Height Growth Paths and Production Relations in Guatemala and the Philippines

Fan Wang, University of Pennsylvania
Esteban Puentes, Universidad de Chile
Jere R. Behrman, University of Pennsylvania
Flavio Cunha, University of Pennsylvania
John Hoddinott, International Food Policy Research Institute
John A. Maluccio, Middlebury College
Reynaldo Martorell, Emory University

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Abstract

We use high frequency data from the Philippines and Guatemala in the first 2 years of life to study the impact of protein on height. First, we estimate individual specific height profile functions using various parametric forms from economics and the natural sciences. Based on in-sample and out-of-sample fits, we find that biologically-based models for predicting height profiles perform very well in capturing the variance of height at different ages. Second, taking advantage of a protein supplementation experiment in Guatemala and extensive information on food prices, we estimate the impact of protein intake on individual-specific height profile function coefficients. We use this information to estimate structural models with reference-dependent preferences for the two countries. We evaluate the impact of various counterfactuals on child height growth, including changing parental reference points and providing households with cash transfers or in-kind protein transfers.

1. **Introduction**

Growth retardation during the first years of life apparently has several important damaging effects. Stunted children, that is, children whose length or height[1] is below two standard deviations below the standards of healthy children according to the World Health Organization (WHO), are less likely to enroll in school, tend to enroll late, attain lower levels of schooling, have lower levels of cognition and have less satisfactory adult health, labor market and marriage market outcomes(Grantham-McGregor, et al., (2007); Engle, et al., (2007); Engle, et al., (2011); Victora, et al., (2008); Behrman, et al., (2009); Hoddinott, et al., (2008, 2013) and Maluccio, et al., (2009). It has been estimated, that stunted children could lose 22% of their yearly adult income (Grantham-McGregor, et al. (2007)). In 2010, 171 million children under the age of 5 were considered stunted in the world (de Onis, Blössner & Borghi (2011)). Moreover, children that suffer from stunting tend to come from low-income families, then configuring a clear path of intergenerational poverty transmission (Grantham-McGregor, et al. (2007)).

The main proximate factors responsible for growth retardation are lack of proper nutrition and infection (Victoria, et al. (2008)). In the economics literature, some papers have studied the effect of nutrition correcting for the endogeneity of intakes (Liu, Morz and Adair (2009), de Cao (2011), Griffen (2014) and Puentes, et al. (2014)), finding consistent evidence of the importance of nutrition in height and weight growth. Moreover, Moradi (2010) and Puentes et al. (2014) find that protein intakes, in particular, have a high impact on height. These and other studies (e.g., Behrman and Wolfe (1984); Pitt and Rosenzweig (1985); Behrman and Deolalikar (1987); Bouis and Haddad (1992); Subramanian and Deaton (1996)) link the determinants of nutrient intakes *inter alia* to a number of familial characteristics, typically primarily family resources (income, wealth), parental schooling attainment, and family demographics. Most of these estimates of the links of familial characteristics with child nutrient intakes are reduced-form demand relations (perhaps as the first-stage for 2SLS production function estimates). An exception is Liu et al. (2009), who embody the production relations and nutrient demands into a structural model that

[1] Typically for very young children (e.g., 24 months and younger) length is measured while they are prone, but for older children height is measured. There are standard conversion factors between length and height measures. For more discussion and comparisons, see WHO (2006). For simplicity in what follows we refer to height for all ages.

explicitly models parental reactions to shocks. This model allows them to study how different counterfactual policies could affect children's nutrition and height.

However, familial decisions about allocating nutrients to their children would seem to depend critically on parental beliefs about what is the normal or average height for their children. For parents who live in poor villages in which most of the children are stunted, for example, that their own children are stunted or nearly-stunted may not cause parents to be concerned if their reference for "normal" or expected child growth is other children in their village. But understanding how such parental beliefs translate into nutrition has not been studied even though understanding how parents' perceptions about normal growth affect actual growth may be a key for developing policies that might help break the circle of poverty and help children to develop their full potential. Therefore we develop and estimate a simple structural model to study how parents choose diet intakes that incorporates the beliefs that parents have about the expected height of their children. To study the role of beliefs, through such reference points, we follow Koszegi and Rabin (2006). These reference points indicate what parents believe would be adequate height of their children. In our model, parents can modify their children's height by changing protein intakes and parents know what is the production function for height, but their choices depend in part on their beliefs about the average or normal height expected for their children. Our paper is the first to our knowledge that investigates the potential role of beliefs in children's height growth.

Using data from Guatemala and the Philippines we first estimate and compare different parametric height functions for children between 0 and 24 months of age. These functions allow us to describe the biological processes of height growth. This has been studied in the literature, for example by Stein et al (2010), but we expand on their work by including more potential parametric functions. We then estimate the effect of protein consumption on the key growth parameter of these functions; in this way we study how nutrition affects height growth. To control for the endogeneity of protein intakes, we use prices of different food products, and in the case of Guatemala, we take advantage of a nutritional intervention that randomly assigned a protein-rich supplement to some villages, while other villages received no protein supplement.

Then, we develop a structural model that considers income, price of protein and preferences for height to calculate optimal protein levels. We include in this model explicitly the beliefs of

parents about height. The model allows us to study the impacts of children's height of changes in prices, income transfers and parental beliefs regarding the normal height of children.

Our preliminary results indicate that the growth process is very similar between children of the same age that live in two different countries and at two different points in time. This is striking considering the differences in environment, diet and genetic components between these two samples. We also find that protein plays a key role in children's height.

In terms of parents' beliefs, we find that what parents consider an average or normal height can have an important effect on their children's heights. Our simulations indicate that if parents were to update their beliefs to even conservative measures of normal height, protein intakes could increase considerably with substantial impacts on the heights of their children.

The paper is divided in six sections. The first is this introduction, the second describes the data, the third presents the estimation of the height parametric functions and how protein affects height growth, the fourth presents the structural model and the fifth estimates the structural model and conducts the counterfactual analysis, and the sixth presents the conclusions of the paper.

2. Data

We estimate the models in this paper using Guatemalan and Filipino databases that contain a unique combination of information about children's height and protein consumption, as well as prices and familial background. In this section we describe the data collection process for each country.

2.1 Guatemala

The Guatemalan data are from a study conducted by The Institute of Nutrition of Central America and Panama (INCAP), which started a nutritional supplementation trial in 1969. Four villages from eastern Guatemala were selected, one pair of villages that were relatively large (900 residents each) and one pair that were smaller (500 residents each). The villages were similar in child nutritional status, measured as height at three years of age (Habitch, Martorell and Rivera, (1995)). Over 50% of children lacked proper nutrition, measured as height-for-age z-

scores less than -3 (severely stunted). The intervention consisted of randomly assigning nutritional supplements. One large and one small village were selected to receive a high-protein drink called *Atole,* and the other two were selected to receive an alternative supplement called *Fresco*. Each serving of *Atole* (180 ml) contained 11.5 grams of protein and 163 kcal. *Fresco* had no proteins and each serving (180 ml) had 59 kcal. The main hypothesis was that better nutrition would accelerate mental development. However, at the same time, it was expected that the nutritional supplement would also have an effect on physical growth (Habitch et al., 1995). The intervention started in February 1969 in the larger villages and in May 1969 in the smaller villages, and lasted until the end of February 1977 with data collection taking place until September 1977 (Maluccio et al., 2009; Islam and Hoddinott, 2009). The nutritional supplements were distributed in feeding centers located centrally in each village. The centers were open twice a day, two to three hours in the mid-morning and two to three hours in the mid-afternoon. All village members had access to the feeding centers.[2]

Information on supplement intake was collected daily for all pregnant women and children up to seven years old. Home dietary information was collected every 3 months for children between 0 and 24 months. The home dietary data corresponds to a 24-hour recall in the large villages and a 72-hour recall in the small villages. From the home dietary data it is possible to calculate protein intakes, which we use in our estimations. Anthropometric measures were collected every three months for children 0 to 24 months-old.

2.2 The Philippines

The Cebu Longitudinal Health and Nutritional Survey (CLHNS) is an ongoing survey of more than 2,000 Filipino children born between May 1983 and April 1984 in 33 communities in the Metropolitan Cebu area. The baseline study collected information for 3327 women at a median gestation week of 30, which resulted in 3080 single live births.[3] During the first two years of each child's life, researchers from the University of North Carolina in collaboration with the Office of Population Studies in Cebu collected data every two months. This data included each

[2] Less than 2% of the families refused to participate in the study (Martorell, et al. (1995))
[3] There were 27 twin births, 170 women who migrated before the childbirth or refused to be interviewed, 37 stillbirths and 13 miscarriages (Liu, et al. (2009)).

child's height and weight, food consumption in the past 24-hours, and recent history of illness. The 24-hour food intake history recorded the types and amounts of food eaten in the past day. Total protein intake information was calculated by summing up the nutritional content for each type of food. It is difficult to impute nutritional value from breast-milk time given heterogeneity across mothers; hence, nutrients from breast-feeding were not included in the nutritional intake calculations.

3. Growth Curves and the Role of Protein

In this section of the paper we estimate growth curves for children between 0 to 24 months of age. For each child in the Philippines and Guatemala we estimate nine parametric growth functions, and we study which of the functions have a better fit in and out of sample. We find that four functions tend to outperform the rest of the specifications. We also study how protein intakes during the first 24 months of life affect the parameters of the production function. We find that despite the differences in nutrition and environment between the countries, there are important similarities in terms of best fit and the effect of proteins on the coefficients of the production functions.

3.1 Parametric functions

In figure 1 we show the growth patterns of children in the Philippines and Guatemala, each point in the graph correspond to a child age-height combinations. We observe that children in the Philippines on average are taller than children in Guatemala; at the same time in both countries there is a concave relationship between age and height. Table 1 also shows how at birth, children in Guatemala and Philippines had similar height, but at age 24 months, children in the Philippines were almost two centimeters taller than children in Guatemala and similar differences can be observed throughout the height distributions.

Because there is not a definitive growth equation that explains height growth, we estimate several specifications. These are:

(1) Difference Quadratic: $h_t - h_0 = a * t + b * t^2$

(2) Difference Exponential: $h_t - h_0 = a * t^b$

(3) Quadratic Exponential: $h_t = h_0 \exp\left(a * \log(t)\right)$

(4) Power Exponential: $h_t = h_0 \exp\left(a * t^b\right)$

(5) AR1: $h_t = a + b * h_{t-1}$

(6) AR1 Transformed $h_t = a\left(\frac{1-b^t}{1-b}\right) + b^t * \log(h_0)$

(7) Weibull (Bridge): $h_t - h_0 = \left(h_0 - h_{asymptotic}\right)(1 - b * \exp(-a * t))$

(7') Weibull (Bridge) Linearized: $\log\left(-\log\left(1 - \frac{h_t - h_0}{h_0 - h_{asymptotic}}\right)\right) = \log(a) + \log(t) * b$

(8) Monomolecular: $h_t = h_{asymtotic} * (1 - b * \exp(-a * t))$

(8') Monomolecular Linearized: $\log\left(1 - \frac{h_t}{h_{asymtotic}}\right) = \log(b) - a * t$

(9) Chapman Richard: $h_t - h_0 = \left(h_{asymptotic} - h_0\right) * \left(1 - \exp(-at)\right)^b$

Where, h_t corresponds to height at age t, h_0 is height at birth, $h_{asympotic}$ is final height and a, b are the parameters that we estimate in each case. All of these equations have two parameters with the single exception of equation (3), the quadratic exponential, which has one parameter.

We estimate these nine equations for each child who has a minimum of 8 height observations in Guatemala and a minimum of 12 height observations of the Philippines. For equations 1 to 6 we use the information of height and age from ages 0 to 24 months, for equations 7 to 9, we include final height, defined as height at age 20 years. There are approximately 300 children for Guatemala and 1,600 children for the Philippines that meet all the data requirements.

Fit of the specifications

Instead of comparing the estimates of each function, that by themselves are not very informative, we compare the fit of each of the nine growth specifications to the data. In Figure 2, we compare the residuals for each child at each age in both countries. Each graph in the figure is for a different specification of the growth equation, one striking finding is that the fit of the data does

not vary much by country; in all graphs the nature of the fit is similar. For instance, for equation (3), the quadratic exponential, we observe a very good fit at age 0 months; however, the model over predicts for the first 400 days of life, and under predicts afterwards for both countries. In Figure 3, the R-squared of each child-equation is plotted, for each growth specification. We observe that equation (1), the Difference Quadratic, has a large dispersion for R-squared, while equations (7), Weibull, and (9), Chapman Richards, show higher and more homogenous R-squareds.

In order to compare which specifications have better fits to the data we use the R-squareds for all specifications, calculating the number of times each specification has the first, second and third best fit for every child. The results of this "horse race" comparison are shown in Figure 4A for Guatemala and Figure 4B for the Philippines. For both countries, the Weibull specification provides the best fit, measured as the times it has the highest R-squared. The other specifications that also provide good in-sample fits are the Weibull, AR, Power Exponential and Difference Power. Despite not being the specification that mostly wins this horse race, the Chapman Richards function has also a good fit to the data, since it is frequently among the first three specifications in terms of R-squared.

Next, we perform an out-of-sample analysis for each specification. In each country, there is information on height available after age 24 months. In the case of Guatemala, there is information on height from ages 30 to 84 months in the original 1969-77 study, and for the Philippines, there is information for ages 7 to 22 years across various survey rounds. In Figure 5 gives the residuals of each out-of-sample prediction for both countries. Again, we find a very consistent pattern by specification for both countries. The Monomolecular (8) and Chapman Richards (9) specifications present superior fits out of sample, while the Difference Exponential (2) and Power Exponential (4) also provide on average good fits, but with more variability. For the out-of-sample predictions we compare the fit of each of specification using the Bayesian Information Criteria (BIC), calculating the number of times each specification is the best, second and third in terms of BIC. The horse race summary is presented in Figure 6A for Guatemala and 6B for the Philippines. The graphs show that the Monomonecular (specially for Guatemala), Chapman Richards, Difference Exponential, Power Exponential and Weibull outperform the rest of the specifications.

The results in this section show how similar are the fits of very different parametric functions to changes in height. These important similarities probably reveal deeper biological growth processes despite that the final heights observed in these populations are very different and, as we observed in Puentes, et al (2014), nutrition, breastfeeding and diseases patterns are very different too. In terms of the functions that provide the best fit, we find that the Difference Equation with a Power term and the Chapman Richard specifications have good performances in-sample and out-of-sample, while the Weibull specification has a good performance in-sample, but not so good out-of-sample. While the Monomolecular specification performs relatively poorly in-sample, it is the best out-of-sample. In the following sections we study the role of diet and beliefs in the growth process. Based on the in-sample and out-of-sample fits, we selected only four of the nine functions to study robustness of our results: Difference Equation with a power, Chapman Richards, Weibull, and Monomolecular.

3.2 Impact of Protein on Parameters of Growth Curves

In this section we study how heterogeneity in growth paths among children can be explained by differences in diets, particularly of proteins. Height paths are the result of several factors, but proteins intakes play a key role. Moradi (2010) finds that high –quality protein, compared to other energy, is a better predict of height in some African countries, and Puentes, et al. (2014), find that protein consistently increases height for children but energy from fat and carbs are not robustly related to height[4]. To study the role of proteins in this context, we use the parameters obtained for each child and for each specification and regress them on the amount of protein consumed over the 0 to 24 month period. We control for initial height, weight and gender. As mentioned in the last section, we restrict our analysis to the following specifications: Difference Equation with a Power, Chapman Richards, Weibull, and Monomolecular.

In detail, the way we study the role of proteins can be illustrated with the monomolecular equation, in which case the parametric function is:

[4] Proteins are needed to balance nitrogen loss, maintain the body's protein mass and fulfill needs related to tissue deposition (WHO, (2007). Moreover, the nutritional literature emphasizes the role of high quality protein, specially animal-based protein, on height growth (Molgaard et al. (2001), Michaeslen (2013) and Dewey (2013)).

$$h_{it} = h_{asymptotic}\left(1 - b_i * exp(-a_i * t)\right)$$

This equation first is estimated for each child in the Philippines and Guatemala. Then, for each set of parameters, the following set of equations are estimated to study how proteins affect the growth path:

$$a_i = \alpha_1 + \alpha_2 H_{i,0} + \alpha_3 W_{i,0} + \alpha_4 Male_i + \alpha_5 Prot_{0,24}$$

$$b_i = \beta_1 + \beta_2 H_{i,0} + \beta_3 W_{i,0} + \beta_4 Male_i + \beta_5 Prot_{0,24}$$

Where $H_{i,0}$ is height at birth, $W_{i,0}$ is weight at birth, $Male_i$ is a dummy variable equal 1 if the child is a boy and $Prot_{0,24}$ is the amount of proteins consumed from ages 0 to 24 months.

Because nutrient intakes reflect choices, we use instrumental variables techniques to control for endogeneity. The instruments used vary by country. For Guatemala we use the *Atole* supplement intervention that took place during 1969 to 1977 and annual prices of several goods that affect the relative demand for proteins: chicken, beef, corn and rice. For the Philippines, we use bi-monthly prices, collected in each Barangay: formula milk, rice and dried fish. Also a hedonic price of protein is constructed using a larger set of prices and the protein content of each good as weights. The hedonic protein price is calculated for Guatemala and the Philippines.

Tables 3A and 3B for Guatemala and 4A and 4B for the Philippines give the estimated impacts of the average protein intakes from ages 0 to 24 months on the coefficients of each specification. In Guatemala, when we use food prices and the *Atole* dummy, we find a significant impact of protein intake on the coefficients of the growth functions. When the protein price is used, standard errors tend to increase, lowering the significance of the protein coefficients. For the Philippines, in Tables 4A and 4B, we find a similar pattern when only prices are used as instruments, all protein coefficients are significant; however, the hedonic protein price increases standard errors, affecting the significance of the parameters.

From the equations it is not directly possible to evaluate if the effect of protein intake on growth is positive or negative. Therefore, to approximate the effect of changing protein intake of growth we calculate counterfactuals. In Figures 7A (Guatemala) and 7B (Philippines) we compare the average difference in height when children eat no protein during their first 24 months of life versus eating the median of protein intake. In each figure we compare the counterfactual exercise

using the OLS coefficients, the IV coefficients when food prices are used as instruments and the IV coefficients when the hedonic protein price is used as instrument. At the same time, we compare the effect for the four different growth models. In almost all cases, increasing protein intake increases height, except for the monomolecular model at early ages.[5] At age 24 months, the differences in height could be of at least 1 cm. These results are consistent with previous research that finds an important effect of protein intakes on height (Moradi (2010), Puentes, et al. (2014)). The effect of protein is related to the importance of protein on tissue accumulation and bone growth, a further discussion can be found in Puentes, et al. (2014).

The result of the protein effect on height is important by itself, but we also use this relationship as an input of a structural model of household decisions that we study in next section.

4. Structural Model

In this section we present a structural model for how households choose the level of protein children consume, considering the beliefs that parents have about how tall their children could be. This model allows us to simulate how different policies that affect parental beliefs can affect their choices and, thus, their children's height.

Household utility depends on consumption other than proteins for the children and height of children. The model is static with households making one choice of protein intakes for the first 24 months of children's lives. Following Koszegi and Rabin (2006), households care about children's height relative to a reference point, which is the expected height of children at 24 months of age. Parents form their beliefs about expected height comparing and averaging the height of children that live in their village. In terms of budget constraints, households have to allocate incomes to protein consumption of children and the rest of the goods for children and the family. Incomes and the price of proteins are exogenous.[6]

We assume the following quadratic household utility function:

[5] In the previous section we observed that the monomolecular model had a very bad fit for height at age 0; this explains the bad fit of the model for the early ages.

[6] We generate income in Guatemala based on a household wealth index and village average and standard deviation income. For the Philippines we use a wealth index and income collected in the baseline.

$$U = c + \rho * c^2 + \gamma_1 * h + \gamma_2 * h^2 + \theta * h * c + \lambda * REF(h)$$

Where c is household consumption other than for child proteins, h is the height of the child at age 24 months and $REF(h)$ is the reference point that parents use when comparing the height of their children with a reference group. For comparison purposes we also consider a linear utility $U = c + \gamma_1 * h + \lambda * REF(h)$ and a quadratic utility without a reference point $U = c + \rho * c^2 + \gamma_1 * h + \gamma_2 * h^2 + \theta * h * c$.

We assume that parents try to minimize the expected distance between their children's height (h) and the average-reference height ($RefH$), taking into consideration that there is a distribution of potential heights of children. The average height that parents expect their children to obtain is the average height of children of the same sex and age in the village where they live. Parents beliefs about the standard deviation of the reference distribution is the observed standard deviation of the mean of heights of children of the same age and sex in the village where they live. Household utility decreases only if the expected distance is negative. Then the reference point part of the household utility we consider is:

$$REF(h) = E_{RefH}[(h - RefH)1\{h < RefH\}]$$

$$= \left(h - \mu_{RefH}\right)\left(1 - \Phi\left(\frac{H - \mu_{RefH}}{\sigma_{RefH}}\right)\right) - \sigma_h \phi\left(\frac{H - \mu_{RefH}}{\sigma_{RefH}}\right)$$

Where $1\{\}$ is an indicator function, μ_{RefH} is the average height of children of the same sex, in the same village at age 24 months, and σ_{RefH} is the standard deviation of the mean of heights of children of the same sex, in the same village at age 24 months. We assume that beliefs follow a normal distribution, under which assumptions we can express the expected value as a function of densities and cumulative functions of a normal distribution. Since the reference point is assumed to vary by village, we can take advantage of the geographic variation in height to identify λ. We assume that height variation in the village is exogenous for individual households and that the village height distribution is unrelated to the choice of living in that village. Then parents face

the height distribution of other children in their village as relevant information about the height potential of their own children.[7]

The budget constraint varies by country. In Guatemala, to take into account that some villages received free protein, we characterize the amount of protein other than the free protein to enter into the budget constraint, treating as exogenous the level consumed of free protein.[8] Then, the budget constraint in villages with free protein is:

$$c = Y - P * (Prot - FreeProtein)$$

Where $Prot$ is the protein consumed by children in the first 24 months of life, Y is income and $FreeProtein$ is the amount of protein consumed from Atole.

The budget constraint of Filipino households and households in Guatemala that did not received free protein is:

$$c = Y - P * Prot$$

Finally, we assume that parents know the height production function, that is, how protein intake affects the coefficients of the height production function. We estimate the structural model using the Weibull, Chapman Richards, Monomolecular and Difference in Power production functions.

5. Estimation

The structural models are estimated using maximum likelihood. For each household we calculate the optimal protein intake and compare this amount with the actual amount, assuming that the actual amount of protein intake is measured with error, and the error term follows a normal distribution with mean zero and standard deviation σ_ε. The estimates are presented in table 5. We restricted the quadratic terms to be negative, and the interaction between height and c was constraint to be positive.

[7] For the Philippines, instead of using information by village, we grouped urban and rural villages and used four reference points, by zone and gender. In Guatemala we have eight reference points, by (four) villages and gender.

[8] In US dollars of 2004 the average income in the Philippines is $1973, and $2278 in Guatemala. The price of 100 grams of protein in the Philippines is $0.84, in Guatemala is $2.49.

Tables 6A and 6B show the fit of the structural model for Guatemala and the Philippines, respectively. Each table shows the fit for three different household utility functions and the four parametric height equations. We compare the mean, standard deviation and the 10th, 25th, 50th, 75th and 90th percentiles of child actual and predicted protein consumption.[9] We also report the R-squared when regressing the actual protein consumption of the model prediction and a constant.

For Guatemala we find that the quadratic utility function with a reference point performs better than the other utility functions in terms of R-squared fit. Also the difference equation with a power of height performs better than the other three parametric height functions. In terms of the distribution of protein consumption, all utility functions and parametric height functions predict zero protein consumption for too many children. In all the 12 possible cases, the 25th percentile predicts zero protein consumption, however predictions for the 75th and 90th percentile are more accurate. The results of the predicted distributions explain why these models predict generally low mean protein consumption and high standard deviations, compare with the actual means and standard deviations.

Table 6B shows the results for the Philippines. We find a better fit in terms of the R-squares and for the overall distribution of protein consumption. Again, the quadratic utility function with the reference point outperforms the other two utility functions, but for the Philippines the Monomolecular height function provides the better fit in terms of R-squared. Similarly to Guatemala, the model tends to over predict zero protein intakes; however, at the 25th percentile the predictions for the Philippines are closer to the actual intakes. In terms of the means and standard deviations of the predictions, the models tend to under predict the means and over predict the standard deviations, though the models perform markedly better than for Guatemala.

Counterfactuals

Using the estimates of the height production functions and the structural model, we simulated three counterfactual exercises: The first one is to equalize *Atole* and *Fresco* villages in Guatemala; to do that we first subtract from *Atole* villages the protein consumption from the

[9] The model predicts consumption without measurement error, while the actual protein consumption includes measurement error.

Atole consumption and force the *Atole* villages to adopt the reference point of the *Fresco* villages. Similarly, in a second part of the exercise, we give to *Fresco* villages the average protein intake from the drink *Atole* consumed in *Atole* villages, and we then study the change in protein in *Fresco* villages if they were to have the reference point of the *Atole* villages.

In figures 8A we show the results of this counterfactual exercise. In the first panel of figure 8A we observe the height distribution: a) in the baseline of *Atole* villages; b) in the baseline of *Fresco* villages; c) when *Atole* villages have the reference point of *Fresco* villages; d) when *Atole* villages are assumed to lose their *Atole* protein intake and; and e) which is c) and d) together. We observe that when *Atole* villages lose their *Atole* intake children's height is reduced from an average of 77 cm to 76.7 cm. Next, if only the reference point changes, the average height is now 76.6 cm. Finally, when both the reference point and the intake changes, the average height drops to 76.1 cm, close to the average of the *Fresco* villages of 76 cm.

The second panel of figure 8A is similar to the first panel, in this case we observe the height distribution for the following cases: a) baseline of *Atole* villages; b) baseline of *Fresco* villages; c) when Fresco villages have the reference point of *Atole* villages; d) when *Fresco* villages are assumed to receive the average *Atole* protein intake of *Atole* villages and; e) which c) and d) together. Similarly to figure 8A, we observe that if *Fresco* villages had the reference point of *Atole* villages, average children's height would increase from 76 cm to 76.7 cm, and if *Fresco* villages were given only the average *Atole* consumption, height would also increase to 76.7. Finally, in the case of changing the reference point and receiving the average *Atole* proteins, the average height of children in *Fresco* villages would be 77.3 cm, higher that the average of 77 cm in *Atole* villages. These exercises show the importance of reference points and the *Atole* intervention to explain the differences in heights in *Atole* and *Fresco* villages.

In figure 8B we perform the same counterfactuals, but using different height production function, similar patterns are found, in all cases the changes in reference points and free proteins make *Atole* and *Fresco* villages more alike.

In the second counterfactual, households in the Philippines receive 8.4 grams of protein for free; this is average of proteins from *Atole* consumed in *Atole* villages. Figure 9A shows the change in height and protein distributions. In the first panel we see that the average height increases from

79 cm to 79.5 cm, while mean protein consumption increases from 7.8 grams to 14.5 grams, which is less than the free proteins given to the households. This substitution of proteins was also found for Guatemalan *Atole* households (Islam and Hoddinott, 2009). Figure 9B shows the same counterfactual exercise but using different height production functions; the same results hold.

The third counterfactual corresponds to changing the reference points that parents have for the WHO height reference (WHO, 2006). We assume that households use the 10^{th} and the 50^{th} percentile of the WHO height distribution as their new reference points. Figure 10A shows the changes in the height distribution for the Philippines and Guatemala, using the 4 parametric height production functions. The graphs show an important increment in height for both countries. In the case of the Philippines, height could increase close to 3 cm if households were to use as reference point the 10^{th} percentile of the WHO height distribution, and close to 6 cm if they were using the 50^{th} percentile. In the case of Guatemala, the changes are more moderate and depend on the parametric height production function assumed. If households were to use the 10^{th} percentile of the WHO distribution, height could increase between 0.6 and 3 cm, while if households were considering the 50^{th} percentile of the WHO height distribution the increase in height ranges from 0.9 to 5.4 cm. Figure 10B shows the changes of protein consumption of children when parents adopt different reference points. For the Philippines we observe important changes in average protein consumption, more than doubling if parents use the 50^{th} percentile of the WHO height distribution as reference points. For Guatemala we also observe important increments in protein consumption.

The counterfactual exercises suggest that households in Guatemala and the Philippines would react more substantially to information about optimal height of their children being the WHO distribution for well-nourished children than to food interventions that provide food for free on the order of magnitude of the INCAP trial. This is an important result because it suggests that health interventions should consider transfer of information as a key component to increase health of children.

6. Conclusion

We adapt and study how parametric functions can describe changes in height for infants between 0 and 24 months of age, finding striking similarities for two different countries at two different

points in time. This result indicates that human biology is very similar despite the observed differences in final height across countries and over time. Additionally, we find that protein intakes play a key role in height growth during the first two years of life.

Another important contribution of our paper is to consider parents' beliefs as important factors that may determine the growth process of their children. Our preliminary results suggest that parents in the Philippines and Guatemala have beliefs about the average height their children that are affecting the potential growth of their children. Our simulations suggest that if parents update their beliefs from local height distributions to even conservative WHO standards, the heights of their children could increase importantly. Moreover, the usual policies to combat under-nutrition such as cash transfers or delivery of nutrients free of charge do not have nearly as strong effects on children's height. These results indicate that a comprehensive policy that includes information about expected height for age, nutritional information and transfers may be needed to improve the health of children. Future research should study how parents create and update their beliefs about what is healthy for their children and what role policies can play in this process.

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Tables and Figures

Table 1: Descriptive Statistics

Summary Statistics for Height, Protein and Protein prices

	mean	sd	p5	p10	p25	p50	p75	p90	p95	count
Cebu										
Average Protein Intake Between Month 6 and 24	15.320	9.129	4.737	5.926	8.712	13.139	19.739	27.208	33.384	1576
Height at Month 0	49.291	2.093	45.800	46.700	48.000	49.350	50.500	51.700	52.500	1576
Height at Month 12	70.806	2.899	65.800	67.100	69.000	71.000	72.800	74.400	75.500	1566
Height at Month 24	79.237	3.610	73.100	74.500	77.000	79.400	81.600	83.700	85.000	1576
hgtFin	157.490	8.214	144.400	146.800	151.400	157.300	163.500	168.200	171.200	1576
Average Protein Price Between Month 6 and 24	2482.080	1144.345	1009.589	1177.147	1632.358	2222.567	3318.527	3863.299	4256.185	1576
Guat										
Average Protein Intake Between Month 6 and 24	20.268	8.791	8.350	10.283	13.900	19.033	24.557	32.100	37.367	296
Height at Month 0	49.554	2.325	45.700	46.700	48.000	49.650	51.200	52.500	53.100	296
Height at Month 12	68.566	2.941	64.000	65.000	66.800	68.600	70.600	72.400	73.100	287
Height at Month 24	77.373	3.446	71.000	72.500	75.200	77.450	79.600	81.800	83.000	296
hgtFin	156.615	8.411	143.800	146.250	150.350	155.800	162.475	167.950	170.500	296
Average Protein Price Between Month 6 and 24	52.644	3.527	46.884	47.647	49.334	52.854	55.901	57.035	57.396	296

Table 2A: Number of Observations available, Guatemala

Guatemala, Number of Rounds Observed for Each Child Between 0 and 24 months

	1-5 rounds observed	6 rounds observed	7 rounds observed	8 rounds observed	9 rounds observed
Number of Children WITHOUT:					
month 0 hgt	305	71	92	84	0
month 24 hgt	375	51	41	27	0
adult hgt	286	30	58	65	132
Number of Children WITH:					
any month hgt	559	121	149	214	370
mth 0 and mth 24 hgt	3	10	28	103	370
mth 0, mth 24, adult hgt	0	6	18	67	238

1.1, Value in cells represent the number of children whose height is observed for x number of rounds between month 0 and month 24

1.2, For example, top left first cell is: the number of children with height observed 0-9 times between 0-24 mth who were not obsered on mth 0

2.1, For proper comparison across individuals, we require children used for estimation to have observation on month 0 and month 24

2.3, For proper comparison across individuals, we require children used for estimation to have at least 8 observations

2.4, For the 3 biological models, we require children to have final height

Table 2B: Number of Observations available, Philippines

Philippines, Number of Rounds Observed for Each Child Between 0 and 24 months

	1-9 rounds observed	10 rounds observed	11 rounds observed	12 rounds observed	13 rounds observed
Number of Children WITHOUT:					
month 0 hgt	4	0	2	1	0
month 24 hgt	236	27	33	41	0
adult hgt	222	31	44	85	535
Number of Children WITH:					
any month hgt	263	55	89	201	2105
mth 0 and mth 24 hgt	27	28	55	159	2105
mth 0, mth 24, adult hgt	17	17	34	99	1570

1.1, Value in cells represent the number of children whose height is observed for x number of rounds between month 0 and month 24

1.2, For example, top left first cell is: the number of children with height observed 0-9 times between 0-24 mth who were not obsered on mth 0

2.1, For proper comparison across individuals, we require children used for estimation to have observation on month 0 and month 24

2.3, For proper comparison across individuals, we require children used for estimation to have at least 12 observations

2.4, For the 3 biological models, we require children to have final height

Table 3A: Protein effect on coefficients, Guatemala

Guat, Instrument Set Multiple Prices

	(1) DPOW a	(2) DPOW b	(3) CHPM a	(4) CHPM b	(5) BRIDGE a	(6) BRIDGE b	(7) MONO a	(8) MONO b
0-24 mths avg GM/DAY Protein	-0.00455	0.00153*	0.00160*	0.00000178**	-0.00874	0.00167*	0.000761***	-0.00000200***
	(-0.89)	(1.90)	(1.77)	(2.47)	(-1.64)	(1.93)	(4.35)	(-4.12)
wgt0	0.000213***	-0.0000301**	-0.0000333**	-1.65e-08	0.000228***	-0.0000303**	-0.00000754***	4.64e-09
	(2.71)	(-2.42)	(-2.40)	(-1.52)	(2.76)	(-2.28)	(-2.88)	(0.62)
hgt0	-0.119***	0.0160***	0.0176***	0.00000582**	-0.123***	0.0156***	-0.00176***	0.00000292*
	(-6.72)	(5.66)	(5.79)	(2.44)	(-6.60)	(5.18)	(-3.13)	(1.81)
Male	0.378***	-0.0572***	-0.0682***	-0.0000670***	0.306***	-0.0633***	0.0256***	0.0000515***
	(6.86)	(-6.56)	(-7.00)	(-8.78)	(5.30)	(-6.80)	(13.82)	(9.99)
Constant	4.495***	-0.0925	-0.142	-0.0000602	-0.117	-0.0220	-0.335***	-0.000535***
	(6.18)	(-0.80)	(-1.14)	(-0.62)	(-0.15)	(-0.18)	(-14.57)	(-8.17)
Hansen-J p	0.582	0.689	0.792	0.794	0.716	0.733	0.518	0.144
Ander Under p	1.07e-19	1.46e-19	1.03e-19	7.17e-19	1.21e-19	3.40e-19	1.18e-19	8.43e-20
First Stage F	25.02	24.86	25.05	23.71	24.92	24.20	24.90	25.51
Atole	instru	instru	instru	instru	instru	instru	instru	instru
Egg Price	instru	instru	instru	instru	instru	instru	instru	instru
Chicken Price	instru	instru	instru	instru	instru	instru	instru	instru
Pig Price	instru	instru	instru	instru	instru	instru	instru	instru
Beef Price	instru	instru	instru	instru	instru	instru	instru	instru
Corn Price	instru	instru	instru	instru	instru	instru	instru	instru
Rice Price	instru	instru	instru	instru	instru	instru	instru	instru
N	295	293	295	291	295	293	296	288
r2	0.205	0.163	0.184	0.210	0.161	0.157	0.438	0.305

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3B: Protein effect on coefficients, Guatemala

Guatemala, Instrument Only Protein Price

	(1) DPOW a	(2) DPOW b	(3) CHPM a	(4) CHPM b	(5) BRIDGE a	(6) BRIDGE b	(7) MONO a	(8) MONO b
0-24 mths avg GM/DAY Protein	-0.00431	0.00145	0.00154	0.00000169**	-0.00815	0.00163	0.000673***	-0.00000215***
	(-0.72)	(1.56)	(1.47)	(2.04)	(-1.32)	(1.62)	(3.37)	(-3.85)
wgt0	0.000212***	-0.0000299**	-0.0000332**	-1.62e-08	0.000226***	-0.0000302**	-0.00000732***	5.02e-09
	(2.69)	(-2.39)	(-2.38)	(-1.49)	(2.73)	(-2.25)	(-2.81)	(0.66)
hgt0	-0.119***	0.0159***	0.0176***	0.00000577**	-0.123***	0.0156***	-0.00179***	0.00000286*
	(-6.69)	(5.62)	(5.77)	(2.41)	(-6.56)	(5.14)	(-3.20)	(1.76)
Male	0.378***	-0.0571***	-0.0681***	-0.0000669***	0.306***	-0.0632***	0.0256***	0.0000516***
	(6.85)	(-6.55)	(-6.99)	(-8.77)	(5.29)	(-6.78)	(13.94)	(9.93)
Constant	4.485***	-0.0894	-0.140	-0.0000571	-0.139	-0.0201	-0.332***	-0.000531***
	(6.09)	(-0.77)	(-1.12)	(-0.58)	(-0.18)	(-0.16)	(-14.45)	(-8.01)
Hansen-J p	0.182	0.669	0.666	0.636	0.395	0.926	0.0970	0.0254
Ander Under p	5.56e-17	7.16e-17	4.57e-17	1.61e-16	5.97e-17	1.54e-16	2.23e-17	1.47e-17
First Stage F	49.13	48.80	49.48	47.48	49.01	47.46	50.70	51.93
Atole	instru	instru	instru	instru	instru	instru	instru	instru
Hedonic Protein Price	instru	instru	instru	instru	instru	instru	instru	instru
N	295	293	295	291	295	293	296	288
r2	0.206	0.165	0.185	0.212	0.163	0.158	0.446	0.296

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4A: Protein effect on coefficients, Philippines

Cebu, Instrument Set Multiple Prices

	(1) DPOW a	(2) DPOW b	(3) CHPM a	(4) CHPM b	(5) BRIDGE a	(6) BRIDGE b	(7) MONO a	(8) MONO b
0-24 mths avg GM/DAY Protein	-0.0262***	0.00460***	0.00508***	0.00000490***	-0.0264***	0.00513***	0.000643***	-0.00000348***
	(-3.24)	(3.64)	(3.55)	(4.09)	(-3.24)	(3.95)	(2.62)	(-5.56)
wgt0	0.000513***	-0.0000750***	-0.0000836***	-5.51e-08***	0.000504***	-0.0000733***	-0.00000445***	-2.35e-09
	(9.36)	(-8.89)	(-8.88)	(-7.11)	(9.18)	(-8.38)	(-2.59)	(-0.54)
hgt0	-0.173***	0.0245***	0.0282***	0.0000148***	-0.177***	0.0247***	-0.00281***	0.00000441***
	(-14.65)	(13.50)	(13.86)	(8.84)	(-15.01)	(13.13)	(-7.69)	(4.75)
Male	0.243***	-0.0321***	-0.0400***	-0.0000488***	0.173***	-0.0395***	0.0298***	0.0000395***
	(7.50)	(-6.44)	(-7.13)	(-10.57)	(5.34)	(-7.65)	(29.70)	(15.53)
Constant	6.785***	-0.443***	-0.579***	-0.000409***	2.200***	-0.409***	-0.304***	-0.000589***
	(14.80)	(-6.27)	(-7.34)	(-6.30)	(4.78)	(-5.57)	(-21.37)	(-16.25)
Hansen-J p	0.0100	0.00298	0.00219	0.000468	0.00628	0.00348	0.557	0.382
Ander Under p	1.50e-22	2.26e-22	3.13e-22	3.43e-22	1.41e-22	1.59e-22	3.25e-22	4.79e-22
First Stage F	29.20	28.96	28.76	28.71	29.23	29.17	28.74	28.53
Formula Milk Price	instru	instru	instru	instru	instru	instru	instru	instru
Egg Price	instru	instru	instru	instru	instru	instru	instru	instru
Rice Price	instru	instru	instru	instru	instru	instru	instru	instru
Dried fish Price	instru	instru	instru	instru	instru	instru	instru	instru
N	1429	1425	1428	1426	1428	1425	1430	1417
r2	0.145	0.131	0.148	0.125	0.154	0.131	0.421	0.189

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4B: Protein effect on coefficients, Philippines

Cebu, Instrument Only Protein Price

	(1) DPOW a	(2) DPOW b	(3) CHPM a	(4) CHPM b	(5) BRIDGE a	(6) BRIDGE b	(7) MONO a	(8) MONO b
0-24 mths avg GM/DAY Protein	-0.00714	0.00242	0.00287	0.00000441***	-0.0113	0.00336**	0.000244	-0.00000473***
	(-0.69)	(1.52)	(1.59)	(2.93)	(-1.10)	(2.05)	(0.74)	(-5.14)
wgt0	0.000455***	-0.0000667***	-0.0000746***	-4.90e-08***	0.000448***	-0.0000653***	-0.00000355**	-1.77e-09
	(9.00)	(-8.50)	(-8.43)	(-6.66)	(8.78)	(-8.00)	(-2.21)	(-0.40)
hgt0	-0.174***	0.0242***	0.0275***	0.0000141***	-0.175***	0.0241***	-0.00280***	0.00000511***
	(-15.35)	(13.77)	(13.84)	(8.56)	(-15.39)	(13.20)	(-7.79)	(5.16)
Male	0.229***	-0.0306***	-0.0385***	-0.0000487***	0.162***	-0.0381***	0.0300***	0.0000398***
	(7.56)	(-6.51)	(-7.23)	(-10.98)	(5.28)	(-7.80)	(31.54)	(15.23)
Constant	6.789***	-0.425***	-0.547***	-0.000389***	2.097***	-0.379***	-0.303***	-0.000612***
	(15.77)	(-6.36)	(-7.24)	(-6.19)	(4.83)	(-5.45)	(-22.20)	(-16.23)
Ander Under p	1.03e-14	9.76e-15	9.46e-15	1.31e-14	7.55e-15	5.91e-15	2.24e-14	5.27e-14
First Stage F	61.98	62.09	62.16	61.46	62.63	63.16	60.33	58.55
Hedonic Protein Price	Instru	instru	instru	instru	instru	instru	instru	instru
N	1596	1592	1595	1592	1595	1592	1596	1580
r2	0.184	0.161	0.168	0.126	0.180	0.157	0.429	0.0625

t statistics in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Model Coefficients

	Model 1: Linear utility reference point		HEIGHT Coefficients	C Quadratic	C*Height	Protein Mrs Error
		Lambda	**Height**			**Measu Err SD**
Guatemala	Weibull	0.031	1.46E-21			14.505
Guatemala	Chapman Richards	0.024	8.00E-16			15.350
Guatemala	Monomolecular	0.042	6.27E-18			13.888
Guatemala	Difference Power	0.029	3.11E-21			14.174
Cebu	Weibull	1.571	3.16E-18			12.212
Cebu	Chapman Richards	1.618	4.38E-212			12.012
Cebu	Monomolecular	1.730	6.62E-32			10.531
Cebu	Difference Power	1.647	4.73E-245			14.265

	Model 2 Quadratic Utility and Reference Point		HEIGHT Coefficients				Protein Mrs Error
		Lambda	**Height**	**Height Squared**	**C Quadratic**	**C*Height**	**Measu Err SD**
Guatemala	Weibull	0.419	0.791	-0.073	-0.146	0.000	13.290
Guatemala	Chapman Richards	0.001	0.000	-9.77E-06	-2.89E-17	0.167	14.832
Guatemala	Monomolecular	0.140	3.923	-0.260	-0.042	0.000	13.835
Guatemala	Difference Power	26.895	77.171	-6.551	-17.354	0.000	13.016
Cebu	Weibull	3.346	0.027	-0.115	-8.49E-09	0.023	9.551
Cebu	Chapman Richards	117.192	0.000	-31.628	-2.21E-08	0.680	9.852
Cebu	Monomolecular	108.171	0.026	-28.231	-9.52E-09	0.663	9.051
Cebu	Difference Power	1.840	4.202	-0.003	-2.16E-06	0.004	11.488

	MODEL 3: Quadratic Utility	HEIGHT Coefficients				Protein Mrs Error
		Height	**Height Squared**	**C Quadratic**	**C*Height**	**Measu Err SD**
Guatemala	Weibull	3.123	-0.206	-3.69E-05	4.10E-10	13.671
Guatemala	Chapman Richards	0.491	-0.914	-1.68E-05	4.31E-09	16.242
Guatemala	Monomolecular	2.983	-0.194	-2.25E-05	5.12E-10	13.856
Guatemala	Difference Power	3.044	-0.204	-0.174	1.00E-13	13.118
Cebu	Weibull	33.664	-21.512	-0.005	4.74E-08	9.657
Cebu	Chapman Richards	38.835	-2.44E-06	-1.82E-29	5.319	10.475
Cebu	Monomolecular	161.793	-1.02E-05	-1.29E-194	19.285	9.448
Cebu	Difference Power	1.60209E-33	-1.11E+10	-3363.374	0.706	17.239

Table 6A: Structural Model Fit

Guat Model 1: Linear Utility and Reference Point

$$U = c + \gamma_1 \cdot h + \lambda \cdot REF(H)$$

GUAT MODEL FIT (do not simulated msr error)

	R2	Mean	SD	p10	p25	p50	p75	p90
Actual Observed	1.00	15.20	5.80	8.35	11.24	14.50	19.00	23.63
Weib Esti	0.02	6.05	10.78	0.00	0.00	0.00	8.85	22.66
Chap Esti	0.03	1.40	5.24	0.00	0.00	0.00	0.00	0.00
Mono Esti	0.02	6.03	10.88	0.00	0.00	0.00	7.99	22.49
Diff Esti	0.03	6.33	10.41	0.00	0.00	0.00	9.95	20.50

NOTE: Hedonic Protein Price as Instrument

Guat Model 2: Quadratic Utility and Reference Point

$$U = c + \rho \cdot c^2 + \gamma_1 \cdot h + \gamma_2 \cdot h^2 + \theta \cdot h \cdot c + \lambda \cdot REF(H)$$

GUAT MODEL FIT (do not simulated msr error)

	R2	Mean	SD	p10	p25	p50	p75	p90
Actual Observed	1.00	15.20	5.80	8.35	11.24	14.50	19.00	23.63
Weib Esti	0.05	11.24	12.64	0.00	0.00	7.88	18.12	30.37
Chap Esti	0.05	3.99	9.20	0.00	0.00	0.00	0.00	17.46
Mono Esti	0.05	9.71	12.61	0.00	0.00	5.30	15.63	26.87
Diff Esti	0.07	11.24	12.51	0.00	0.00	7.81	17.48	29.97

NOTE: Hedonic Protein Price as Instrument, Quadratic Utility with Reference Point

Guat Model 3: Quadratic Utility

$$U = c + \rho \cdot c^2 + \gamma_1 \cdot h + \gamma_2 \cdot h^2 + \theta \cdot h \cdot c$$

GUAT MODEL FIT (do not simulated msr error)

	R2	Mean	SD	p10	p25	p50	p75	p90
Actual Observed	1.00	15.20	5.80	8.35	11.24	14.50	19.00	23.63
Weib Esti	0.04	9.97	12.42	0.00	0.00	5.18	16.68	28.47
Chap Esti	0.00	0.03	0.48	0.00	0.00	0.00	0.00	0.00
Mono Esti	0.04	9.43	12.47	0.00	0.00	5.03	15.79	27.09
Diff Esti	0.07	11.04	12.61	0.00	0.00	7.20	17.48	29.69

NOTE: Hedonic Protein Price as Instrument

Table 6B: Structural Model Fit

Cebu Model 1: Linear Utility and Reference Point

$$U = c + \gamma_1 \cdot h + \lambda \cdot REF(H)$$

CEBU MODEL FIT (do not simulated msr error)

	R2	Mean	SD	p10	p25	p50	p75	p90
Actual Observed	1.00	15.29	9.12	5.92	8.71	13.11	19.68	27.21
Weib Esti	0.14	17.17	12.05	0.43	7.84	16.19	24.43	33.34
Chap Esti	0.13	8.27	9.16	0.00	0.00	5.54	13.68	20.85
Mono Esti	0.28	8.45	9.94	0.00	0.00	5.27	13.80	23.14
Diff Esti	0.09	10.22	11.95	0.00	0.00	6.16	16.80	27.25

NOTE: Hedonic Protein Price as Instrument

Cebu Model 2: Quadratic Utility and Reference Point

$$\boldsymbol{U = c + \rho \cdot c^2 + \gamma_1 \cdot h + \gamma_2 \cdot h^2 + \theta \cdot h \cdot c + \lambda \cdot REF(H)}$$

CEBU MODEL FIT (do not simulated msr error)

	R2	Mean	SD	p10	p25	p50	p75	p90
Actual Observed	1.00	15.29	9.12	5.92	8.71	13.11	19.68	27.21
Weib Esti	0.32	14.55	10.92	0.55	6.48	13.09	21.01	29.04
Chap Esti	0.28	14.77	10.73	0.00	6.84	13.98	21.14	28.82
Mono Esti	0.43	13.95	11.45	0.00	4.98	12.07	20.59	29.15
Diff Esti	0.24	13.53	12.62	0.00	2.96	10.80	21.01	31.14

NOTE: Hedonic Protein Price as Instrument, Quadratic Utility with Reference Point

Cebu Model 3: Quadratic Utility

$$U = c + \rho \cdot c^2 + \gamma_1 \cdot h + \gamma_2 \cdot h^2 + \theta \cdot h \cdot c$$

CEBU MODEL FIT (do not simulated msr error)

	R2	Mean	SD	p10	p25	p50	p75	p90
Actual Observed	1.00	15.28	9.11	5.92	8.71	13.11	19.65	27.17
Weib Esti	0.32	14.57	11.10	0.13	6.14	13.20	20.93	29.55
Chap Esti	0.22	14.32	10.83	0.00	5.80	13.69	20.87	28.68
Mono Esti	0.38	13.58	11.46	0.00	4.25	11.69	20.35	29.08
Diff Esti	0.09	1.21	7.46	0.00	0.00	0.00	0.00	0.00

NOTE: Hedonic Protein Price as Instrument

Figure 1: Height profiles

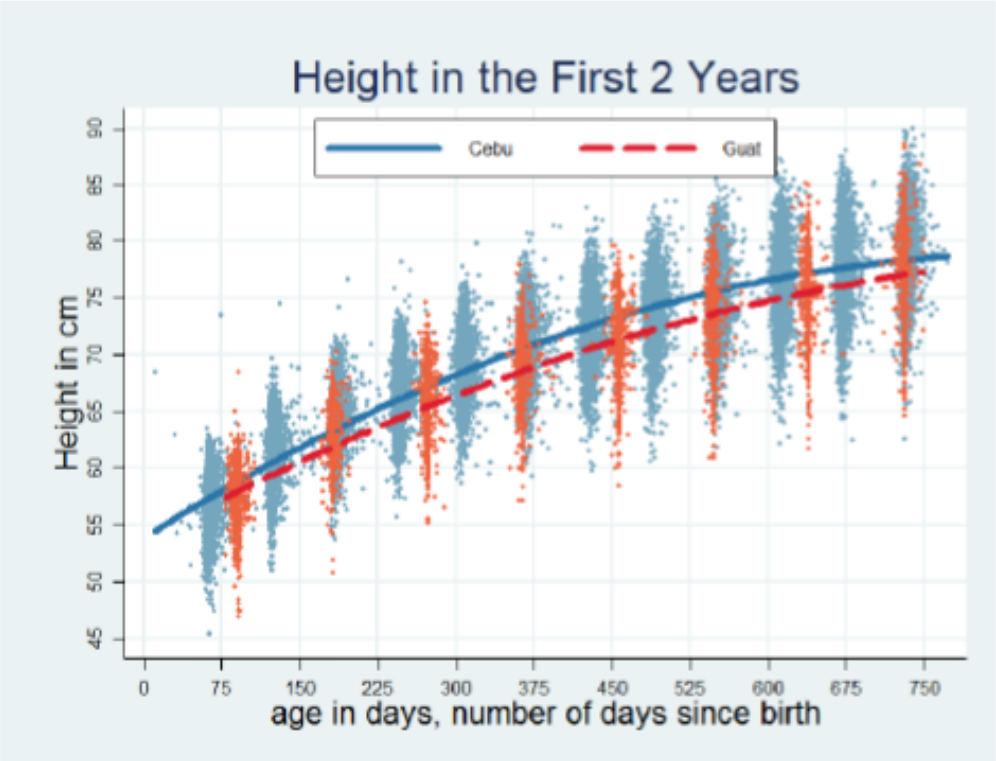
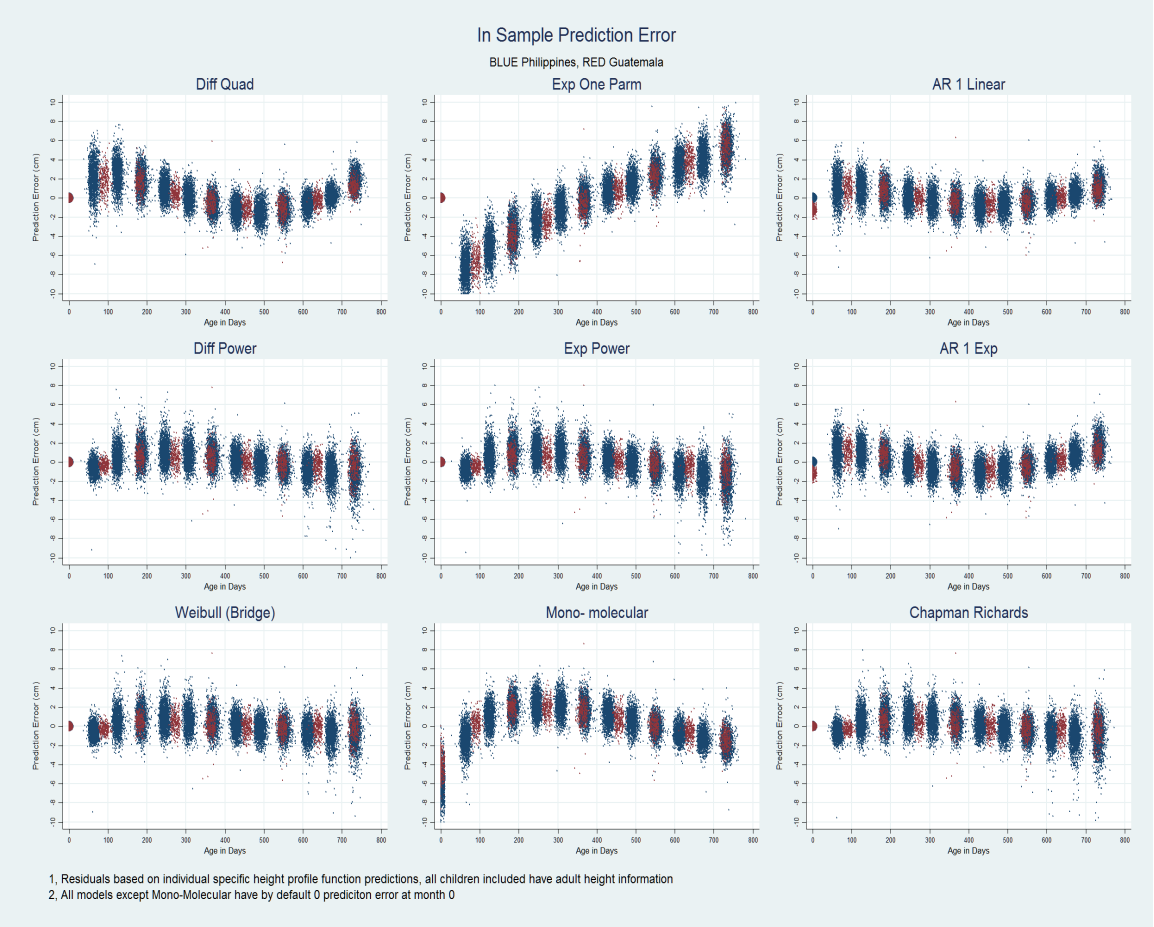


Figure 2: Height Equations Fit, Residuals



1, Residuals based on individual specific height profile function predictions, all children included have adult height information
2, All models except Mono-Molecular have by default 0 prediciton error at month 0

Figure 3: Height Equations Fit, R-Square

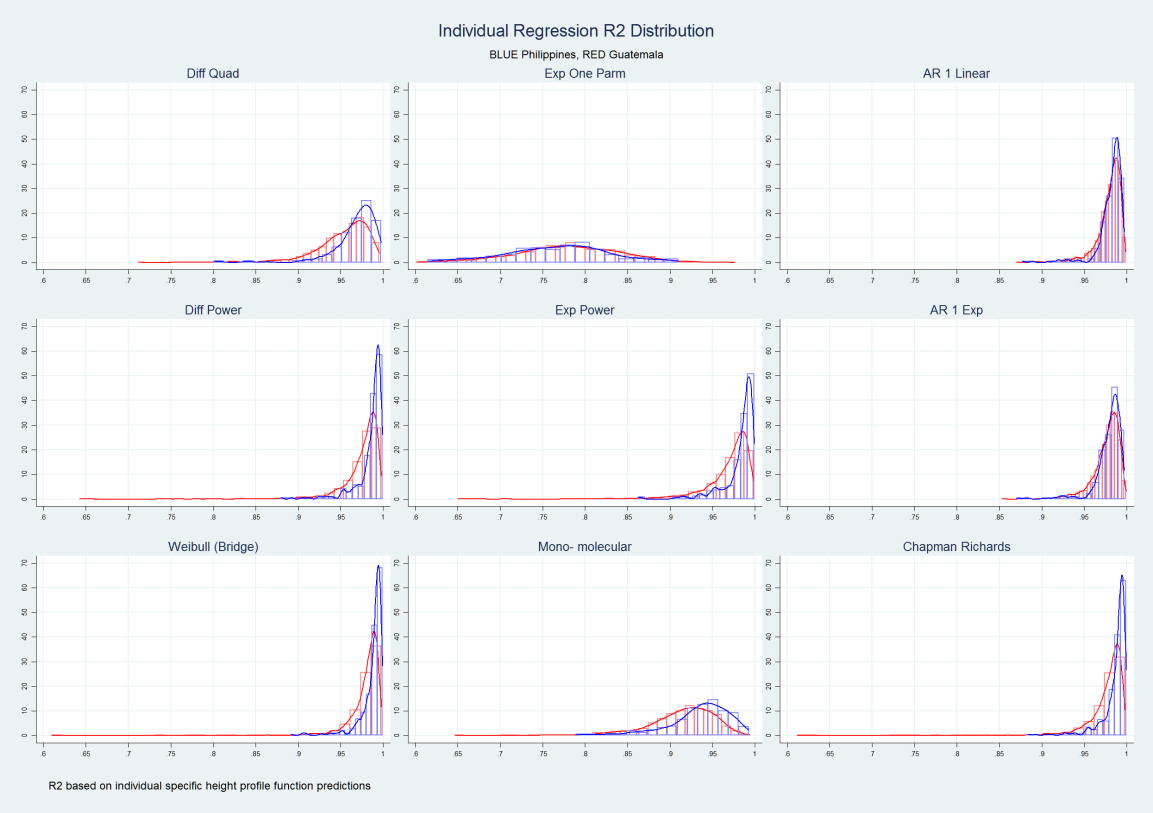


Figure 4A: Comparing best Fit for Guatemala

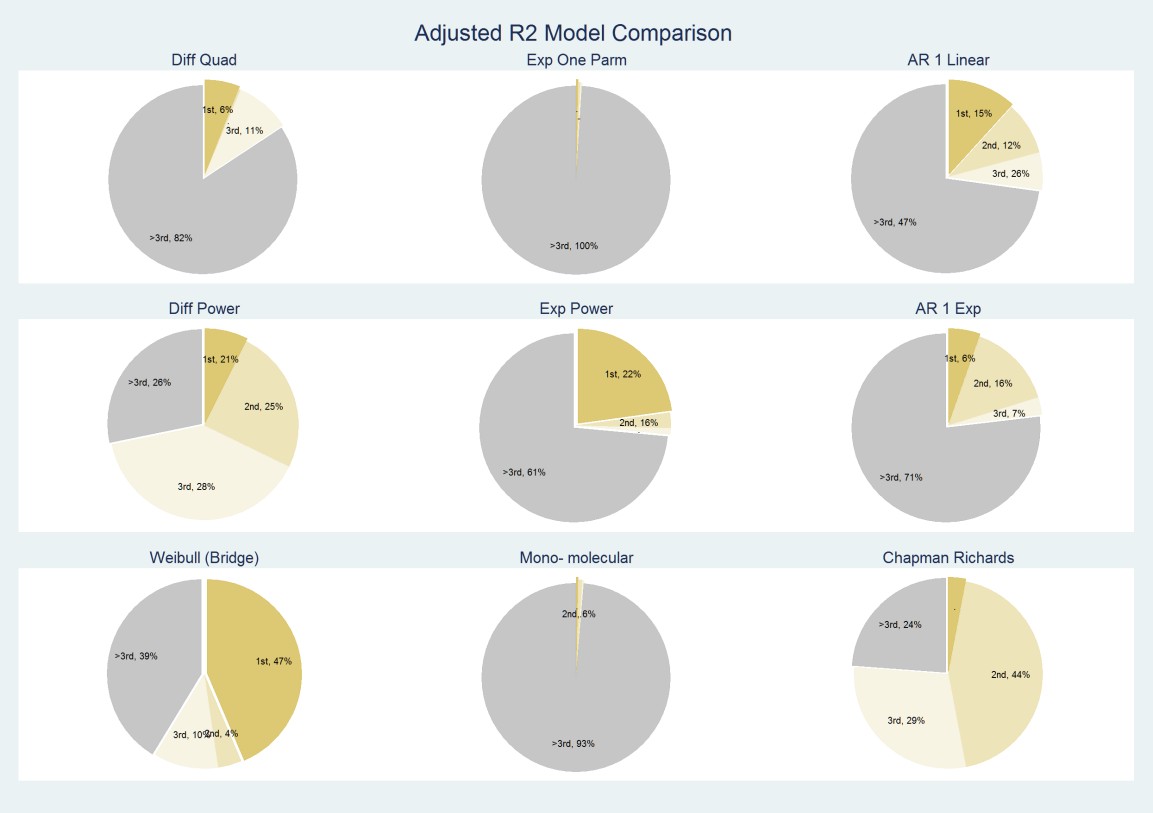


Figure 4B: Comparing best Fit for the Philippines

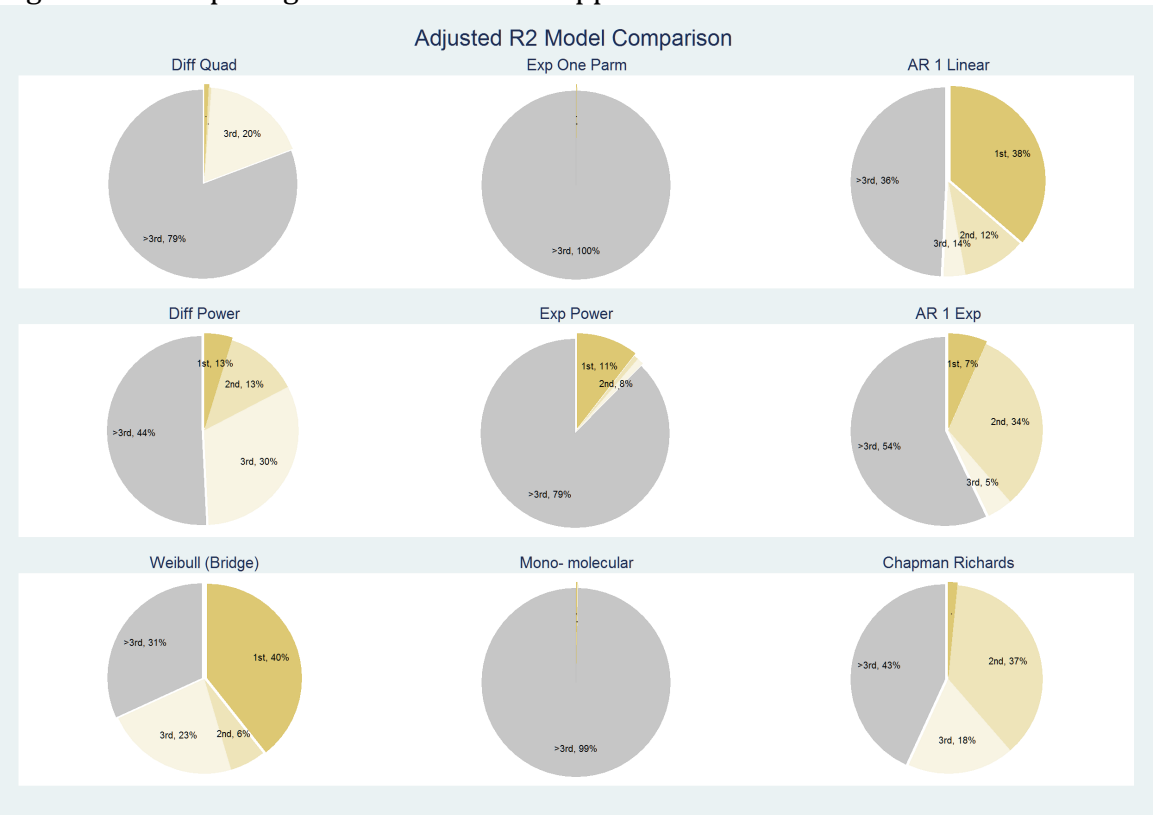
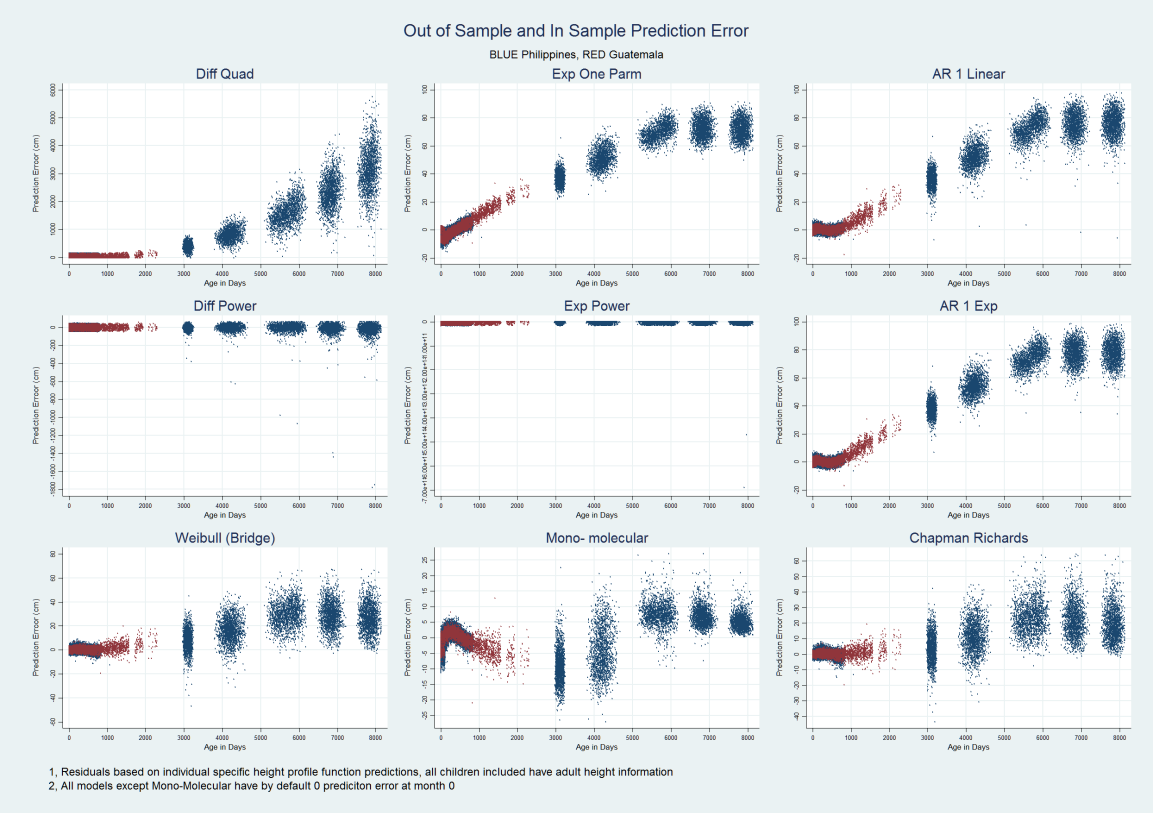


Figure 5: Height Equations, Out of Sample Prediction



1, Residuals based on individual specific height profile function predictions, all children included have adult height information
2, All models except Mono-Molecular have by default 0 prediciton error at month 0

Figure 6A: Height Equations, Best fir out of sample. Guatemala

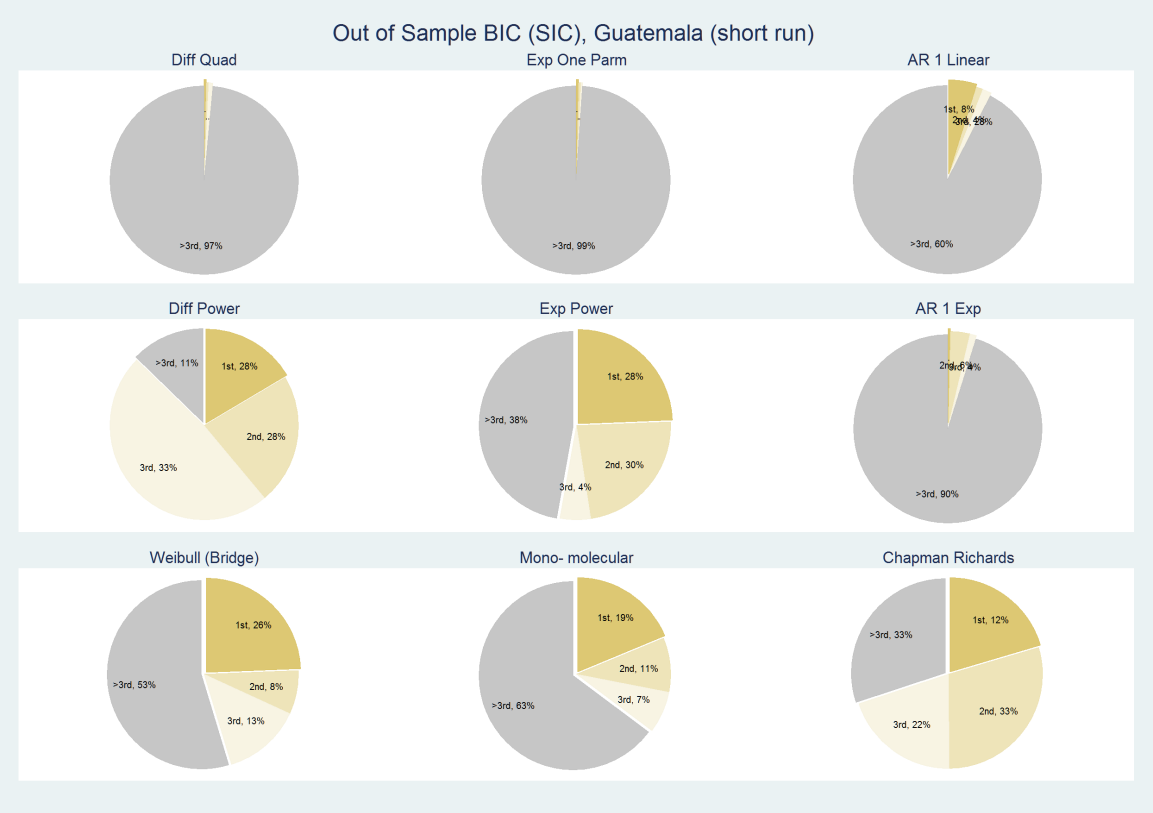


Figure 6B: Height Equations Best fir out of sample. Philippines

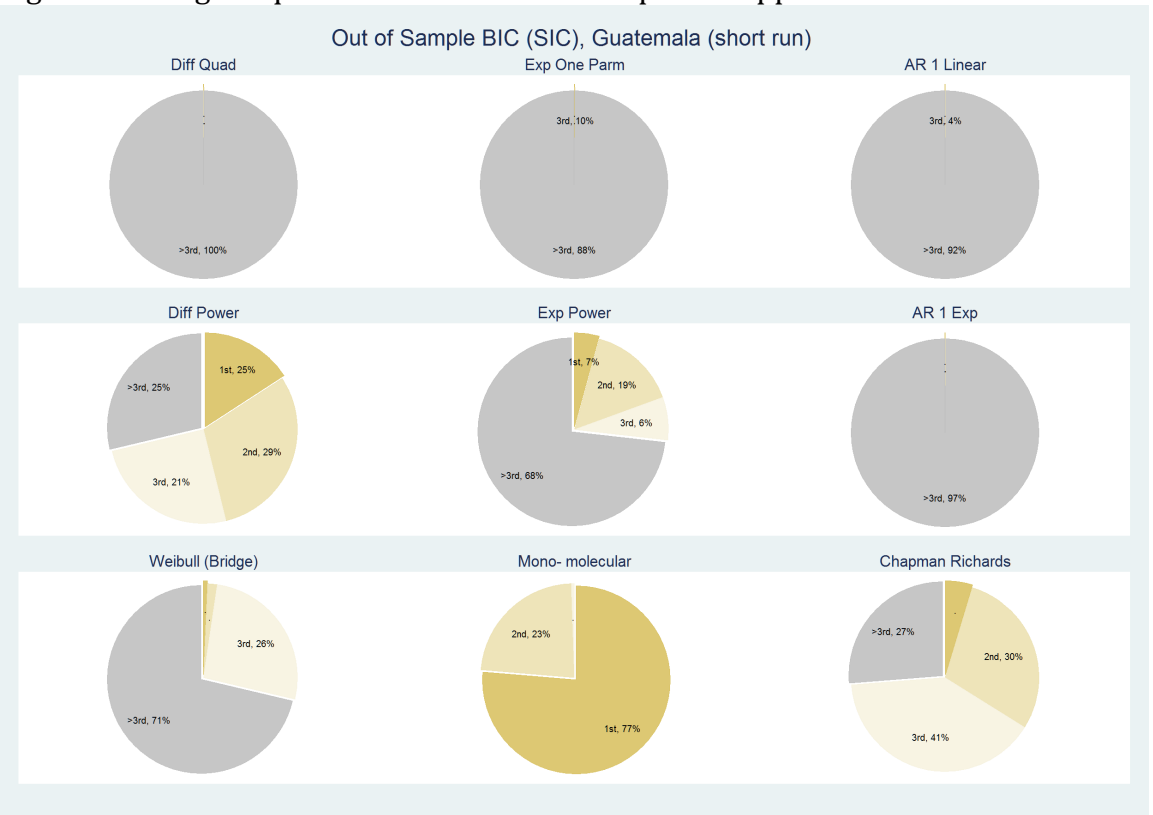


Figure 7A: Effects of increasing protein intakes, Guatemala

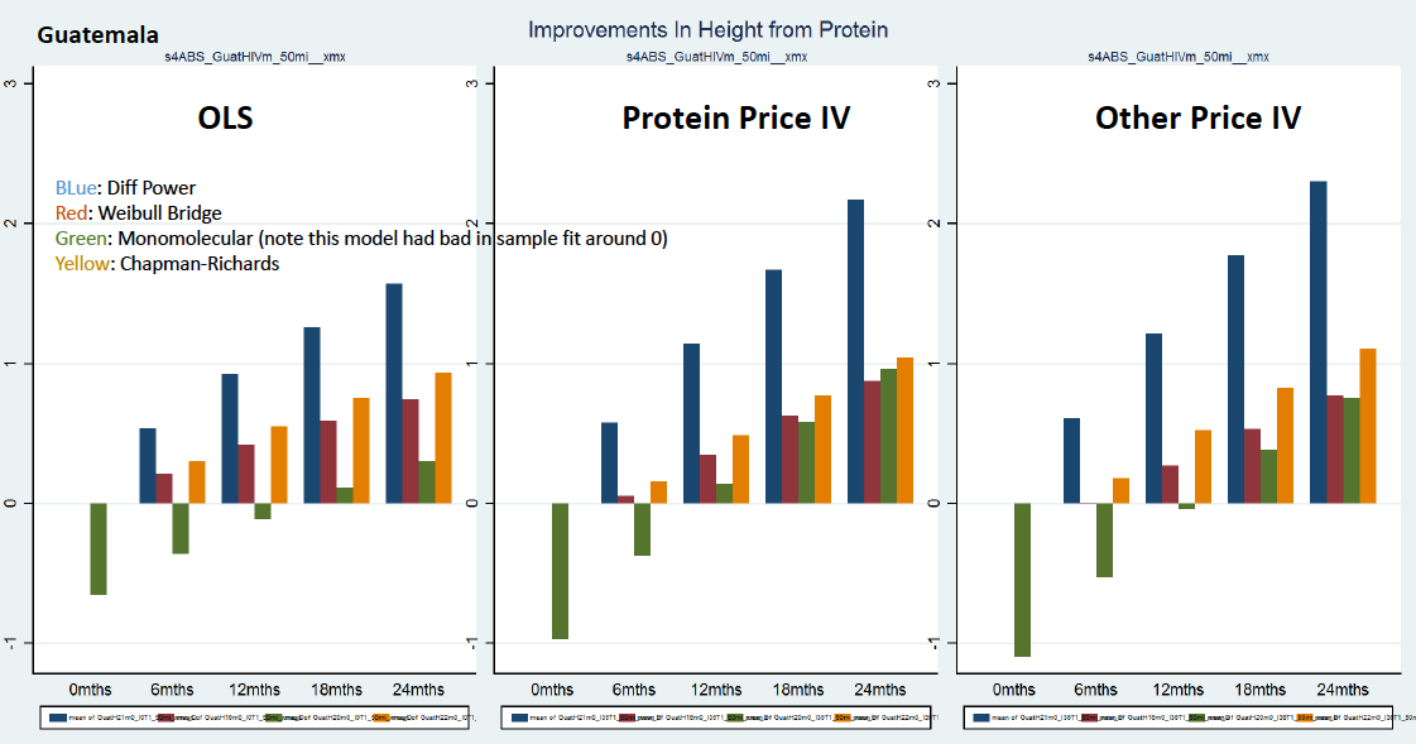


Figure 7B: Effects of increasing protein intakes, Philippines

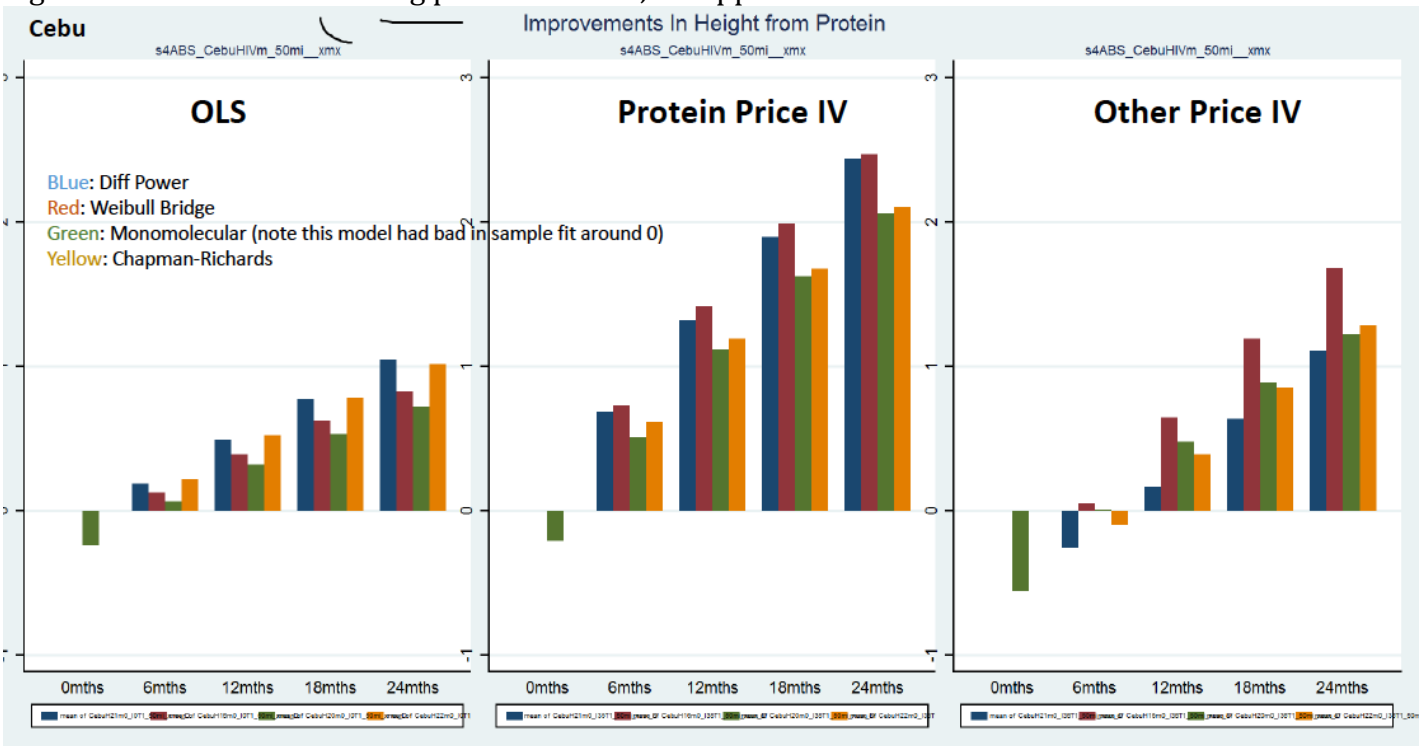


Figure 8A: Counterfactual 1: Guatemala, Close Atole and Fresco Gap.

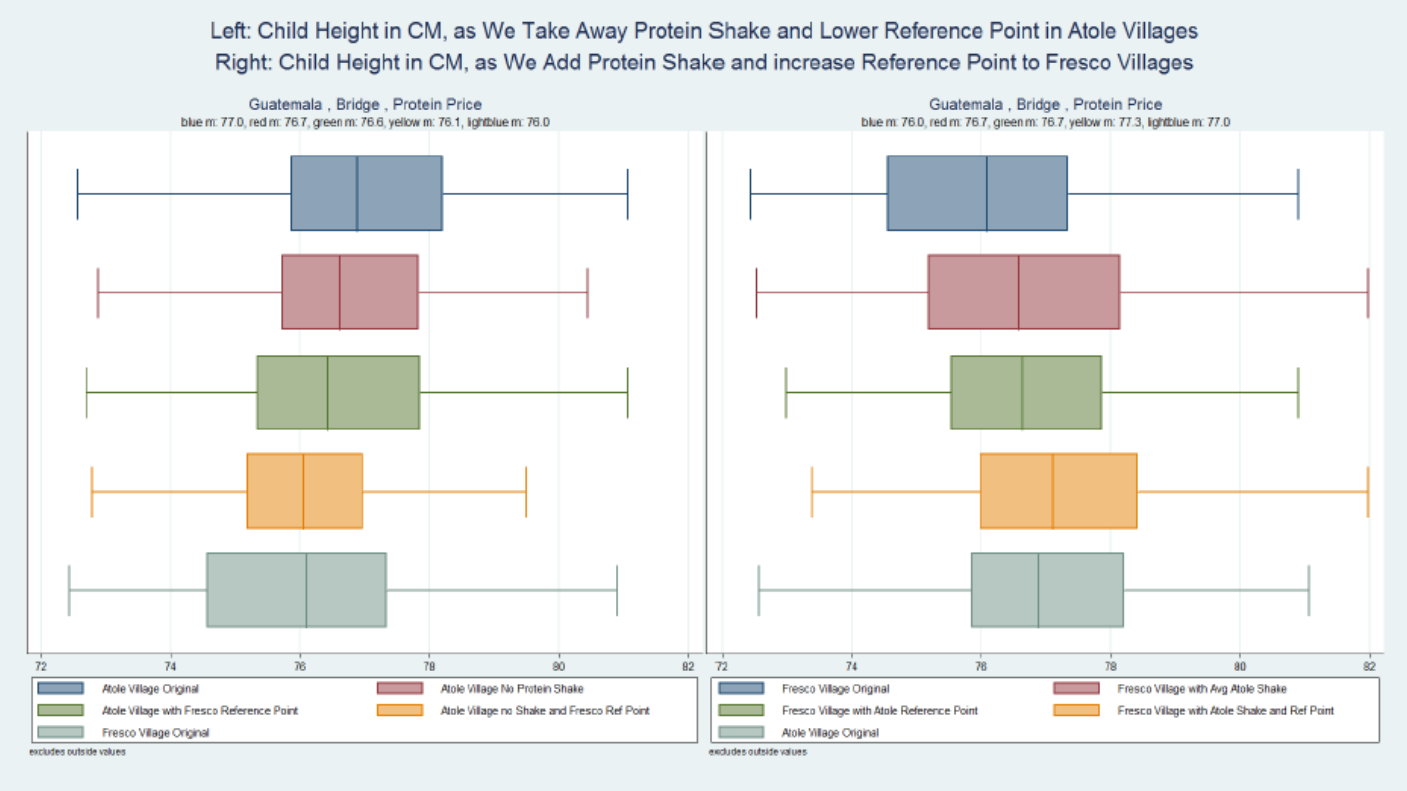


Figure 8B: Counterfactual 1, different height equations

Figure 9A: Counterfactual 2, Free Protein intake in the Philippines

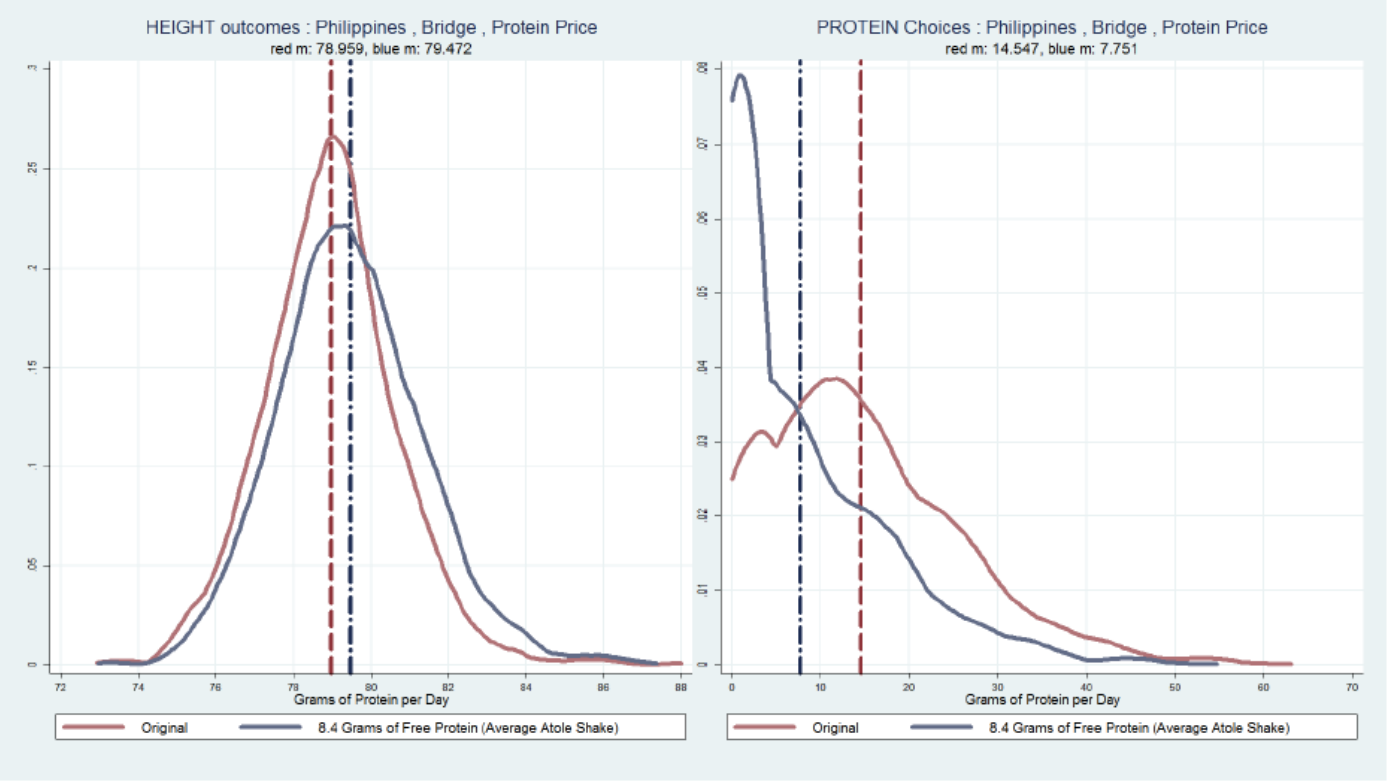


Figure 9B: Counterfactual 2, other height equations

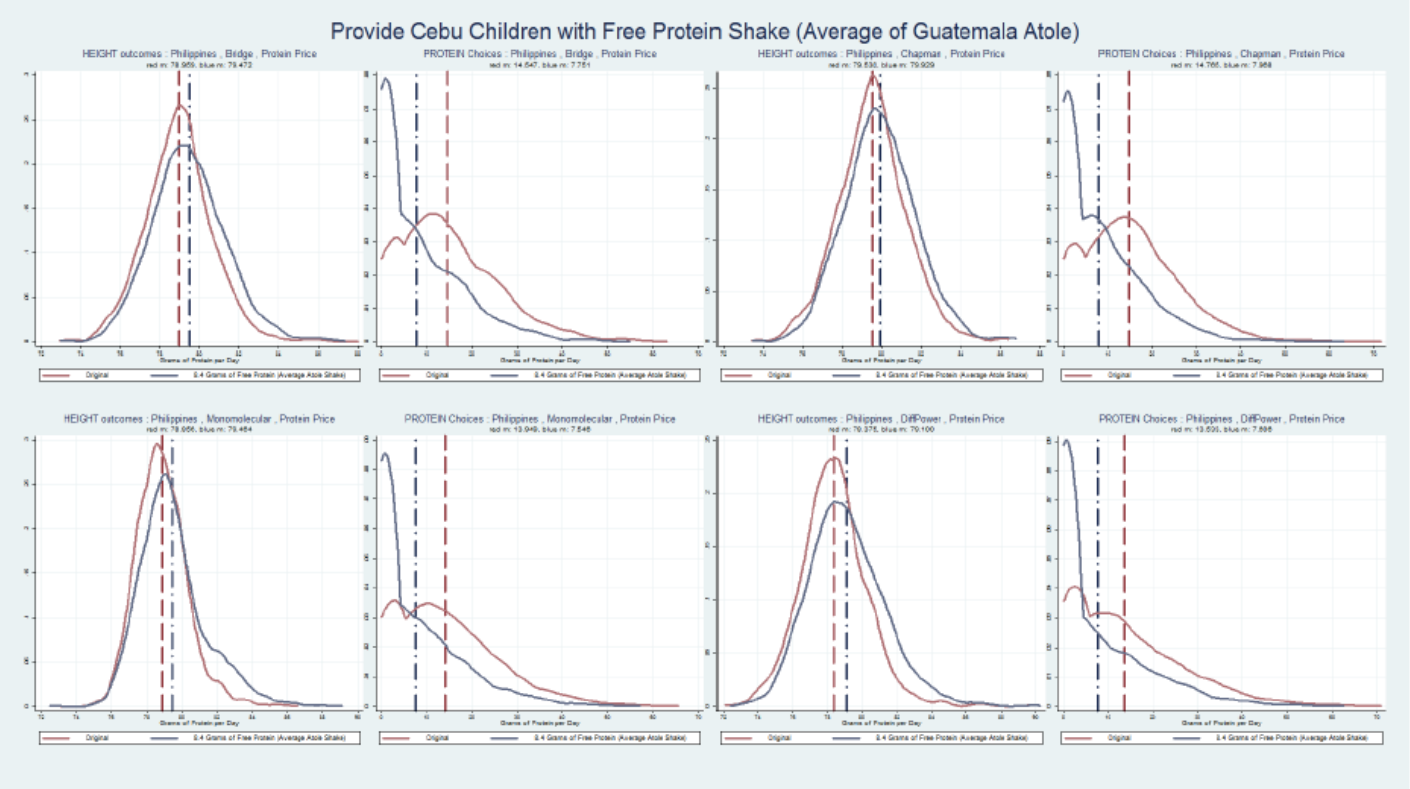


Figure 10A: Counterfactual 3, Changing Reference Points

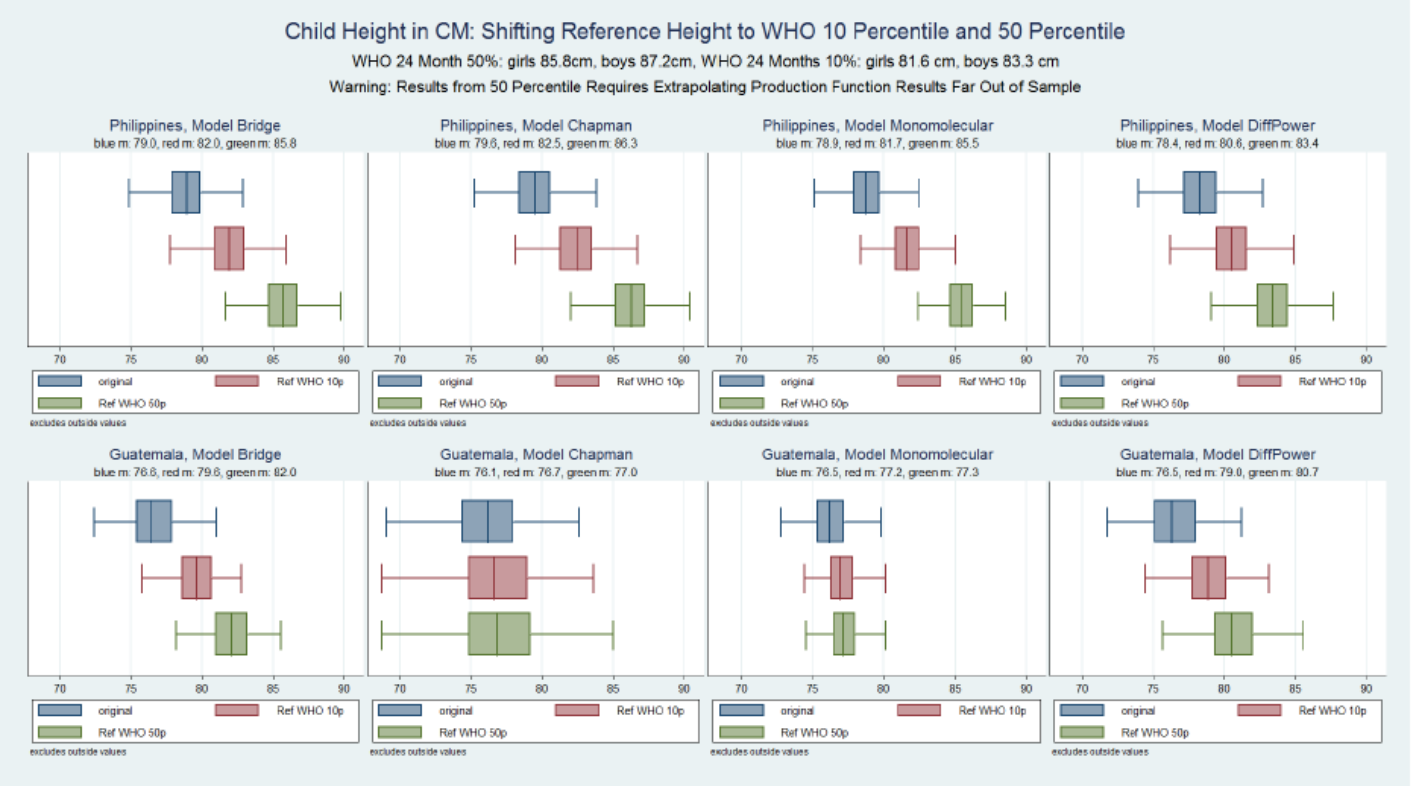


Figure 10B: Counterfactual 3, Changing Reference Points