extensions. A detailed description of the variables can be found in Section VII.

II. Conceptual framework

The aim of this research is to estimate the impact of body size, height and BMI, on labor wage rates for a sample of Guatemalan workers aged 25-42. Consider a typical wage production function, conditional on health and other individual factors:

$$\ln(wage_i) = f(h_i, x_i, \varepsilon_i) \qquad i=1,\ldots,n \qquad (1)$$

where $\ln(wage_i)$ denotes the natural logarithm of current hourly wage for worker i; **h** stands for a vector of individual health indicators, current height and BMI; **x** denotes other individual characteristics such as education, age, age squared, and villages; and ε is an unobserved error term. In fact, only wages for those individuals who work in the labor market can be observed; thus, selectivity into labor force, especially for women, can potentially bias the estimates. Thus, the model is estimated separately for males and females in an attempt to determine gender specific parameters and significance.

The vector of health characteristics, **h**, captures a dimension of health measured, using standard methods, by two anthropometric indicators: height and BMI. While these variables can be considered as less subjective and, thus, more reliable, other studies, such as Thomas and Frankenberg (2002b), use self-reported anthropometric measures. These authors show that males tend to overstate their height and that above age 50 the overstatements increases with age. Apparently, as men shrink with age, they do not update their height. On the contrary, they do not find a significant level of overstatement in female's height. Interestingly, they also show that while men overstate their height, females overstate their weight.

A key point in this study is that adult BMI and height appear as outputs of the quality of nutrition during childhood and, a priori, both could be treated as endogenous variables. It is unambiguously arguable that adult height is predetermined; however, this characteristic does not imply strictly exogeneity. Height is a cumulative measure reflecting both investments in nutrition during one's life, mostly as a child, and probably infectious disease experience. In the context of a developing country, the usual assumption in previous literature is that adult height represents long-run nutritional status, determined in substantial part during early childhood. Given this assumption, this literature considers height as statistically predetermined, rather than the output of dynamic investments that individuals make in the presence of persistent genetic and other endowments, as Behrman, Hoddinott and Maluccio (2005) argue. The former treatment seems unconvincing in light of the vast evidence on the effect of persistent unobserved characteristics such as genetic endowments. For instance, Behrman and Rosenzweig (1999, 2002, 2004, 2005); Behrman, Rosenzweig and Taubman (1994, 1996); Pitt, Rosenzweig and Hassan (1990); Rosenzweig and Schultz (1985, 1987); and Rosenzweig and Wolpin (1995) find that these unobserved characteristics are relevant. Thus, if these unobservable factors are correlated with the observed characteristics, returns to height may be biased since they may confound effects arising from both the observed height and the long-run genetic endowments. Therefore, this paper proceeds without assuming that height is exogenous and, subsequently, performs an empirical test for whether or not height can actually be treated as exogenous.

BMI is calculated from a person’s weight and height but does not measure body fat directly. However, the US Centers for Disease Control and Prevention (Department of Health and Human Service) suggest that it is a reliable indicator of body fatness for people. Thus, BMI can be considered an alternative for direct measures of body fat since it is an inexpensive and easy-to-perform method of screening for weight categories that may lead to health problems. Furthermore, BMI is thought to be correlated with physical capacity and extremes values of BMI have been shown to be related to elevated morbidity and mortality (Thomas and Frankenberg, 2002b). Generally, BMI is suitable for recognizing trends within sedentary or overweight individuals because there is a smaller margin for errors. However, BMI categories do not take into account factors such as frame size and muscularity and the categories do not distinguish what proportions of a human body's weight are muscle, fat, bone and cartilage, or water weight. Despite this, equations that included BMI, sex and age were shown to predict body fat percentage relatively accurate (Deurenberg et al., 1991). The World Health Organization (WHO) has been using BMI as the standard for recording obesity statistics and developed the following classification that is age-independent and the same for both sexes[4]:

[4] http://www.who.int/bmi/index.jsp

Table 1

International classification of adult underweight, overweight and obesity according to BMI.

Classification	BMI(kg/m^2) Principal cut-off points
Underweight	<18.5
Severe thinness	<16
Moderate thinness	16 - 16.99
Mild thinness	17 - 18.49
Normal range	18.5 - 24.99
Overweight	≥25
Pre-obese	25 - 29.99
Obese	≥30
Obese class I	30 - 34-99
Obese class II	35 - 39.99
Obese class III	≥40

In fact, BMI depends on the net energy intake and, thus, varies through the life course. It captures both long and short term dimensions of nutrition and it is related to aerobic capacity and endurance, independent of energy intake. On the one hand, current BMI may be affected by contemporaneous movements in income or prices; on the other hand, current BMI partly reflects previous health investments. In other words, while better health may result in a worker being more productive, higher income may be spent on improving one's health: this bidirectional relation, or reverse causality, is one of the key aspects in this study. Thus, this potential correlation between health indicators and the unobserved error term cannot be ignored to obtain consistent estimations.

In addition, the vector **x** in equation (1) includes schooling attainment, age, age squared and dummy villages. Even though schooling is not a dimension of health, it is, as well as nutrition, a human capital investment and it is highly related to well-being since it can be seen as a channel through which early nutrition affects current wages.

The unobserved error term in (1) includes genetic endowments that can neither be observed nor measured. If these genetic endowments simultaneously affect body size indicators and wage rates, then an OLS estimator of the impact of height and BMI on productivity would be inconsistent. Therefore, this research assumes that health, in the form of body size indicators, and genetic endowments interact in a non-trivial, unknown way. On one hand, if genetic endowments and health are substitutes in the generation of human capital, then the marginal returns to the accumulation of human capital might be expected to decrease with endowments and hence, health contributes relative more to low endowed individuals. In this case, an estimate that ignores the endogeneity bias would be underestimated. On the other hand, if endowments and health are complements in the generation of human capital, then health has an additional indirect effect on human capital (through the interaction with endowments) that increases its otherwise constant contribution to earnings. In this case, returns would then be higher for the better endowed and any estimate that ignores the endogeneity bias would be overestimated.

A priori, the interaction between health and endowments is unknown and this paper proceeds without observing genetic endowments. Hence, it is not possible to model the relationship between genetic endowments and height and BMI explicitly by including additional regressors. Moreover, the key assumption is that health is not randomly assigned to individuals and thus, body size, a proxy for health, cannot be assumed to be as exogenous.

Consequently, the implementation of an instrumental variable estimator isolates the effect of body size on hourly wages, as in Thomas and Strauss (1997). Even though these authors treat BMI as endogenous, they assume that height is strictly exogenous and hence, do not perform any empirical endogeneity test. The arguments previously discussed, however, suggest that height is a potentially endogenous variable. Hence, this paper moves forward and tests for whether or not this argument can be empirically validated.

III. Methods

This paper aims at consistently estimating the effects of height and BMI on hourly wages in a quantile regression framework, obtaining unbiased estimates at different quantiles of the conditional wage distribution. This strategy requires a set of instruments that are assumed to be correlated with observed body size but not with unobserved characteristics, such as genetic endowments, that affect wages, height and BMI simultaneously. The method proceeds as follows.

A. Consistent estimator

The arguments exposed in Section II suggest the use of an instrumental variable (IV) estimator with the purpose of isolating the causal effect of body size on hourly wages, an indicator of labor productivity. Variables correlated with body size but, at the same time, uncorrelated with the unobserved error term in (1) can serve as valid instruments. Thus, exogenous variables used as instruments in this paper come from the randomized experiment conducted during 1969-77 in four Guatemalan villages[5] and are defined as three dummy variables that characterize exposure cohort to the supplemental drink, four dummy variables that measure distance to the supplementation center and two current food prices that vary by community and year.

Current height and BMI are associated with the quality of nutrition during childhood and, thus, it is rational to assume that these instruments have a direct effect upon adult body size but do not affect current wages except through their impact upon the body size indicators. Such assumption seems realistic considering that employers may not directly observe the nutritional status of the workers but instead observe their current body size, height and BMI, which is the result of past nutritional investments, and pay wages according to it. In other words, the estimation strategy assumes that individuals who were exposed to the nutritional supplement, those who lived in the experimental villages, are currently better nourished, an attribute reflected in their height and BMI (Rivera et al. 1995, Habicht et al. 1995, Corvalan et al. 2007), and, thus, more productive.

B. Heterogeneity in marginal effects

A mean regression, whether instrumented or not, only estimates the effects of health on average wages. This model might be incomplete because it ignores the estimates at other parts of the conditional, on the observed

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[5] See Section IV for a more detailed description of the data.

characteristics, wage distribution. Thus, this paper aims at estimating the effects of height and BMI at different quantiles of the conditional distribution of earnings. For instance, the impact of height at the 10% conditional quantile may be significantly different from the impact of height at the 90% conditional quantile, implying heterogeneity in the height premium. A quantile regression approach (Koenker and Basset, 1978; Koenker and Hallock, 2001) may provide very interesting results when estimating the relationship between height, BMI and productivity. Consequently, in order to obtain a widespread picture of how height and BMI impact different quantiles of the conditional wage distribution, model (1) is estimated using a quantile regression (QR) approach. See Section III.C.1 for a formal description of this technique.

C. Combining Instrumental variables (IV) and Quantile regression (QR)

Two-step quantile regression estimates yield a family of quantile estimators while simultaneously correct the endogeneity bias. Amemiya (1982) first proposed this method[6], followed by Powell (1983) and Chen and Portnoy (1996), who extended the first established properties of this consistent estimator.

To sum up, this research pursues two main goals: (1) give a widespread picture of the effect of body size on productivity over the entire conditional wage distribution, not only on the mean; and (2) obtain consistent estimates of such impacts. Thus, this paper combines both purposes through the use of two-step quantile regression (IV-QR) contributing, in this way, to the literature on this topic; further details are given in Section III.C.2. For instance, Arias et al. (2001) apply this technique to consistently estimate returns to schooling.

1. Quantile regression

A quantile estimation can be defined as in Koenker and Basset (1978) and Koenker and Hallock (2001) as the solution to the problem of minimizing a weighted sum of absolute residuals. The τ-quantile in a sample of n observations $\{y_1, \dots, y_N\}$ can be computed by

$$\min_{\xi \in \Re^p} \sum_{i=1}^{n} \rho_\tau (y_i - \xi) = \sum_{i=1}^{n} [\tau I(y_i > \xi) + (1-\tau) I(y_i < \xi)] |y_i - \xi| \qquad (2)$$

[6] Amemiya called the technique 'Two Stage Least Absolute Deviations Estimators' (2SLAD).

where I denotes the indicator function that takes a value of one if the event is true and zero otherwise. Consequently, the conditional linear quantile of Y is estimated by replacing ξ by $x'_i\beta$, where β are the coefficients for the τ^{th} quantile and x_i is a matrix of *p* explanatory variables, and solve

$$\min_{\beta \in \Re^p} \sum_{i=1}^{n} \rho_\tau (y_i - x'_i \beta) \qquad (3)$$

The resulting regression fit $x'_i \beta$ describes the τth quantile of the response variable y_i (the wage of worker i) given the vector of characteristics x_i (height, BMI, years of schooling, age). Thus, the solution to the linear problem above yields a vector of p estimated coefficients for each quantile τ, and β can be seen as $\beta(\tau)$. The full sample of n observations is used in the estimation of each quantile and there is no loss in estimating as many quantiles as desired. Consequently, quantile regression is more general than a simple mean regression, and is extremely powerful when the $\beta(\tau)$ coefficients differ significantly across quantiles, suggesting that the marginal effect of a particular variable, returns to body size in this paper, is not homogeneous across τ's.

2. Two-step quantile regression

Quantile regressions on a wage equation like (1) yield inconsistent estimates of the returns to body size in the same way OLS delivers an inconsistent estimate of the mean return if explanatory variables are correlated with the unobserved error term. The previous section recognizes the existence of unobservable factors, such as genetic endowments, ability and unobservable background characteristics and family effects, that will be correlated with the observed regressors, body size indicators, making the causal interpretation difficult, as pointed out in Behrman, Hoddinott and Maluccio (2005) and Thomas and Strauss (1997). As already mentioned, this endogeneity bias can be corrected adopting an instrumental variable approach in the quantile regression framework.

Consider the following structural model:

$$Y = X_1\gamma + X_2\beta + \varepsilon \qquad (4)$$

where Y is the response variable, X_1 is a matrix of k_1 endogenous variables correlated with the error term ε, such as health, X_2 is a matrix of k_2 exogenous regressors, such as age, and γ and β are vectors of associated coefficients respectively.

Collecting a set of z instruments in the matrix Z, quantile regression is combined with the classical instrumental variable approach to consistently estimate heterogeneity across quantiles of the conditional wage distribution. The method proceeds in two steps. The first stage projects each endogenous variable contained in X_1 on the space spanned by the instruments, included in Z, and by the exogenous variables, included in X_2, which are, by assumption, uncorrelated with the error term. Thus, the first step is a typical OLS regression of the endogenous variables on the instruments. The second stage performs quantile regressions of the dependent variable on the fitted values from the first step, $\hat{X}_1$, and on the exogenous variables, X_2.

The reduced form equations for Y and X_1 corresponding to model (4) are as follows:

$$Y = X\Pi + V \tag{5}$$

$$X_1 = X\Pi_1 + v \tag{6}$$

where $X = [X_2, Z]$ is a n x (k_2+z) matrix grouping all the exogenous variables, and V and v are independent and identically distributed error terms. The reduced form equation (5) gives an estimate the effects of the instruments (and the exogenous variables in X_2) on the response variable Y. The reduced form equation (6) shows the effect of the exogenous variables (X_2 and Z) on the endogenous variables (X_1). The asymptotic properties of this two-step quantile regression estimator were proved by Powell (1983), Chen (1988), and Chen and Portnoy (1996).

In this framework, equation (5) represents the effect of an improved nutrition during childhood, and family and community backgrounds on wage rates. Analogously, equation (6) represents the effect of an improved nutrition and family and community backgrounds on body size indicators. As mentioned earlier, estimates of the reduced form equation (5) are provided in Hoddinott et al. (2008); estimates of equation (6) can be found in Rivera et al. (1995), Habicht et al. (1995), and Corvalan et al. (2007).

IV. Data

This paper uses a longitudinal data set collected over a 35 year period in four poor Guatemalan villages by the Institute of Nutrition for Central America and Panama (INCAP). A more complete report and further details can be found in see Grajeda et al. (2005), Hoddinott, Behrman and Martorell (2005), Maluccio, et al. (2005a), Martorell et al. (2005) and Stein et al. (2005).

During 2002-04, a team of researchers undertook a follow-up data collection on the participants in a randomized trial intervention during the period 1969-77. The original INCAP Longitudinal Study was recorded for children 7 years or younger, so the year of birth for the participants ranges from 1962 to 1977, implying that these participants were 0 to 15 years old. The length and timing of exposure to the nutritional interventions for particular children depended on their respective birth dates. For example, only children born after 1969 and before February 1974 were exposed to the nutritional intervention for all of the time they were from 0 to 36 months of age, which often is posited to be a critical time period for child growth in the nutrition literature (World Bank, 2006).

By the time of the 2002-04 data collection, sample members ranged from 25 to 42 years of age; from the original sample of 2,393 individuals in 1969-77, approximately 4% were untraceable, 11% had died and 8% had migrated abroad. This fact might lead to systematic bias that may invalidate the estimates due to attrition. However, Maluccio et al. (2008) and Hoddinott et al. (2008), using the same Guatemalan cohort, find that adjustment for attrition bias does not change the results.

The principal hypothesis underlying the 1969-77 intervention was that improved pre-school nutrition accelerates physical growth and mental development. To test this hypothesis, 300 villages were screened to identify those of appropriate size, compactness, ethnicity, diet, educational levels, demographic characteristics, and nutritional status. From this screening, village pairs similar in these characteristics were determined: Conacaste and Santo Domingo, relatively crowded villages, and San Juan and Espíritu Santo, relatively less crowded villages.

Two villages, Conacaste and San Juan, were randomly assigned to receive a high protein-energy drink, Atole, as a nutritional supplement. Atole contained Incaparina, a vegetable protein mixture developed by the INCAP, dry skim milk, and sugar and had 163 kcal and 11.5 g of protein per 180 ml cup. This design reflected the prevailing view of the 1960's that protein was the critically limiting nutrient in most developing countries. Atole, the Guatemalan name for hot maize gruel, was served hot, it was pale gray-green and slightly gritty, but with a sweet taste.

In designing the data collection, there was considerable concern that the social stimulation associated with attending feeding centers, such as the observation of children's nutritional status, and the monitoring of their intakes of Atole, also might affect child nutritional outcomes, thus confounding efforts to understand the impact of the supplement. To address this issue, an alternative drink, Fresco, was provided in the remaining villages, Santo Domingo and Espíritu Santo. Fresco was a cool, clear-colored, fruit-flavored drink. It contained no protein and only sufficient sugar and flavoring agents. It contained fewer calories per cup (59 kcal/180 ml) than Atole. Several micronutrients were added to the Atole and Fresco in amounts that achieved equal concentrations per unit volume. This was done to sharpen the contrast between the drinks to protein; the energy content differed, of course, but this was not recognized to be of importance at the time.

The nutritional drinks were distributed in supplementation centers and were available daily, on a voluntary basis, to all members of the community during times that were convenient to mothers and children but that did not interfere with usual meal times. Interestingly, Schroeder, Kaplowitz and Martorell (1992) show a large differential in the nutritional intake between Atole and Fresco villages. Averaging over all children in the Atole villages (i.e., both those that consumed any supplement and those who never consumed any), children 0-12 months consumed approximately 40-60 kcal per day, children 12-24 months consumed 60-100 kcal daily and children 24-36 months consumed 100-120 kcal per day as supplement. In contrast, children in the Fresco villages consumed virtually no Fresco between the ages of 0-24 months (averaging at most 20kcal per day) with this figure rising to approximately 30 kcal daily by age 36 months. Micronutrient intakes from the supplements were also larger for Atole than Fresco villages; also, the Atole contributed significant amounts of high-quality protein, while the Fresco contributed none.

Given this large differential exposure to treatment, this study exploits the intensive structure of the longitudinal survey to construct the variables used as instruments. The key point is that these instruments, which capture childhood exposure to the nutritional supplement during 1969-77, are correlated with adult body size. Additionally, the follow-up conducted during 2002-04 provides information on current wages and human capital variables: height, BMI and schooling. Section VII gives a full description of all variable definitions from both studies.

This paper includes 645 wage earners or dependent workers[7] (65.3% males) and 980 dependent and/or independent workers (53.6% males), all original participants resurveyed in 2002-04 for whom the measures of body size, height and BMI, are both available. Out of 421 (224) male (female) dependent workers, 197 (72) are also involved in agricultural activities and/or have their own business.

The dependent variable in the earnings production function (1) refers to hourly income and two specifications are analyzed. First, the hourly income from wage activities and, second, the hourly income from wages, agricultural activities and own business is explored as a different definition. Figure B1 shows the distributions of the logarithm of hourly wages for four different groups: males with no schooling, males with some years of schooling, females with no schooling and females with some years of schooling. As is typical for income distributions, the wage distribution is closer to log-normal than to normal. As expected, the wage distribution for males with some schooling appears to the right compared to the other categories, implying that educated men have, on average, higher earnings. Additionally, total annual earned income (from dependent activities and from dependent and independent activities) is used as an alternative outcome variable.

Two measures of body size are included as indicators of human capital in the right side of equation (1): height and BMI. Height was measured to the nearest 0.1 cm, with the subjects bare footed, standing with their backs to a stadiometer; weight was measured on subjects dressed in their normal underclothes with no shoes or objects in their pockets. This measure was taken using a digital scale with a precision of 100 grams. Then, BMI becomes the ratio between weight (in kilograms) and height (in meters) squared. Additionally, completed years of formal schooling capture another dimension

[7] Two males with hourly wages greater than 90 quetzals (local currency) are dropped from the sample. Also, 41 males and 25 females who reported annual hours worked greater than 4,380 are excluded from the analysis.

of human capital and refer to an indicator of educational attainment (adult and informal education are excluded).

Table A1 presents descriptive statistics for the main variables. Consistent with Figure B1, males have a larger mean hourly wage than females, 11.7 and 8.4 quetzals[8], respectively. Furthermore, Table A1 shows that while the average male is taller than the average female (162.8 and 150.6 cm, respectively), women show, on average, higher BMI than men (26.9 and 24.6, respectively). Additionally, there is, as expected, a positive and statistically significant at 1% correlation between wages and height for both males and females (approximately 0.22); see Table A2. However, wages and BMI are positively correlated for males (0.18, significant at 1%) but not for females (0.008, not significant). Also, there is a positive and significant at 1% correlation between wages and schooling attainment for both sexes (0.40 for males and 0.34 for females). In addition, schooling is positively correlated with adult height (0.22 for males and 0.25 for females, both statistically significant at 1%). Surprisingly, there is a positive correlation of 0.11 between schooling and BMI for males, but negative for females (-0.14), both statistically significant at 5%. Finally, the correlation between height and BMI is not statistically significant for both men and women, even thought it is positive for males (0.03) but negative for females (-0.01).

Finally, Figures B2, B3 and B4 illustrate the distributions of height, BMI and schooling, respectively. As expected from Table A1, Figure B2 shows that men are, on average, taller than women. Moreover, males (females) with some schooling are taller than males (females) with no schooling, consistent with the positive correlation between height and schooling. In addition, Figure B3 reveals that there is a larger proportion of women at higher levels of BMI (>20); however, the picture does not evidence a clear association between BMI and schooling. So, how is schooling distributed? Figure B4 shows unequally distributed years of schooling with a mean value of approximately 5 and 4.5 years for males and females, respectively. The highest frequency is at six years (29.7% for males and 21.4% for females), were primary school is completed. There are secondary modes at zero grades (15.9% for males and 18.3% for females) and three grades (8% for males and 12% for females).

[8] At the time of the survey, a dollar was equivalent to 7.59 quetzals.

The instruments, assumed to be uncorrelated with the unobserved error term but correlated body size indicators, come from the original study conducted in 1969-77 and are grouped in three categories:

(1) Exposure to supplementation: Exposure is measured with binary variables that capture cohort exposure to supplementation, with exposure at ages 0-36 months as the central defining characteristic. Figure B5 gives the definition of these cohorts for the more populous villages in which the intervention started in January 1969 and ended in February 1977; in the less populous villages the definitions are similar but the intervention started in May 1969. Following this characterization, first stage instruments refer to three dummy indicators for exposure to Atole for cohorts 2, 3 and 4. Thus, the omitted category is exposure to Atole for cohort 1 as well as exposure to Fresco for all cohorts. Binary variables for Fresco cohorts are not included because of non-significance of any of the coefficients.

(2) Distance to the supplementation center: Distance to the supplementation center is indicated by four dummy variables where the reference category is the closest group to the center.

(3) Current food prices: Unit prices of cream and tortillas come from Instituto Nacional de Estadistica de Guatemala and vary by community and year of the interview. Other food prices are available, such as meat, corn, oil and sugar; however they are not included because of high collinearity between prices and the results do not change significantly.

To sum up, these three groups of instruments are assumed to be correlated with current body size, measured by height and BMI; however, there is no reason to expect that these instruments are correlated with current wage rates other than indirectly through body size indicators.

V. Results

A. Non-parametric approach

This section presents evidence of the association between body size indicators and wage rates using locally weighted regressions, method that smoothes the data and, thus, it is extremely useful to capture non-linearities. Although Stata '*lowess*' command selects a default bandwidth of 0.8, a bandwidth of 0.85 is used to avoid undersmoothing the results.

For visual exploration, Figures B6 and B7 show bivariate nonparametric regressions between wage rates, in logarithm scale, and height and BMI for males. Bootstrapped 95% confidence intervals with 100 replications (not shown in the graphs) suggest that the nonparametric estimates are statistically significant in all the cases. For instance, Figure B6 presents a nonparametric regression between height and wage rates by schooling level. The smoothed curves are somewhat linear and almost parallel when comparing male workers with no schooling with those with some schooling. One may argue that height can be considered as a proxy for education; thus, some of the association between height and wages might be attributed to education. However, as Figure B6 reveals, the correlation persists for those males with no schooling at all. This finding is consistent with the pattern found by Strauss and Thomas (1998) for male Brazilian workers. In addition, Figure B7 shows the non-parametric relationship between BMI and wage rates by schooling level. Interestingly, the association between BMI and wages is non-linear. As expected, the smoothed curve for males with some schooling is above the curve for those with no schooling. While both smoothed curves have a positive slope for intermediate values of BMI, between 20 and 30, an increase in BMI is associated with higher returns for males with no schooling. It is plausible that for these men, a larger BMI is associated with greater physical strength, which is of value for manual labor, but that strength is of less value among the better educated who might be more likely to have sedentary occupations. Therefore, the positive correlation between wages and BMI persists for those with no schooling; however, it becomes negative when BMI exceeds 30. Thus, extreme values of BMI, which correspond to higher risk of diseases, show lower outcomes.

B. Parametric approach

This section estimates returns to body size across quantiles of the conditional wage distribution after accounting for the endogeneity bias. In other words, the aim is to answer the following questions: (a) do body size indicators, height and BMI, have a true effect on productivity?; (b) if yes, how large is that impact?; (c) is this effect homogeneous or heterogeneous across quantiles of the conditional wage distribution?; and (d) is the effect similar for males and females?

The estimated specification, with hourly wages as main outcome, includes height, BMI, completed years of formal schooling, age and age squared and dummy variables for three out of the four experimental villages and is estimated separately for males and females. In all regressions, the dependent variable and the indicators of body size are introduced in logarithm scale; thus, the coefficients have the interpretation of height elasticity and BMI elasticity. Standard errors are calculated allowing for clustering at the mother level for all mean regressions (Tables A3 and A4) and are based on the bootstrap method with 5,000 replications for all quantile regressions (Tables A5 and A6).

First, Table A3 presents simple OLS regressions to explore the mean association between body size measures and wage rates; columns (1), (4), (7) and (10) do not include body size indicators, columns (2), (5), (8) and (11) add height in logarithm scale, and columns (3), (6), (9) and (12) add height and BMI both in logarithm scale. For males, returns to schooling always decrease when height and BMI are included reflecting the fact that both measures of body size are positively correlated with schooling (see Table A2). Conversely, for three out of the four different outcomes, returns to schooling for females decrease when height is added, but remain at the same level when BMI is incorporated; the exception is annual earned income from wage activities.

Analyzing the average height elasticity, the estimates are always positive for male workers, statistically significant at 10% for hourly wages and statistically significant at 5% for hourly income and total annual income from dependent and independent activities. For instance, a 1% increase in height is associated with a 1.54% increase in hourly wages. Furthermore, the BMI elasticity for males is always positive and statistically significant at 1%; a 1% increase in BMI is associated with a 0.75% increase in hourly wages. For females, although BMI elasticity is never significant, height elasticity for hourly wages is positive, statistically significant at 5% and larger than the estimated value for males: a 1% increase in height is associated with a 2.55% increase in hourly wages.

Nonetheless, estimates presented in Table A3 seem premature and do not measure the casual effect of body size on earnings because they do not correct for the endogeneity bias previously discussed. Therefore, Table A4 moves forward and shows body size elasticity estimates based on an instrumental variable approach. A priori, height could be considered as endogenous following the arguments exposed in Section II and III. However, a χ^2 postestimation test accepts the null hypothesis that height can actually be treated as exogenous yielding, for instance, a p-value of 0.906 for males and 0.308 for females in the hourly wage specification.

Consequently, all regressions in Table A4 treat BMI as endogenous and height as exogenous. The instruments used in the first step regression are described in the previous section. On the one hand, height elasticity does not change significantly compared to estimates from OLS regressions. On the other hand, BMI elasticity increases substantially revealing that the non-instrumented estimates are downward biased. For example, a 1% increase in BMI is translated into a 2.79% increase in hourly wages for males, magnitude that is more than 3 times larger than the OLS estimate. Another result is the attainment of significance of BMI elasticity for females with annual earned income as outcome but not with hourly income.

In addition, Table A4 shows specification tests of the instruments and endogenous variables. The null hypothesis of the Sargan-Hansen overidentification test is that the instruments are valid: uncorrelated with the error term and correctly excluded from the estimated equation. With only two exceptions, the null cannot be rejected; for instance, the p-value for the hourly wage equation is 0.48 for males. Moreover, the endogeneity test rejects, in most of the cases, the null that BMI can be treated as exogenous, p-value equals 0.017 for males in the hourly wage model. Finally, the underidentification test Kleibergen-Paap is a test of whether the equation is identified, i.e., that the instruments are correlated with the endogenous regressors. A rejection of the null indicates that the model is identified; the null is rejected in all four alternative specifications for men. However, it cannot be rejected for women, suggesting that the model could be underidentified and that the estimated coefficients for female workers should be treated with caution. In summary, it arises, according to all these tests, that only the regressions for male dependent workers, columns (1) and (2), satisfy all specification tests.

For posterior comparison, Table A5 presents quantile regression estimates that do not correct for the endogeneity bias. Standard errors are based on the bootstrap method with 1,000 replications. Height elasticity is only significant at higher quantiles for hourly income from male dependent workers; for example, a 1% increase in height is associated with a 5% increase in wages at the 95% quantile. Moreover, when independent workers are included, height elasticity becomes significant at some lower quantiles of the conditional hourly wage distribution: a 1% increase in height is associated with a 1.6% increase in hourly income for males at the 25% quantile.

BMI elasticity, on the other hand, appears statistically significant at almost all quantiles of the conditional hourly income distribution for males, with the exception of the 95% quantile. For instance, a 1% increase in BMI is associated with a 0.71% (1.02%) increase in hourly wages at the 25% (75%) quantile. Conversely, BMI elasticity is never significant for females.

Moreover, Table A5b presents tests of equality between coefficients of the same variable at different quantiles. The null hypothesis is equality of returns. A low p-value rejects the null implying statistically significant differences. For example, height elasticity at the 5% quantile for hourly income for dependent and independent male workers is statistically different from the elasticity at 25% (p-value 0.033).

Table A6 shows the estimates from the two-step quantile regressions where BMI is treated as endogenous, thus, jointly determined with earnings. The coefficients are reported separately for males and females like in all previous regressions. However, only hourly income and not total annual income is estimated because the procedure is computationally intensive. The method, fully detailed in Section III, consistently estimates the effects of body size at different quantiles of the conditional wage distribution. Similar to Table A5, standard errors are based on the bootstrap method with 1,000 replications. Results for women are presented in Table A6 for the sake of completeness but not discussed because they are likely to be underidentified; see specification tests in Table A3. Furthermore, and consistent with prior evidence, returns to body size for women are not statistically significant in almost all quantiles, suggesting that labor markets are differently structured for men and women.

Compared to Table A5, significance of the coefficients for males in Table A6 does not change considerably. As expected from the estimates in Table A3, BMI elasticity increases significantly when the endogeneity bias is corrected implying that the non-instrumented estimated are downward biased. For instance, a 1% increase in BMI can be translated into a 3.16% (4.16%) increase in hourly wages for males at the 25% (75%) quantile when BMI is instrumented. Compared to estimates from Table A5, this implies that the instrumented BMI elasticity is more than four times larger.

Moreover, Table 6B presents tests of equality between coefficients at different quantiles. As in Table 5B, the null hypothesis is equality of elasticity. For example, BMI elasticity at the 5% quantile is statistically different from the elasticity at 25% for the hourly wage equation (p-value 0.027). Although the elasticity at the 5% quantile appears significantly different from the estimate at all other quantiles, it is not statistically significant. In addition, the test of equality of BMI elasticity cannot be rejected at higher quantiles.

To sum up, Figures B8 and B9 show graphically the BMI elasticity at different quantiles for male wage earners and for male dependent and/or independent workers, respectively, comparing the instrumented and the non-instrumented versions of the estimates. Also, 95% confidence intervals for the instrumented version are included. Figure B8 suggests that the endogeneity corrected estimates for the BMI elasticity are likely to be different from the uncorrected coefficients at the 25%, 50% and 75% quantiles of the conditional hourly wage distribution.

This regression results should be interpreted in the context of Guatemalan villages, poor and rural areas in a developing country. Consistent with previous work, the estimates of the effect of body size on wages appear more robust for males than for females, likely because of the structure of the labor market in those settlings. One limitation of the analysis is that the selectivity bias may potentially affect the estimates for females. This fact should be taken in mind when interpreting the results.

VI. Conclusions and further extensions

Establishing a relationship between health and productivity is not straightforward. It is likely that causality runs in both directions. On one hand, higher income individuals invest more in human capital, including health: as their income grows, they invest in better diets, improved sanitation and better health care. On the other, if a worker is healthier, less susceptible to disease, and more alert and more energetic, then he or she will probably be more productive and experience higher earnings. This paper focuses on the second pathway and examines the effect of a dimension of health, measured by body size indicators, height and BMI, on wage rates, an indicator of labor productivity. Data come from a longitudinal study originally conducted during 1969-77 and followed-up during 2002-04 in four Guatemalan villages.

This research consistently estimates returns to body size, in the form of height and BMI elasticity, at different quantiles of the conditional wages distribution. Thus, this approach provides a widespread picture of health effects, rather than a mean effect. Consistent with previous research, the evidence is more robust for males than for females, suggesting that labor markets are differently structured for men and women.

Further extensions to the analysis comprise:

- correction for attrition following the Fitzgerald, Gottschalk and Moffitt (1998) methodology,
- inclusion alternative measures of productivity as outcome variable, such as hours worked per week, which may include hours of housework,
- inclusion alternative measures of body composition to capture physical strength and energy such as skinfold thicknesses and circumferences (Ramirez-Zea et al. 2006),
- inclusion interaction terms between schooling and height and between schooling and BMI,
- account for the selectivity bias into the labor markets including hazard rates, as in Heckman (1974).

VII. Variable definitions

A. Response variables

Wage rate: Ratio between income from wages and hours worked in wage activities.

Hourly income: Ratio between total income from wages, agricultural activities and own business and total hours worked in all activities.

B. Key explanatory variables

Height: Measured to the nearest 0.1 cm, with the subjects bare footed, standing with their backs to a stadiometer (GPM, Switzerland). All measurements were done twice. If the difference between the two first measurements was greater than 1.0 cm for height, a third measurement was done and the two closest measurements were used.

BMI: Defined as weight (kg) / height squared (m^2), BMI has been promoted as a useful indicator for chronic energy deficiency, and to a lesser extent to indicate obesity.

Schooling: Years of completed formal schooling (excludes informal or adult education).

C. Control variables

Age: Age of respondent at interview. The INCAP Longitudinal Study was conducted from 1969-77 and recorded for children between 0 and 7 years, so the year of birth ranges from 1962-77.

Atole: Dummy = 1 if community received atole (Conacaste and San Juan). Indicator of whether or not the child lived in one of the two Atole villages.

Large village: Dummy = 1 if the village is relatively large (Conacaste and Santo Domingo).

*Large village * Atole:* Dummy = 1 if atole = 1 and large village = 1 (Conacaste).

D. Instruments

*Cohort2 * Atole:* Dummy = 1 if the individual was born between 1969 and 1974 and lived in one of the two Atole villages (Conacaste or San Juan).

*Cohort3 * Atole:* Dummy = 1 if the individual was born between 1966 and 1969 and lived in one of the two Atole villages (Conacaste or San Juan).

*Cohort4 * Atole:* Dummy = 1 if the individual was born between 1962 and 1966 and lived in one of the two Atole villages (Conacaste or San Juan).

Distance: Distance to the supplementation center indicated by four dummy variables (reference category is the closest group to the center).

Unit price of cream and unit price of tortillas: food prices come from *Instituto Nacional de Estadistica de Guatemala* and vary by community and year.

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A. Tables

Table A1
Adult characteristics of subjects born 1962-77 in four Guatemalan villages and remeasured in 2002-04, by gender

Variable	Males		Females		Male-female difference
	Mean	Std. Dev.	Mean	Std. Dev.	
Dependent workers	N=421		N=224		
Wage rate (Q/h)	11,71	8,31	8,44	7,07	3.27***
Annual earned income (Q)	24.251,20	18.775,37	12.590,04	13.123,95	11661.16***
Annual hours worked (h)	2.122,21	961,60	1.589,35	1.087,14	532.86***
Dependent + independent workers	N=525		N=455		
Hourly income (Q/h)	11,60	9,06	8,92	10,15	2.673309***
Annual earned income (Q)	26.377,86	20.112,20	11.051,94	14.866,12	15325.92***
Annual hours worked (h)	2.359,07	900,47	1.411,64	1.195,67	947.44***
Height (cm)	162,76	5,90	150,52	5,88	12.24***
BMI (kg/m^2)	24,58	3,56	26,89	4,88	-2.31***
Completed grades of schooling	4,97	3,53	4,12	3,39	0.84***
Age of respondent at interview (years)	32,88	4,08	33,49	4,25	-0.61**

*** p<0.01, ** p<0.05, * p<0.1

Table A2

Correlation coefficients between labor market outcomes and human capital characteristics in Guatemalan dependent workers, by gender

Males [N=421]	Wage rate (Q/h)	Annual earned income (Q)	Annual hours worked (h)	Height (cm)	BMI (kg/m2)	Grades of schooling	Age
Wage rate (Q/h)	1						
Annual earned	0.7621***	1					
Annual hours worked (h)	-0,0754	0.4639***	1				
Height	0.2156***	0.1407***	0,0006	1			
BMI	0.1838***	0.1731***	0,042	0,0254	1		
Grades of schooling	0.4001***	0.4076***	0.1108**	0.2231***	0.1134**	1	
Age	0,0058	-0,0332	-0,0495	-0,0351	0.1756***	-0.1755***	1
Females [N=224]	**Wage rate (Q/h)**	**Annual earned income (Q)**	**Annual hours worked (h)**	**Height (cm)**	**BMI (kg/m2)**	**Grades of schooling**	**Age**
Wage rate (Q/h)	1						
Annual earned	0.6572***	1					
Annual hours worked (h)	-0,1087	0.5213***	1				
Height	0.2213***	0.2037***	-0,0429	1			
BMI	0,0079	-0,0405	-0,0594	-0,0132	1		
Grades of schooling	0.3404***	0.4240***	0.1229*	0.2451***	-0.1431**	1	
Age	0,0642	0,0913	0,0346	-0,0042	0.1155*	-0.1601**	1

*** p<0.01, ** p<0.05, * p<0.1

Table A3. Associations of adult body composition with wage rates and annual income in Guatemala, by gender (OLS regressions)

	Dependent workers						Dependent + independent workers					
	Log wage rate (Q/h)			Log annual earned income (Q)			Log hourly income (Q/h)			Log annual earned income (Q)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Males											
	N=421 [clusters=309]						N=525 [clusters=350]					
Log height		1.548*	1.537*		2.051	2.038		2.295**	2.323**		2.650**	2.682**
SE		0.843	0.826		1.403	1.396		0.963	0.948		1.287	1.283
Log BMI			0.753***			0.925***			0.990***			1.164***
SE			0.192			0.327			0.216			0.276
Grades of schooling	0.085***	0.080***	0.076***	0.112***	0.106***	0.101***	0.085***	0.078***	0.074***	0.082***	0.074***	0.069***
SE	0.008	0.008	0.008	0.013	0.013	0.013	0.009	0.009	0.009	0.012	0.013	0.013
Log likelihood	-338.087	-336.059	-328.157	-547.337	-546.022	-541.658	-534.702	-530.976	-519.868	-668.750	-665.773	-656.624
Adj R2	0.214	0.219	0.246	0.153	0.156	0.171	0.142	0.152	0.186	0.082	0.091	0.120
F Test [p-value]	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Females											
	N=224 [clusters=185]						N=455 [clusters=329]					
Log height		2.557**	2.549**		-1.621	-1.543		2.153	2.147		4.491*	4.526**
SE		1.064	1.062		1.920	1.935		1.316	1.319		2.303	2.289
Log BMI			0.056			-0.536			0.017			-0.097
SE			0.285			0.511			0.233			0.471
Grades of schooling	0.061***	0.053***	0.053***	0.115***	0.120***	0.117***	0.071***	0.065***	0.065***	0.145***	0.131***	0.130***
SE	0.014	0.015	0.014	0.020	0.022	0.021	0.013	0.013	0.013	0.021	0.021	0.021
Log likelihood	-230.512	-228.043	-228.018	-368.911	-368.626	-367.974	-613.612	-611.899	-611.897	-877.929	-875.594	-875.570
Adj R2	0.102	0.117	0.113	0.095	0.093	0.094	0.068	0.073	0.071	0.082	0.089	0.087
F Test [p-value]	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Notes: Standard errors were calculated allowing for clustering at the mother level.
*** p<0.01, ** p<0.05, * p<0.1
Additional variables included but not reported are age, age squared and dummy variables for three out of the four experimental villages.

Table A4. Effect of adult body composition on wage rates and annual income in Guatemala, by gender (IV regressions)

	Dependent workers		Dependent + independent workers		Dependent workers		Dependent + independent workers	
	Log wage rate (Q/h)	Log annual earned income	Log hourly income (Q/h)	Log annual earned income	Log wage rate (Q/h)	Log annual earned income	Log hourly income (Q/h)	Log annual earned income
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Males				Females			
	N=421 [clusters=309]		N=525 [clusters=350]		N=224 [clusters=185]		N=455 [clusters=329]	
Log height	1.508*	2.001	2.358**	2.721**	2.305**	-2.581	1.205	-0.508
SE	0.898	1.480	0.963	1.306	1.069	3.166	1.425	4.655
Log BMI	2.788***	3.466**	2.274***	2.570**	1.731	6.592**	2.626	13.849***
SE	0.847	1.443	0.847	1.021	1.120	2.803	1.810	5.081
Grades of schooling	0.065***	0.087***	0.067***	0.062***	0.064***	0.160***	0.085***	0.240***
SE	0.011	0.017	0.010	0.014	0.016	0.041	0.021	0.065
Log likelihood	-380.075	-572.554	-538.258	-669.861	-248.336	-447.432	-661.939	-1140.616
Adj R2	0.036	0.040	0.126	0.075	-0.063	-0.841	-0.157	-1.927
F Test [p-value]	0.000	0.000	0.000	0.000	0.000	0.024	0.000	0.007
Overidentification test of all instruments Sargan-Hansen [p-value]	0.477	0.221	0.098	0.042	0.110	0.577	0.833	0.959
Endogeneity test [p-value]	0.017	0.007	0.119	0.161	0.154	0.005	0.107	0.000
Underidentification test Kleibergen-Paap rk LM statistic [p-value]	0.009	0.009	0.001	0.001	0.155	0.155	0.166	0.166
Weak identification test Kleibergen-Paap rk Wald F statistic	3.108	3.108	4.612	4.612	1.758	1.758	1,425	1.425

Notes: Standard errors were calculated allowing for clustering at the mother level.

*** p<0.01, ** p<0.05, * p<0.1

Additional variables included but not reported are age, age squared and dummy variables for three out of the four experimental villages.

Excluded instruments for BMI are three dummy variables that characterize exposure cohort to atole, four dummy variables that measure distance to the supplementation center and two food prices that vary by community and year.

Table A5. Associations of adult body composition with wage rates and annual income in Guatemala, by gender (quantile regressions)

	Log hourly income (Q/h)							Log annual earned income (Q)						
Quantile:	**0,05**	**0,1**	**0,25**	**0,5**	**0,75**	**0,9**	**0,95**	**0,05**	**0,1**	**0,25**	**0,5**	**0,75**	**0,9**	**0,95**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Males														
Dependent workers N=421														
Log height	0.369	1.656	-0.135	1.069	2.052	2.925*	5.048***	6.600*	0.996	1.523	-0.653	0.969	0.678	0.220
SE	1.257	1.024	0.915	1.100	1.250	1.768	1.868	3.548	3.479	2.081	1.472	1.421	1.495	1.886
Log BMI	0.904**	0.780**	0.706***	0.490*	1.015***	1.122**	0.548	0.842	0.862	1.006**	0.677**	1.042***	1.407***	1.019**
SE	0.372	0.327	0.207	0.261	0.347	0.464	0.479	0.990	0.856	0.419	0.315	0.380	0.389	0.507
Grades of schooling	0.054**	0.068***	0.075***	0.076***	0.078***	0.075***	0.062***	0.163***	0.137***	0.106***	0.101***	0.081***	0.074***	0.065***
SE	0.021	0.015	0.007	0.014	0.014	0.016	0.016	0.047	0.034	0.020	0.015	0.013	0.015	0.022
Dependent + independent workers N=525														
Log height	5.802***	2.116	1.614**	2.246*	1.876	2.581	4.018*	6.025**	4.906**	3.509**	1.253	1.136	1.630	3.061*
SE	2.044	1.382	0.771	1.213	1.269	1.781	2.133	2.610	2.489	1.533	1.275	1.414	1.424	1.588
Log BMI	1.909***	1.278***	0.884***	0.643**	1.237***	0.864*	0.441	1.961**	1.719**	0.918**	0.885***	1.259***	1.180***	0.609
SE	0.553	0.361	0.230	0.313	0.335	0.441	0.467	0.880	0.709	0.363	0.302	0.290	0.391	0.417
Grades of schooling	0.049**	0.081***	0.069***	0.077***	0.076***	0.074***	0.063***	0.031	0.077***	0.074***	0.078***	0.075***	0.053***	0.045**
SE	0.019	0.013	0.009	0.013	0.014	0.016	0.022	0.044	0.029	0.017	0.013	0.012	0.016	0.019
Females														
Dependent workers N=224														
Log height	-2.344	0.210	2.849**	1.921	2.778*	4.364**	4.076*	-9.760	-6.098	-2.240	0.449	2.406	1.439	2.458
SE	2.798	2.527	1.434	1.601	1.412	1.940	2.325	8.929	6.212	3.050	1.872	1.898	1.589	1.613
Log BMI	0.221	0.070	-0.209	0.309	0.046	0.210	0.551	-0.342	0.112	-1.054	-0.119	-0.238	0.303	0.362
SE	0.788	0.683	0.439	0.338	0.369	0.349	0.372	1.762	1.214	0.910	0.567	0.343	0.362	0.363
Grades of schooling	0.065	0.058*	0.056**	0.052***	0.056***	0.039**	0.050**	0.128	0.107	0.174***	0.099***	0.070***	0.075***	0.092***
SE	0.041	0.035	0.022	0.018	0.020	0.019	0.021	0.090	0.079	0.043	0.023	0.017	0.017	0.021
Dependent + independent workers N=455														
Log height	5.697	2.446	2.314	2.084	2.747**	1.216	0.892	3.420	1.573	7.494*	3.804	2.339	3.125*	4.272**
SE	3.458	2.761	1.629	1.539	1.289	2.579	3.059	6.425	6.623	4.221	2.871	1.582	1.603	2.022
Log BMI	-0.515	0.028	-0.379	0.045	0.294	0.426	0.766	1.554	0.628	-0.340	-0.356	-0.058	0.211	0.223
SE	0.768	0.509	0.453	0.285	0.281	0.349	0.654	1.380	1.250	0.903	0.573	0.365	0.389	0.473
Grades of schooling	0.102***	0.071**	0.091***	0.054***	0.053***	0.064***	0.055**	0.199**	0.216***	0.176***	0.135***	0.095***	0.075***	0.052***
SE	0.037	0.028	0.021	0.015	0.018	0.021	0.024	0.078	0.075	0.038	0.025	0.016	0.016	0.019

Notes: Standard errors were calculated by the method of bootstrap (1,000 replications)

*** p<0.01, ** p<0.05, * p<0.1

Additional variables included but not reported are age, age squared and dummy variables for three out of the four experimental villages.

Table A5b. Test of equality [p-value] of height and BMI elasticity for quantile regression estimates

Quantile		Dependent workers						Dependent + independent workers					
		Log wage rate (Q/h)			Log annual earned income (Q)			Log hourly income (Q/h)			Log annual earned income (Q)		
		Height	BMI	Schooling	Height	BMI	Schooling	Height	BMI	Schooling	Height	BMI	Schooling
							Males						
0,05	0,10	0,190	0,653	0,394	**0,092**	0,980	0,473	**0,021**	0,115	**0,061**	0,618	0,716	0,180
0,05	0,25	0,693	0,570	0,294	0,141	0,861	0,197	**0,033**	**0,041**	0,280	0,328	0,208	0,309
0,05	0,50	0,630	0,316	0,326	**0,037**	0,868	0,185	0,101	**0,025**	0,190	**0,071**	0,212	0,285
0,05	0,75	0,294	0,817	0,320	0,122	0,846	**0,081**	**0,089**	0,262	0,241	**0,078**	0,427	0,328
0,05	0,90	0,207	0,711	0,403	0,113	0,595	**0,061**	0,234	0,121	0,319	0,123	0,397	0,635
0,05	0,95	**0,033**	0,559	0,752	0,108	0,873	**0,050**	0,547	**0,038**	0,634	0,323	0,158	0,768
0,10	0,25	**0,056**	0,790	0,592	0,863	0,848	0,297	0,676	0,169	0,338	0,519	0,178	0,916
0,10	0,50	0,633	0,435	0,624	0,617	0,825	0,276	0,934	0,107	0,838	0,133	0,221	0,972
0,10	0,75	0,778	0,595	0,595	0,994	0,838	**0,098**	0,889	0,925	0,807	0,146	0,516	0,945
0,10	0,90	0,504	0,542	0,720	0,931	0,552	**0,075**	0,832	0,444	0,752	0,225	0,477	0,468
0,10	0,95	**0,097**	0,686	0,808	0,842	0,871	**0,063**	0,456	0,145	0,496	0,517	0,170	0,354
0,25	0,50	0,247	0,380	0,901	0,225	0,384	0,782	0,539	0,402	0,478	**0,095**	0,921	0,796
0,25	0,75	**0,092**	0,373	0,830	0,794	0,939	0,194	0,837	0,306	0,638	0,160	0,375	0,965
0,25	0,90	**0,100**	0,392	0,980	0,716	0,432	0,144	0,600	0,965	0,783	0,308	0,576	0,341
0,25	0,95	**0,009**	0,757	0,481	0,623	0,984	0,136	0,277	0,370	0,790	0,822	0,555	0,230
0,50	0,75	0,391	**0,083**	0,922	0,234	0,268	0,115	0,765	**0,068**	0,929	0,924	0,186	0,798
0,50	0,90	0,298	0,183	0,951	0,454	**0,084**	0,112	0,858	0,645	0,859	0,814	0,478	0,169
0,50	0,95	**0,044**	0,908	0,498	0,687	0,526	0,123	0,437	0,694	0,558	0,319	0,556	0,120
0,75	0,90	0,560	0,799	0,868	0,833	0,331	0,612	0,643	0,343	0,893	0,730	0,824	0,155
0,75	0,95	0,101	0,345	0,406	0,704	0,964	0,475	0,296	**0,097**	0,557	0,266	0,122	0,118
0,90	0,95	0,153	0,139	0,399	0,769	0,305	0,637	0,361	0,297	0,532	0,265	**0,089**	0,617
0,90	0,99	0,491	0,629	0,214	0,822	**0,035**	0,191	0,730	**0,046**	0,923	0,731	**0,094**	0,812

Table A5b(continued). Test of equality [p-value] of height and BMI elasticity for quantile regression estimates

Quantile		Dependent workers						Dependent + independent workers					
		Log wage rate (Q/h)			Log annual earned income (Q)			Log hourly income (Q/h)			Log annual earned income (Q)		
		Height	BMI	Schooling	Height	BMI	Schooling	Height	BMI	Schooling	Height	BMI	Schooling
							Females						
0,05	0,10	0,247	0,795	0,830	0,540	0,732	0,753	0,237	0,368	0,303	0,732	0,394	0,796
0,05	0,25	**0,055**	0,553	0,815	0,373	0,680	0,594	0,304	0,853	0,745	0,505	0,160	0,751
0,05	0,50	0,151	0,910	0,743	0,249	0,899	0,745	0,312	0,459	0,194	0,952	0,161	0,401
0,05	0,75	**0,087**	0,830	0,824	0,175	0,953	0,519	0,403	0,308	0,208	0,864	0,239	0,183
0,05	0,90	**0,042**	0,990	0,540	0,214	0,719	0,562	0,275	0,264	0,342	0,964	0,332	0,113
0,05	0,95	**0,066**	0,696	0,726	0,175	0,693	0,695	0,287	0,206	0,262	0,898	0,354	**0,065**
0,10	0,25	0,241	0,617	0,945	0,477	0,290	0,338	0,957	0,373	0,437	0,268	0,375	0,530
0,10	0,50	0,519	0,714	0,853	0,283	0,848	0,915	0,897	0,973	0,536	0,727	0,415	0,259
0,10	0,75	0,339	0,972	0,946	0,171	0,773	0,634	0,915	0,617	0,554	0,905	0,577	0,109
0,10	0,90	0,176	0,844	0,600	0,232	0,879	0,685	0,728	0,500	0,823	0,815	0,739	**0,064**
0,10	0,95	0,245	0,521	0,826	0,171	0,844	0,848	0,691	0,358	0,637	0,695	0,754	**0,033**
0,25	0,50	0,537	0,157	0,828	0,340	0,230	**0,051**	0,887	0,256	**0,039**	0,322	0,983	0,211
0,25	0,75	0,966	0,581	0,991	0,128	0,348	**0,014**	0,801	0,138	0,106	0,200	0,743	**0,029**
0,25	0,90	0,485	0,400	0,484	0,248	0,138	**0,025**	0,686	0,122	0,320	0,306	0,550	**0,010**
0,25	0,95	0,633	0,158	0,813	0,145	0,136	**0,078**	0,658	0,127	0,231	0,481	0,570	**0,003**
0,50	0,75	0,557	0,427	0,818	0,266	0,801	0,152	0,610	0,377	0,942	0,563	0,545	**0,070**
0,50	0,90	0,230	0,808	0,507	0,607	0,473	0,342	0,717	0,319	0,650	0,815	0,339	**0,019**
0,50	0,95	0,392	0,594	0,918	0,335	0,442	0,793	0,687	0,283	0,992	0,884	0,399	**0,004**
0,75	0,90	0,346	0,638	0,325	0,540	0,141	0,798	0,474	0,696	0,566	0,610	0,455	0,181
0,75	0,95	0,560	0,243	0,780	0,978	0,162	0,359	0,496	0,461	0,953	0,380	0,564	**0,046**
0,90	0,95	0,869	0,286	0,491	0,430	0,855	0,309	0,884	0,524	0,630	0,517	0,976	0,180
0,90	0,99	0,522	0,350	0,324	0,179	0,124	0,329	0,558	0,559	0,371	0,428	0,168	0,104

Table A6

Effect of adult body composition on wage rates in Guatemala, by gender (two-step quantile regressions)

	Log hourly income (Q/h)						
Quantile:	**0,05 (1)**	**0,1 (2)**	**0,25 (3)**	**0,5 (4)**	**0,75 (5)**	**0,9 (6)**	**0,95 (7)**
	Males						
	Dependent workers N=421						
Log height	0,254	1,199	0,483	0,613	2,458	4.593**	4.305**
SE	1,198	1,165	0,975	1,134	1,545	2,024	1,865
Log BMI	0,184	2.319**	3.164***	3.368***	4.159***	4.047***	2.859**
SE	1,367	1,175	1,047	1,123	1,539	1,539	1,444
Grades of schooling	0.060**	0.060***	0.062***	0.058***	0.060***	0.054***	0.063***
SE	0,024	0,017	0,012	0,016	0,018	0,019	0,017
	Dependent + independent workers N=525						
Log height	2,684	2.756**	1,138	1,542	2,266	4.114**	3.493*
SE	2,324	1,249	0,963	1,140	1,437	1,737	2,087
Log BMI	3,122	3.169**	2.473**	1.851*	3.181**	3.182**	1,354
SE	2,287	1,365	1,169	1,030	1,298	1,427	1,703
Grades of schooling	0.061**	0.077***	0.067***	0.069***	0.055***	0.056***	0.069***
SE	0,027	0,017	0,011	0,014	0,016	0,019	0,022
	Females						
	Dependent workers N=224						
Log height	-2,881	-0,830	2.658*	2,134	2.663*	4.597**	5.005**
SE	2,745	2,426	1,436	1,633	1,470	1,798	2,502
Log BMI	4.522+	3.547+	2.126+	1,129	0,192	0,467	0,598
SE	2,884	2,483	1,603	1,236	1,323	2,000	2,230
Grades of schooling	0.077**	0.071**	0.067***	0.053***	0.058***	0,034	0,034
SE	0,039	0,034	0,021	0,017	0,021	0,021	0,022
	Dependent + independent workers N=455						
Log height	3,486	2,595	2,030	2,127	2.691**	0,246	0,740
SE	3,727	2,930	1,707	1,455	1,336	2,681	3,245
Log BMI	5.329+	3,724	5.104*	3.532*	1,333	0,676	1,099
SE	4,796	3,913	3,036	2,019	2,000	3,026	3,792
Grades of schooling	0.098***	0.073**	0.072***	0.053***	0.060***	0.059***	0,034
SE	0,036	0,029	0,023	0,015	0,019	0,020	0,022

Notes: Standard errors were calculated by the method of bootstrap (1,000 replications)
*** p<0.01, ** p<0.05, * p<0.1
+ Coefficient is statistically significant under the bias-corrected confidence interval
Additional variables included but not reported are age, age squared and dummy variables for three out of the four experimental villages.
Excluded instruments for BMI are three dummy variables that characterize exposure cohort to atole, four dummy variables that measure distance to the supplementation center and two food prices that vary by community and year.

Table A6b: Test of equality [p-value] of height and BMI elasticity for quantile regression estimates with instrumental variables

Quantile		Males						Females					
		Dependent workers			Dependent + independent workers			Dependent workers			Dependent + independent workers		
		Log hourly income (Q/h)											
		Height	BMI	Schooling	Height	BMI	Schooling	Height	BMI	Schooling	Height	BMI	Schooling
0,05	0,10	0,344	**0,035**	0,979	0,968	0,978	0,440	0,373	0,605	0,839	0,771	0,627	0,462
0,05	0,25	0,851	**0,027**	0,916	0,486	0,759	0,810	**0,036**	0,362	0,782	0,682	0,957	0,489
0,05	0,50	0,806	**0,050**	0,955	0,630	0,580	0,779	**0,081**	0,221	0,538	0,715	0,692	0,217
0,05	0,75	0,231	**0,039**	0,998	0,871	0,981	0,842	**0,069**	0,143	0,638	0,836	0,421	0,343
0,05	0,90	**0,056**	**0,056**	0,835	0,610	0,982	0,874	**0,021**	0,213	0,301	0,473	0,403	0,343
0,05	0,95	**0,060**	0,176	0,913	0,791	0,525	0,810	**0,031**	0,246	0,311	0,571	0,484	0,131
0,10	0,25	0,471	0,416	0,896	0,155	0,548	0,497	0,116	0,478	0,894	0,824	0,647	0,956
0,10	0,50	0,667	0,458	0,923	0,406	0,347	0,660	0,228	0,289	0,591	0,872	0,958	0,468
0,10	0,75	0,475	0,293	0,987	0,779	0,994	0,295	0,194	0,176	0,719	0,975	0,568	0,694
0,10	0,90	0,135	0,339	0,785	0,508	0,994	0,372	**0,062**	0,274	0,327	0,538	0,537	0,676
0,10	0,95	0,151	0,763	0,907	0,757	0,384	0,772	**0,077**	0,320	0,331	0,659	0,635	0,281
0,25	0,50	0,897	0,849	0,768	0,696	0,545	0,881	0,724	0,424	0,450	0,953	0,519	0,330
0,25	0,75	0,193	0,529	0,898	0,448	0,612	0,446	0,998	0,228	0,713	0,725	0,241	0,650
0,25	0,90	**0,043**	0,599	0,657	0,102	0,664	0,579	0,340	0,436	0,206	0,547	0,282	0,642
0,25	0,95	**0,047**	0,857	0,967	0,284	0,566	0,921	0,386	0,508	0,225	0,714	0,400	0,223
0,50	0,75	0,171	0,555	0,922	0,582	0,246	0,331	0,726	0,416	0,776	0,683	0,244	0,664
0,50	0,90	**0,041**	0,666	0,804	0,151	0,358	0,515	0,211	0,726	0,350	0,479	0,327	0,789
0,50	0,95	**0,053**	0,753	0,808	0,365	0,781	0,985	0,280	0,805	0,399	0,672	0,519	0,454
0,75	0,90	0,213	0,941	0,711	0,207	1,000	0,961	0,231	0,866	0,176	0,262	0,788	0,931
0,75	0,95	0,310	0,440	0,870	0,530	0,276	0,528	0,328	0,842	0,265	0,510	0,946	0,272
0,90	0,95	0,830	0,331	0,513	0,691	0,161	0,455	0,824	0,933	0,998	0,839	0,875	0,188
0,90	0,99	0,621	0,967	0,169	0,949	0,706	0,385	0,784	0,760	0,774	0,452	0,187	0,130

B. Figures

Figure B1

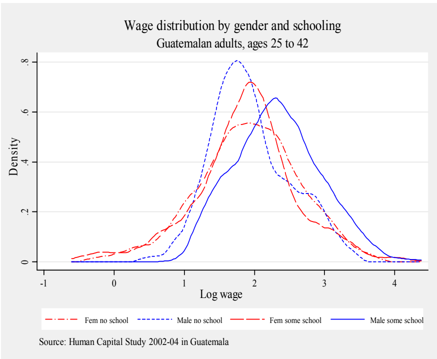


Figure B2

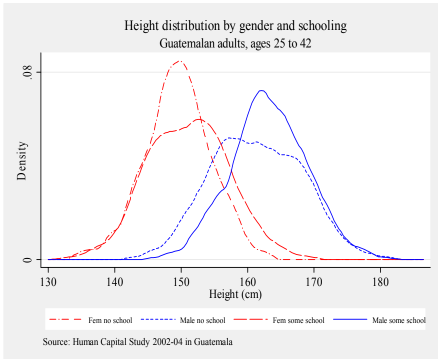


Figure B3

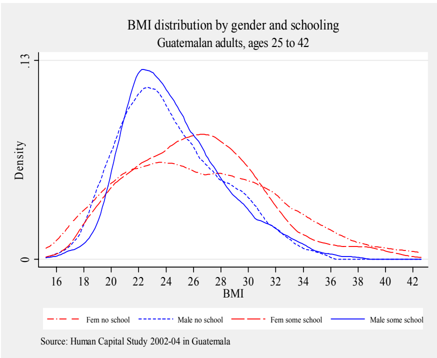


Figure B4

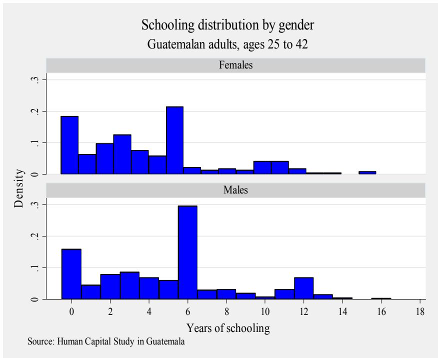
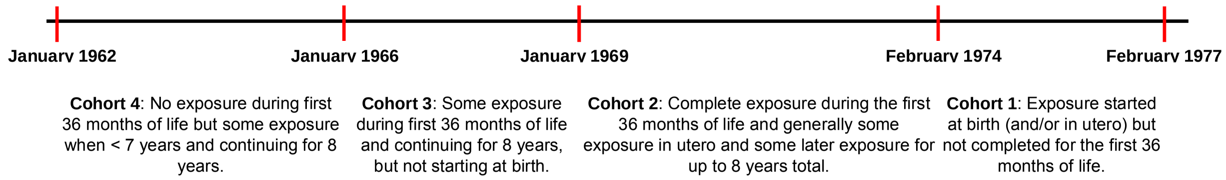


Figure B5
Definition of 4 birth cohorts based on whether exposed for complete initial 36 months of life in 2 more populous villages *



* In two less populous villages, supplementation was initiated in May 1969, thus the initial birthdates for the first three cohorts are pushed back to May 1962, 1966, and 1969, respectively.

Figure B6

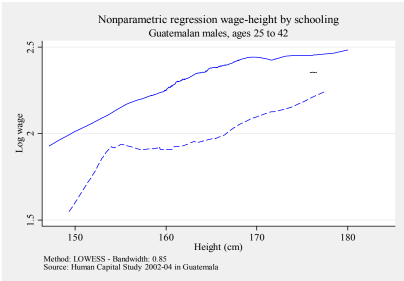


Figure B7

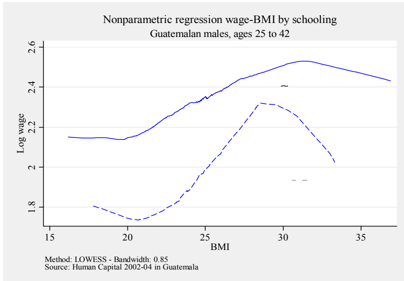


Figure B8

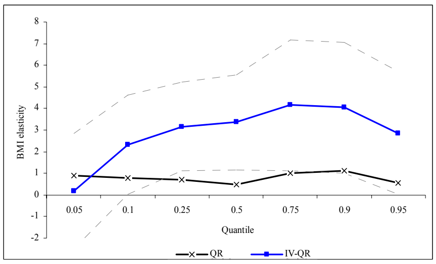


Figure B9