You Are What Your Parents Think: Height and Local Reference Points

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Abstract

Recent estimates are that about 170 million children under five years of age are stunted, with significant long-run negative consequences on their schooling, cognitive skills, health and economic productivity. Understanding what determines such growth retardation, therefore, is very important. We build a structural model for nutritional choices and height growth with reference-dependent preferences. Parents care about the relative height of their child compared to some reference population. In our empirical model, reference height is an equilibrium object determined by the parental nutritional choices for earlier cohorts in the same village. Taking advantage of a protein-supplementation experiment in Guatemala, we use exogenous variations in differential height growth paths between treated and control villages to estimate the model. We conduct a number of counterfactual policy simulations. First, we find that reference point changes account for up to 60% of the 1.7cm in height difference between experimental and control villages at 24 months of age. Second, focusing on one-period effects, to obtain the same mean effects as an 1 cm increase in reference points would require a protein-price discount of 37 percent or an income increase of 60 percent. Third, endogenous reference points changes lead to significant policy spillovers: under poor-targeted subsidy policies, richer households over time gain up to 50 percent of the height gains of poorer households; under an universal subsidy policy, poorer households’ height gains increase from an initially low level by up to 4.8 times across periods as richer households, who also receive subsidies, help push up height reference points. JEL: I15, D8, D9, O15

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1 Introduction

About 170 million children under five years of age are stunted (De Onis, Blössner, and Borghi 2012). Studies suggest that these children are at risk of not developing their full potential in terms of schooling, cognitive skills, health, other dimensions of human capital and income (Behrman et al. 2009; Black et al. 2017; Hoddinott et al. 2008; Hoddinott et al. 2013a; Hoddinott et al. 2013b; Maluccio et al. 2009; Richter et al. 2017; Victora et al. 2008). Therefore, the long-run economic costs of early-life growth retardation appear considerable.

Height is an inheritable trait, but genes explain only 10% of the variability of adult height (Lango Allen et al. 2010; Berndt et al. 2013). Furthermore, the variability in potential height due to race or ethnicity is negligible among children who are raised in favorable environments and born to mothers whose nutritional and health needs are met (Habicht et al. 1974). In contrast, environmental factors related to hygiene and sanitation, infections, maternal nutritional status, and protein intake are major determinants of growth in the first two years of life (Martorell and Zongrone 2012).

We focus on a critical height determinant: the amount of protein in the diets of children. We focus on protein because it is an important input in the production of height (Puentes et al. 2016; Victora et al. 2008). As noted in the nutritional literature, stunting rates are generally higher in locations in which families feed their young children with staple foods that have low protein density because of their availability or affordability (Dewey 2016). In these regions, policies that supplement food via lipid-based nutrient supplementation (e.g., Dewey (2016)) or that increase parental resources may improve infant outcomes (e.g., Groot et al. (2017)). However, it is important to recognize that stunting also occurs in locations in which animal-source foods are available and affordable (Penny et al. 2005). This finding suggests that factors other than family resources or prices of foods rich in protein play an important role in determining malnutrition in general and stunting in particular. In this paper, we estimate the extent to which parental perceptions about what constitutes “normal” height influences parental feeding practices and thereby children’s growth.

Recent successful policies in the prevention of child stunting included actions to influence parental perceptions of normal growth. Marini, Rokx, and Gallagher (2017) provide a comprehensive description of how Peru successfully reduced stunting rates by 50 percent in the ten-year period between 2007 and 2016. In particular, it is important to emphasize two initiatives that may have contributed to shifting perceptions. First, the World Bank funded the production and dissemination of a video that communicated height standards that were easy to understand.2

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1. i.e., have height-for-age more than two standard deviations below the median for a well-nourished population.
2. The English version of the video link: Link (Accessed on February 21st 2018). There are Spanish
Second, the government extended to the entire country the practices introduced by the UNICEF “Good Start” Program. In particular, the government trained health professionals in local clinics so that they could assess, once a month, each child’s weight and height monthly and plot the information on the child’s growth chart. The health professionals used the visual information to inform the parents about the child’s growth status and to inform parents about corrective actions if the child’s growth had not met targets. The Peruvian case, while illustrative of the forces studied in our paper, cannot be used to identify the importance of shifting parental and societal norms about “normal” growth because the country simultaneously implemented many different interventions.

Evidence from Africa confirms the importance of parental perceptions in influencing feeding practices and reducing stunting rates. Fink et al. (2017) evaluate an intervention in which villages in rural Zambia were assigned to one of three mutually exclusive groups: (1) a control group; (2) a community-meeting group; and (3) a growth-chart group. In the community meeting, children were measured for height and weight and parents received information about feeding practices that promoted healthy growth. Parents in the third group had a full-size growth chart installed in their home so that they could track children’s growth. The chart had a simple design (red if children were stunted for their ages, green if not) and contained information about how feeding practices could influence children’s healthy growth. The authors show that parents’ reports of protein intake increased in both intervention groups. However, stunting rates were reduced by 22 percentage points (from 94% to 72%) in the group of parents that received the growth charts, but not in the group with community meetings.

The evidence described above motivates the development of a model that incorporates parental perceptions of “normal” height. In our model, parental preferences depend on the parents’ reference height distribution in a way that is similar to Prospect Theory (Kahneman and Tversky 1979). We assume that parents believe that height and Quechua versions of this video. Due to the perceived impact of the video, the World Bank has produced versions of the same videos for other countries.

3. See Lechtig et al. (2009) for an evaluation of the UNICEF’s “Good Start” Program.
4. The UNICEF’s Good Start Program used a growth chart that was divided in two regions: red (indicating undernutrition) and green (indicating normal nutritional status). This simple visual chart contrasts with other growth charts that use percentile information that are not easily understood by parents (see evidence in Ben-Joseph, Dowshen, and Izenberg (2009)).
5. UNICEF and various ministries of health have advocated such growth monitoring for decades, but until recently there has been little systematic evidence of much if any effects of such efforts (e.g., (Ruel and Habicht 1992)).
6. See Marini, Rokx, and Gallagher (2017) and World Bank (2016) for a helpful summary of all of the programmatic actions that may have contributed to the reduction in stunting.
7. The design is similar to the one used in Peru. See Marini, Rokx, and Gallagher (2017) for the design used in Peru and Fink et al. (2017) for the design used in Zambia. However, the Zambia chart also contained information about feeding practices.
is normally distributed and that they estimate the mean and variance parameters by observing the heights of children from slightly older cohorts who reside in the same location. This assumption is consistent with evidence reported by research in medical and anthropological literatures that concludes that parents observe older siblings, other children in the family, or their friends’ children to infer what constitutes “normal” height and weight (see, e.g., Reifsnider, Allan, and Percy 2000; Lucas et al. 2007; Thompson, Adair, and Bentley 2014).

We justify our choice of reference-dependent preferences because they are consistent with data about parental behavior as documented in health and anthropology literature. Our parameterization of preferences introduces two distinct forces: asymmetry in responses and delay in action due to uncertainty about norms. Asymmetry in responses relates to the fact that parents who are concerned that their child may not reach the parent’s perceived height milestone by age 24 months will behave in different ways from parents of otherwise identical children who have lower perceptions about height milestones at age 24 months. This asymmetry in response is documented in the medical literature with respect to obesity and other dimensions of children’s health (May et al. 2007; Laraway et al. 2010; Mathieu, Drapeau, and Tremblay 2010; Moore, Harris, and Bradlyn 2012; Swyden et al. 2015; Almoosawi et al. 2016).

In our framework, parents are uncertain about height milestones at age 24 months. Because of uncertainty, parents may not seek help unless they have identified that their children are falling behind in many dimensions of development. Uncertainty coupled with biased reference means may lead parents to take too long to seek help (as reported, for example, in Ryan and Salisbury (2012) as well as Mulcahy and Savage (2016)). If there are critical or sensitive periods of development, delays in adjustment of parental behavior may cause permanent damages to children’s human capital formation (Victora et al. 2008; Victora et al. 2010).

Parental uncertainty is captured by the reference height distribution that at each period $y$ is an equilibrium object that is partially determined by the nutritional choices of parents of children born in period $y - 1$ in the same village (we assume each period to be 2 years). We assume that parents have adaptive expectations: parents of children born in period $y$ observe the heights of the children born in year $y - 1$ and estimate the reference height distribution parameters. We argue that our adaptive expectation assumption is consistent with the results reported in Hansen et al. (2014) who showed that changes in development of children across cohorts affected parental perceptions of normal development as well as their reports about the developmental status of their own children.

We use data from The Institute of Central America and Panama (INCAP) nutritional

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8. Parents also report comparing children’s clothing to clothing recommended for their children’s ages.
trial to estimate the model described above. For this trial, there were four participant villages; two were randomly selected to receive a high-protein supplement, while the other two received a supplement devoid of proteins. In the data, we observe increasing height and nutritional input gaps between villages that experimentally received and did not receive protein-rich nutritional supplements. We estimate the model taking advantage of the exogenous variation in protein prices and reference points generated by the experimental design.

With our estimated model, we conduct four sets of counterfactuals. Our first counterfactual focuses on decomposing channels of impacts for the actual INCAP protein-supplementation experiment. Our second counterfactual focuses on the one-period effects of the model and what price and income changes would be required to have the same impact on child height as a given change in reference points. In our third and fourth sets of counterfactuals, we exploit dynamic features of our model to distinguish among three possible effects of subsidy policies in an environment with reference-dependent preference for height: (1) the direct impact of subsidies on treated children; (2) the indirect effect of subsidies via shifting reference points on treated children; (3) the impact of shifting reference points on untreated children.

In our first set of counterfactuals, in a decomposition exercise to better understand what happened under the protein-supplementation experiment, we find that reference point changes account for up to 60% of the nearly two centimeters in height difference between experimental and control villages at 24 months of age. We interpret the increasing gaps in heights and nutrition with children’s ages as largely coming from changes in reference points in treatment villages.

In our second set of counterfactuals, we compare the one-period relative impacts of shifting household income, food price, and reference points in determining nutritional choices and heights. We find that the changes of 1 cm in reference points correspond to a discount of 37 percent in the price of protein or to an increase of 60 percent in income. If households could be convinced through an information campaign that they should consider a higher-height reference population in making nutritional choices, the information campaign could potentially be more cost-effective than reducing protein prices or increasing income.

For our third set of counterfactuals, we compare the differing effects of poor-targeted and universal subsidy policies. To be budget constant, we increase the subsidy to the poor when the program becomes more targeted. There is significant debate in the early childhood and development literature on the relative tradeoffs between targeted and universal policies. We contribute to this literature by evaluating policies taking into consideration endogenous shifts in reference points over time induced by trans-

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9. See for example, Besley and Kanbur (1990), Gelbach and Pritchett (1997), and Coady, Grosh, and Hoddinott (2004)
fer policies under the assumption that poorer and richer households share common local reference points. This introduces a channel for policy spillovers from the richer to the poorer households and vice-versa. We show that the effects of a universal policy on the poor is initially small, but could increase by up to 4.8 times given subsequent endogenous upwards shifts in reference points as all village children—all of whom receive subsidies under the universal policy—increase nutritional intakes. We also show that, under a policy that targets only the poor, relatively richer households, who do not receive subsidies, could experience up to 50 percent of the height gains experienced by poorer households.

Finally, in our fourth set of counterfactuals, we consider the effects of providing subsidies to all the children in one locality (concentrated) or to subsidize the same number of children but across several localities (distributed). If reference points do not matter, these two policies would have identical mean effects. Under the distributed policy, because a subset of children in all villages receive subsidies, there are significant spillover effects through reference points changes on untreated children in all villages. Under the concentrated policy, because subsidies are concentrated in one village, there are significant positive self-reinforcing effects of reference points on treated children in the treatment village, but untreated children in the other villages do not gain from spillovers.

With respect to the literature, the assumption that agents in general, and parents in our case, compare themselves to agents who are close to them, but not necessarily to the general population has been previously studied. For instance, Card et al. (2012), finds that job satisfaction depends on the relative-income position among co-workers of the same pay unit. Also, Liu and Zuppann (2016) find that children who move to a different location might use the weights of their new peers as reference points for their relative obesity, and these new reference points affect their behaviors. It has also been studied that comparing with peers instead of the general population could lead agents to non-optimal investment decisions. For instance, Kinsler, Pavan, and others (2016) find that parents compare the abilities of their children with children from the same school, which translates in low investment levels from parents (helping with homework or hiring a tutor) for children at the bottom of the skills distribution. In the case of height, there is evidence that relative height is important for well-being, Carrieri and De Paola (2012) find that men in Italy who are taller than their reference group report higher subjective well-being. However, Gil and Mora (2011) find that individuals in Spain care about their relative weight but not height.

We present the data in Section 2. We describe our model, model solution and es-

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10. Similarly, Boneva and Rauh (2016) find that parents might use wrong beliefs to decide investments, and if those beliefs were updated, children with parents at the bottom of the income distribution would benefit.
imation in Section 3. Section 4 shows parameter estimates and model fits. Finally Section 5 discusses four sets of policy-relevant counterfactuals based on the estimated model. Section 6 concludes.

2 Data

2.1 Survey Design and Sample

The data we used in this paper comes from an experimental intervention 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 populous (~900 residents each) and one pair that were less populous (~500 residents each). The villages were similar in child nutritional status, measured as height at three years of age (Habicht, 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 physical and mental development (Habicht, Martorell, and Rivera 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 the supplements at the feeding centers.

Information on supplement intake was collected daily for all pregnant women and children up to seven years old. Height and home dietary information was collected every 3 months for children between 0 and 24 months. The home dietary data corresponds to 24-hour recall in the large villages and 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.

Given the quarterly data collection for the INCAP dataset, in the first 24 months of life, a child was observed for up to 9 times. There were 1155 individuals for whom we have at least 1 height observation between months 0 and 24, and 363 individuals
for whom heights were observed 9 times. We focus on 503 individuals for whom we have heights at birth, heights at month 24, and at least 2 observations of nutritional inputs between months 15 and 24. For these 503 individuals, we also have data on household incomes and food prices.

2.2 Descriptive statistics

Table 1 presents summary statistics for key variables we use from the survey. In Panels A and B, we show statistics on gender, income and prices for our main sample of 503 individuals (Panel A) and gender and income for the fuller sample of 1155 individuals (Panel B). In Panels C and D, we show statistics on heights and nutritional intakes respectively. Table 1 has five columns. The first column presents the overall mean and standard deviations in Atole and Fresco villages combined. The second and third columns present Atole and Fresco village-specific means and standard deviations. Column four shows the gaps in means between Atole and Fresco villages for each variable, and column five presents the p-value for the statistical significance of these gaps.

Panel A and B show that the survey is well-balanced for gender and income between Atole and Fresco villages. Panel A shows that male children account for 52 percent of our main sample in both Atole and Fresco villages. In Panel B, for the larger sample that includes any individuals for whom we observe height once in the first two years, the male share is 53 percent in both Atole and Fresco villages. These indicate that differences between Atole and Fresco villages in height outcomes and nutritional intakes are not driven by gender composition differences.

Panel A and B also show that household annual incomes for Atole and Fresco villages are similarly distributed. In Panel A, for our main sample, average annual household income was 503 quetzales in Fresco villages, and 526 quetzales in Atole villages. The difference is statistically insignificant with the p-value equal to 0.59. Standard deviations for both villages are almost identical at ~460 quetzales, indicating high similarity in the distribution of incomes between Atole and Fresco villages. For the larger sample in Panel B, average incomes per year are almost identical at 454 quetzales in Atole villages and 444 quetzales in Fresco villages, a statistically insignificant difference of only 2 percent. The higher income in Panel A’s main sample compared to

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11. For 378 individuals, we observe nutritional intakes in months 15, 18, 21 and 24, for 100 individuals, we observe nutritional intakes 3 times, and for 25 individuals, we observe nutritional intakes 2 times.

12. The survey contains a wealth index constructed with data collected in 1967 and 1975 for all individuals. We also know the mean and the standard deviation of income for the year 1974 but only at the village level. Assuming that household annual income follows the same distribution as the household wealth distribution, and assuming also log-normality of the income distribution, we impute household annual income from the wealth percentiles. For structural estimation of our model, we multiply annual income by 2 to calculate total resources available for each household in the first two years a child’s life.

13. Real terms for 1975, exchange rate was 1 quetzal for 1 US dollar.
<table>
<thead>
<tr>
<th>Panel A: Gender Income Price (N=503, main sample)</th>
<th>All</th>
<th>Group Averages</th>
<th>p-Values Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>0.52</td>
<td>0.52</td>
<td>-0.00 0.92</td>
</tr>
<tr>
<td>(0.50)</td>
<td>(0.50)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Income (quetzale)</td>
<td>515.57</td>
<td>503.68</td>
<td>22.32 0.59</td>
</tr>
<tr>
<td>(460.9)</td>
<td>(464.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mth 15-24 Protein Price (quetzale/10k grams)</td>
<td>52.58</td>
<td>52.47</td>
<td>0.21 0.54</td>
</tr>
<tr>
<td>(3.87)</td>
<td>(3.93)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel B: Gender Income (N=1115, height observed once in first 24 months)</th>
<th>All</th>
<th>Group Averages</th>
<th>p-Values Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>0.53</td>
<td>0.53</td>
<td>0.00 0.98</td>
</tr>
<tr>
<td>(0.50)</td>
<td>(0.50)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Income (quetzale)</td>
<td>449.49</td>
<td>444.63</td>
<td>9.43 0.72</td>
</tr>
<tr>
<td>(432.3)</td>
<td>(446.4)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel C: Height</th>
<th>All</th>
<th>Group Averages</th>
<th>p-Values Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Month 0 (cm) N=503</td>
<td>49.64</td>
<td>49.79</td>
<td>-0.27 0.19</td>
</tr>
<tr>
<td>(2.29)</td>
<td>(2.29)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Month 6 (cm) N=463</td>
<td>62.72</td>
<td>62.49</td>
<td>0.44 0.05</td>
</tr>
<tr>
<td>(2.46)</td>
<td>(2.50)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Month 12 (cm) N=475</td>
<td>68.81</td>
<td>68.45</td>
<td>0.68 0.01</td>
</tr>
<tr>
<td>(2.99)</td>
<td>(3.13)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Month 18 (cm) N=482</td>
<td>73.37</td>
<td>72.88</td>
<td>0.92 0.00</td>
</tr>
<tr>
<td>(3.23)</td>
<td>(3.26)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Month 24 (cm) N=503</td>
<td>77.66</td>
<td>76.94</td>
<td>1.36 0.00</td>
</tr>
<tr>
<td>(3.47)</td>
<td>(3.49)</td>
<td></td>
<td></td>
</tr>
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<table>
<thead>
<tr>
<th>Panel D: Average Daily Nutritional Intake</th>
<th>All</th>
<th>Group Averages</th>
<th>p-Values Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Month 15 (grams/day) N=464</td>
<td>17.43</td>
<td>14.29</td>
<td>5.78 0.00</td>
</tr>
<tr>
<td>(10.5)</td>
<td>(9.14)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Month 18 (grams/day) N=461</td>
<td>21.52</td>
<td>18.27</td>
<td>6.14 0.00</td>
</tr>
<tr>
<td>(11.4)</td>
<td>(9.61)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Month 21 (grams/day) N=475</td>
<td>24.45</td>
<td>20.17</td>
<td>7.82 0.00</td>
</tr>
<tr>
<td>(11.4)</td>
<td>(9.03)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Month 24 (grams/day) N=462</td>
<td>26.99</td>
<td>22.51</td>
<td>8.56 0.00</td>
</tr>
<tr>
<td>(12.0)</td>
<td>(9.02)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg Mth 15-24 (grams/day) N=503</td>
<td>22.54</td>
<td>18.81</td>
<td>6.99 0.00</td>
</tr>
<tr>
<td>(8.98)</td>
<td>(6.43)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Avg Mth 15-24 (kcal/day) N=503</td>
<td>691.78</td>
<td>681.78</td>
<td>18.77 0.38</td>
</tr>
<tr>
<td>(236.5)</td>
<td>(236.2)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

the income in Panel B’s larger sample indicates potential selection in terms of which children were observed more often and consistently, but both gender and income in both Panel A and B are almost exactly balanced, indicating high similarity between
Atole and Fresco villages.

Panel A also presents summary statistics for the village averages of individual average protein prices between months 15 and 24 of age for each child. We calculate annual protein prices based on the average of annual food prices for rice, eggs, chicken, corn and beef weighted by their respective protein shares. By construction, food prices differ for each calendar year, but are identical for Atole and Fresco villages. For each child, we average over prices that the child faces in months 15, 18, 21, and 24 of age—the months over which we calculate average nutritional intakes shown in Panel D. Depending on the month and year of birth, the average price for each child differs. In Column one of Panel A, we show the overall averages of these individual averages, which is 52.58 quetzales per 10k grams of protein. The standard deviation is 3.87 quetzales or 7.4 percent of the means, indicating significant price variations across individuals. The averages for Atole and Fresco villages are almost identical at 52.47 and 52.68 quetzales (p-value 0.54 for difference), indicating that the distribution of birth-dates between Atole and Fresco villages are well-balanced.

In Panel C of Table 1, we show heights for all cohorts between 1970 and 1975 at 0, 6, 12, 18 and 24 months of age. These data indicate that Atole children were born with similar heights as Fresco children, but grew taller by 24 months of age. At birth, Atole village children, with average height at 49.52 cm, are in fact 0.27 cm shorter on average than Fresco village children whose average height is 49.79 cm. This difference, however, is not statistically different (p-value 0.19). As we move from birth to month 24, heights for children in Atole villages increase faster on average than heights for children from Fresco villages. At month 6, Atole children are on average 0.44 cm taller than Fresco children. This gap widens to 0.68 cm at 12 months and 0.92 cm at 18 months of age. At month 24, the average height in Atole villages is 78.28 cm, and the average height in Fresco villages is 76.94 cm—the Atole height premium is 1.36 cm (p-value \( \leq 0.005 \)).

Panel D of Table 1 presents averages for nutritional intakes per day for children across birth cohorts between 1970 and 1975. We focus on nutritional intakes in the second year of life in months 15, 18, 21 and 24. For month 15 of age, Atole children

14. We obtain protein shares from USDA Food Composition Database (Agriculture 2016), which provides the protein values per 100 grams of various food items. We also have from the INCAP survey food price data measured at wholesalers’ purchasing cost per 10,000 grams of each type of food. The food prices are common for Atole and Fresco villages. Using these data, we estimate protein prices from a simple hedonic pricing equation system in which the price for each unit of food item is determined by the sum of the protein and non-protein caloric values for each unit of food item multiplied by the year-specific protein and non-protein-calorie prices up to a random error term. More information is available upon request.

15. The birth date distributions in Atole and Fresco villages are shown in Panels 1.1 and 2.1 of Figure 1 where the size of scatter plots indicate the relative sample sizes of birth in each half-calendar-year between 1970 and 1975.

16. In the first year of life, a significant portion of children obtain nutrition from breast milk, and it is difficult to impute the protein and caloric values of breastmilk given heterogeneity in breastmilk and
average 20.07 grams of protein intake per day, 5.78 grams more than children in Fresco villages. In months 18, 21 and 24 of age, the average daily intake gap between Atole and Fresco villages widens to 6.14, 7.82 and 8.56 grams per day. Overall, averaging across the four quarters in the second year of life for each child, average protein intake in Atole villages at 25.80 grams is 6.99 grams (37 percent) higher than the average for Fresco villages (18.81 grams per day). The final row of Panel D shows the village averages of individual average kcal per day of caloric intakes from non-protein sources over months 15, 18, 21 and 24 of age, which is 700.55 kcal per day in Atole villages and 691.78 kcal per day in Fresco villages, a statistically insignificant gap of 2.7 percent.

2.3 Gaps Across Cohorts

We now present data on heights and nutritional intakes across cohorts of children born between 1970 and 1975. We focus on heights at 24 months of age across cohorts, and show village averages for average protein intakes between months 15 and 24 of age. As described earlier, the nutritional-supplementation experiments started in the first half of 1969. The 503 children in our main sample were born in different months between 1970 and 1975.17

The feeding centers that distributed the protein supplements stayed in place between 1970 and 1975, and there were no changes to the protein or protein-free supplements they offered. Surprisingly, however, when we examine the height at month 24 of children—as shown on the left Panels (1.1, 1.2 and 1.3) of Figure 1—there is a widening height gap between Atole and Fresco village children across cohorts from 1970 to 1975. Corresponding to the increasing gaps in heights at month 24 are increasing gaps in protein intakes across cohorts shown on the right Panels (2.1, 2.2 and 2.3) of Figure 1.

In Panels 1.1 and 2.1 of Figure 1, we aggregate children into 6-month birth groups. In Panels 1.2 and 2.2, we show results for children in annual birth-cohort groups. Panels 1.3 and 2.3 show height and protein intake gaps for 1970, 1971, 1972-73 and 1974-75.

2.3.1 Height Gaps Across Cohorts

Panel 1.1 shows that children born in the first half of 1970 have approximately the same average height in Atole and Fresco villages at 24 months of age—both at approximately 76.4 cm. For those born in the second half of 1975, however, the average month 24 heights are 78.9 cm and 76.9 cm for Atole and Fresco village children, respectively.

17. We have data on the birth date of children for these children, which allows us to aggregate children into annual birth cohorts. Out of the 503 children in our sample, 39 were born in 1970, 82 in 1971, 93 in 1972, 96 in 1973, 101 in 1974, and 92 in 1975.
Figure 1: Increasing Protein and Height Gaps Across Cohorts
Panel 1.2 presents results for cohorts aggregated over each birth year between 1970 and 1975. The average height at month 24 gaps between Atole and Fresco children are 0.2 cm (76.6-76.4) for the 1970 cohort, and 1.6 cm (78.8-77.1) for the 1975 birth cohort.

Panels 1.1 and 1.2 also show linear and local polynomial approximated height trends in Atole and Fresco Villages (the linear and local polynomial approximations are similar). They show a relatively flat pattern for height at month 24 across cohorts in Fresco villages and a significantly increasing pattern for height at month 24 across cohorts in Atole villages. Specifically, the linear trend indicates that each additional cohort year is associated with an increase of 0.34 cm (s.e. 0.13) in height at month 24 in Atole villages and a slightly positive but insignificant increase of 0.11 cm (s.e. 0.14) in height at month 24 in Fresco villages.

In Panel 1.3, we test whether the increasing height at month 24 gap across cohorts in Atole and Fresco villages could be explained by other variables. We regress height at month 24 on four birth cohort year groups–1970, 1971, 1972-73, and 1974-75—and the interaction of these birth cohort groups with the Atole dummy. We include here as covariates gender, protein prices, incomes and initial heights, the variables in the household state-space of our structural model (see Table 1). Panel 1.3 plots out the cohort-group and Atole interaction coefficients along with 95 percent confidence intervals. The connected-diamond line shows results from the regression including the covariates, and the connected-circle line shows raw height gaps for each cohort group between Atole and Fresco Villages. Across the cohort groups, the raw height gaps between Atole and Fresco villages are 0.21 cm (1970), 0.35 cm (1971), 1.28 cm (1972-73) and 1.46 cm (1974-75). Controlling for covariates, the height gaps are 0.62 cm, 1.06 cm, 1.54 cm and 1.32 cm. The results with and without covariates are similar, which is not surprising given that, as we saw in Table 1, there are no significant statistical differences between Atole and Fresco villages in gender ratios, incomes, protein prices, and initial heights. The 1970 and 1971 cohorts’ gaps are not statistically different from 0; the 1972-73 and 1974-75 cohorts’ gaps are statistically different from 0 at the 99 percent confidence level.

### 2.3.2 Nutritional Gaps Across Cohorts

Panels 2.1, 2.2 and 2.3 show protein intakes across cohorts. As mentioned before, we show village cohort averages aggregated over individual averages for 15, 18, 21 and 24 months of age. Panel 2.1 shows that Atole children born in the first half of 1970 have 21.1 grams of Protein per day on average, and corresponding Fresco children have 17.4 grams per day on average (3.7 grams gap). For those born in the second half of 1975, the cohort-group average increased to 27.3 grams per day in Atole villages, and to 18.9 grams in Fresco villages (8.4 grams gap). We aggregate results to full-year
cohorts in Panel 2.2, which shows that the average protein intake gap between Atole and Fresco villages in 1970 was 3.9 grams (21.3-17.4) and 7.9 grams (26.3-18.4) in 1975. Looking at percentage differences, for the annual cohorts, the average protein intakes in Atole villages are 22, 36, 37, 35, 40 and 43 percent higher in Atole villages than in Fresco villages for the six annual birth cohorts from 1970 and 1975.

Panels 2.1 and 2.2 show trends from linear and local polynomial approximations of average protein intakes across cohorts that are similar to those for heights. Specifically, we find that each additional cohort year is associated with a 0.68 grams (s.e. 0.38) increase in intakes for Atole children, and an insignificant increase of 0.17 (s.e. 0.36) grams in intakes for Fresco children.

In Panel 2.3, we test for the significance of the average protein-intake gap between Atole and Fresco villages across cohorts. Similar to Panel 1.3, we include gender ratios, food prices, incomes and initial heights as covariates. Without controls, the average intake gaps are 3.85 (1970), 6.76 (1971), 6.70 (1972-73) and 8.02 (1974-75) grams per day between Atole and Fresco village cohorts. Including controls, the gap estimates are 4.31, 7.35, 6.88 and 7.88 grams per day, still showing a generally increasing trend.

Overall, the Panels in Figure 1 show that there are overall protein intake gaps between Atole and Fresco villages that correspond to the overall height gaps. Furthermore, for successive cohorts from 1970 to 1975, measuring height at month 24 and averaging intakes over months 15, 18, 21, and 24, there are generally increasing protein intake gaps that correspond to increasing height gaps between Atole and Fresco villages. The overall Atole and Fresco protein-intake and height gaps have been observed before (see for example Puentes et. al. 2016), but not the increasing protein-input and height gaps across cohorts.

The empirical question that we face is what can explain these increasing gaps between Atole and Fresco villages. Table 1 and Panel 1.3 and 2.3 of Figure 1 show that gender shares, incomes, prices and initial heights do not differ significantly between Atole and Fresco villages and do not seem to be able to explain the increasing differences between Atole and Fresco villages across cohorts. We are also not aware of any changes in the protein and non-protein supplementation policies carried out by local feeding centers over time that might have impacted cohorts differentially.

Our structural model with reference-dependent utility can help to explain these increasing protein-intake and height gaps between Atole and Fresco villages.
3 The Model

3.1 Model Description

Each household solves a static maximization problem after the birth of a child. Individuals’ choices, however, have aggregate implications and determine the dynamic transition of height at month 24 distributions. We assume that households make a single decision about the total nutritional input for their new-born child from month 0 to month 24. The nutritional input household chooses is grams of proteins, which has a larger effect on height than other macro-nutrients (see Moradi 2010; Puentes et al. 2016). Choices are functions of prices and incomes, as well the expected reference point distribution which is an equilibrium object.

3.1.1 Preferences

The utility for a household in village $v$ after the birth of a child in period $y$–each period is two calendar years–is determined by the height that this child will reach at 24 months of age $h_{24}$, and household expenditure $c$ other than on nutrition N for the first 24 months for this child:

$$u_{yv} = c + \rho \cdot c^2 + \gamma \cdot h_{24} + \lambda \cdot (h_{24} - R_{yv})1(h_{24} > R_{yv})$$

(1)

where $1$ denotes the indicator function. Utility would be quasilinear in $c$ if $\rho$ were zero. If $\rho < 0$, utility is concave in $c$.

Preferences for $h_{24}$ represent the expected life-time values of children’s heights to households. Preferences for height are functions of the heights of the children relative to $R_{yv}$–the reference height with which households compare their children’s height. $\gamma$ is positive, but, depending on the relative values of $\lambda$ and $\lambda$, preferences for height are flexible and could be linear, convex or concave. If $\lambda = 0$, preferences are linear in heights $h_{24}$. If $\lambda > 0$, preferences are convex in height and parents invest more in heights after heights exceed the reference point. If $\lambda = -\gamma$, households gain utility from increasing heights up to the reference height $R_{yv}$, but there are no utility gains from increasing heights beyond that point. If $\gamma < -\lambda$, preferences for heights peak at the reference point, meaning that households want their children to be taller below the reference point but not beyond it. These four cases are shown graphically in Panels (a), (b), (c) and (d) of Figure 2 respectively.
3.1.2 Budget

Y is the income of the household over the first 24 months of life after the birth of a child, which is spent on c or N:\n\[
c = Y - \left(p_{Nv}^N \cdot (1 - \delta \cdot 1 (v = atole))\right) \cdot N \tag{2}\]
\]

\(p_{Nv}^N\) is the price for N during the two calendar years that correspond to the first two years of life for each child. We model the protein supplementation policy in Atole villages as a \(\delta\) discount on the price of protein in Atole villages.\(^{20}\)

3.1.3 Production function

Height at month 24 is determined by:
\[
h_{24}(N, X, \epsilon) = \exp(A + X \cdot \alpha + \epsilon) \cdot N^\beta \tag{3}\]

where covariate vector X includes the initial height and gender of the child, \(\epsilon\) represents the normally distributed i.i.d. height productivity shock for each child with standard deviation \(\sigma_{\epsilon}\).\(^{21}\) \(A\) relates to the average level of productivity of N in producing \(h_{24}\), and \(\alpha\) represents the impact of covariates on the marginal productivity of N. Initial height has positive impacts on month 24 height depending on the value of \(\alpha_0\).\(^{22}\) The production function includes protein input N in the first two years,\(^{23}\) with \(\beta < 1\) determining the concavity of the production function with respect to nutritional inputs.

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18. The budget constraint implies that households are able to perfectly smooth incomes earned in the first 2 years after the birth of a child.
19. Modeling the supplementation policy as a price discount implies that if an Atoll village child consumes X grams of protein, the fraction \(\delta\) comes from the feeding centers’ protein supplements. The share of proteins obtained from the feeding centers for each child is positive for all households, is on average 33 percent across cohorts, and is not significantly different across cohorts (F-test p-value 0.63).
20. A potential alternative approach of modeling the protein supplementation policy would be to add a fixed cost to accessing the feeding centers and impose a quantity constraint on how much free protein could be obtained per trip, but that would lead to some households not obtaining protein supplements. Another alternative would be to model the protein supplements as fixed amounts of intake provided to households, but that would force all households to consume the same levels of protein supplements contrary to what actually was observed.
21. Given that the model only has one-period, we do not need to distinguish between permanent unobserved heterogeneity and one-period shocks. With the assumption of i.i.d shocks, we are assuming that shocks are unrelated to the distribution of X, which means the variance of productivity shocks are not specific to gender or different levels of initial height.
22. This is a more general specification than a model in which the difference in height between month 0 and month 24 is the production function output and initial height is not included in X. Compared to a model with difference in height as the output and that also includes initial height in X, the model here produces similar coefficients.
23. Potentially, the timing of nutritional intakes within the first 24 months of life could matter. In the data, however, lagged input over the first 24 months of life is persistent, and it is difficult to distinguish relative productivity across subperiods within the first 24 months of life (Puente et al. 2016).
3.1.4 Information

We assume that households know the production function, and observe the i.i.d. productivity shocks at the time of making nutritional choices. This means nutritional choices are endogenous to productivity shocks that are unobserved by the econometrician.

Additionally, we assume that at the time of making nutritional choices in birth period $y$ in village $v$, households do not know the exact value of the reference height $R_{yv}$. However, households know that the reference point follows distribution $F(R_{yv})$, which is normal with mean $\mu_{R_{yv}}$ and $\sigma_{R_{yv}}$. We assume that $\mu_{R_{yv}}$ and $\sigma_{R_{yv}}$ are the average and standard deviation of realized heights from the cohort born in period $y-1$.

Observing the heights of children from earlier cohorts in the same village is plausible given the close proximity of households within these villages and the high level of economic and cultural interactions among households within villages. The assumption that the relevant comparison groups corresponds to the children from the same village is in line with the literature that has found that the relevant comparison groups are individuals who are closer. For instance, Card et al. (2012) finds that job satisfaction depends on the relative position among co-workers of the same pay unit and Kinsler, Pavan, and others (2016) find that parents compare the abilities of their children with children in the same school.

Given that households only know the distribution of $F(R_{yv})$, in deciding nutritional choices, households integrate over $F(R_{yv})$ for the reference-height component of preferences:

$$\gamma \cdot h_{24} + \lambda \cdot \int_{R_{yv}} (h_{24} - R_{yv}) \mathbb{1}(h_{24} > R_{yv}) \, dF(R_{yv})$$  \hspace{1cm} (4)

The presence of uncertainty changes the shape of preferences with respect to height. Panels (e) and (f) of Figure 2 show these graphically. In both panels, we show the sum from Equation 4 on the Y-axis and individual height levels on the x-axis.

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24. We do not have survey information about households’ knowledge with respect to production functions for height. The local feeding centers that distributed the protein and non-protein supplements and also provided health checkups were potentially sources of health information for villagers but they attempted to provide the same health services and the same information for all Atole and Fresco villages.

25. The assumption that parents learn from observing other children about reference points also relates to the assumption that parents know the production function parameters. We assume that when parents of children born 1972 see the height distribution of children born in 1970, they update their reference point, but they do not update production function parameters. This assumption is based on the literature described above and also that, for parents it is relatively easy to observe the height distribution of children born two years earlier, but much more difficult to update production function parameters since this requires close experience with feeding and observing children born to other parents two years earlier.

26. This also means that if a family moves to another village or location where the reference height distribution is different, they would adjust their nutritional choices given the updated reference distribution. Liu and Zuppann (2016) study, for example, shifts in reference weights for children who move in the US.
Figure 2: Reference Point and Preference for Height

(a) Reference Coefficient $\lambda = 0$

(b) $\lambda > 0$

(c) $\gamma = -\lambda$

(d) $\gamma < -\lambda$

(e) Shift $R_\sigma$ ($R_\mu = 77.75, \gamma = 0.03, \lambda = -0.045$)

(f) Shift $R_\mu$ ($R_\sigma = 3.5, \gamma = 0.03, \lambda = -0.045$)
Panel (e) of Figure 2 presents four curves with $\sigma_{Ryv}$ set at 0, 3, 3.5 and 4 cm, and with $\mu_{Ryv}$ fixed at 77.75 cm and $\gamma < -\lambda$. The curves show that preferences for height with $\sigma_{Ryv} = 0$ are piecewise linear with a kink at $\mu_{Ryv}$; with $\sigma_{Ryv} > 0$, preferences for height are continuously differentiable and concave in heights. Additionally, at low and high levels of heights, the marginal gains and losses from additional units of height are identical across the four curves and are determined by the values of $\gamma$ and $\lambda$. Finally, with uncertainty over the reference point, marginal gains (loses) of additional units of height are larger (more negative) at height values further away from the reference point.

In panel (f) of Figure 2, we fix $\sigma_{Ryv}$ at 3.5 cm and show height preference curves for $\mu_{Ryv}$ equal to 77, 77.5, 78 and 78.5 cm, respectively. The curves show that peak height preferences shift with the mean reference point, and the gap in preferences across different mean reference point curves widens significantly for higher heights. This means that a higher mean reference point increases the region of heights where marginal gains from additional height are positive, and also increases marginal gains in the region where marginal gain from additional height would be positive with a lower mean reference point.

We should note that an alternative interpretation of $\sigma_{Ryv}$ is that it measures household uncertainty with respect to what the realized height gap between $h_{24}$ and $\mu_{Ryv}$ will be. In the above discussion, we have assumed that this uncertainty comes from uncertainty over reference points, but we can see from Equation 4 that uncertainty over $h_{24}$—in the form of an shock term that is unobservable to the household, but that will help determine realized height—will have equivalent effects. In our modeling framework, households do not distinguish between these two shocks, so they both have the same effect on household choices.

3.1.5 Maximization Problem

Given $\mu_{Ryv}$, $\sigma_{Ryv}$, and price $p_{yv}^N$, each household solves the following maximization problem:

$$\max_{c,N} c + \rho \cdot c^2 + \left\{ \gamma \cdot h_{24} + \lambda \cdot \int_{Ryv} \left( h_{24} - R_{yv} \right) \mathbb{1} \left\{ h_{24} \geq R_{yv} \right\} dF(R_{yv}) \right\}$$ (5)

where:

$$c = Y - \left( p_{yv}^N - \delta \cdot \mathbb{1} \left( v = atole \right) \right) \cdot N$$

$$h_{24}(N, X, \epsilon) = \exp(A + X \cdot \alpha + \epsilon) \cdot N^\beta$$

The realized household utility $u_{yv}$ is a function of parameters and $Y, p_{yv}^N, X, F(R_{yv}), \epsilon$. Households make choices given $\Omega = (Y, p_{yv}^N, X)$, the i.i.d. productivity shock $\epsilon$, and
Figure 3: Indifference Curves

Indifference Curve and Consumption Possibility Frontier for one individual

At estimated parameter values.

Figure 4: Optimal Choice and Reference Points

Indifference Curve and Consumption Possibility Frontier for one individual, two $R_\mu$

At estimated parameter values.
At the birth of a child, a household chooses the optimal amount of nutrition for the child over the next 24 months given the joint relative distribution of the reference height and their own child’s height given that child’s productivity shock and nutritional intake. The parents choose knowing that more nutritional intake—at a decreasing rate of return—will increase the probability that their child will catch up to or exceed the reference height. To illustrate model mechanisms, in Figures 3 and 4, we show the consumption and height possibility frontier and indifference curves for an individual.

3.1.6 Evolution of Reference Points and Month 24 Height

Let \( \Gamma_{yv} \) be the probability measure of \( h_{24} \) for children born in period \( y \) and village \( v \). \( \Gamma_{yv}(H) \) reports the probability measure of individuals for whom \( h_{24} \in H \). Under our assumptions about reference point distributions described in the previous section, \( \Gamma_{yv} \) is realized in period \( y+1 \) and observed by parents of new-borns in period \( y+1 \) to determine an updated reference point distribution, specifically:

\[
\mu_{R_{y+1,v}} = \int h_{24} \cdot \Gamma_{yv}(dh_{24}) \\
\sigma_{R_{y+1,v}}^2 = \int \left( h_{24} - \mu_{R_{y+1,v}} \right)^2 \cdot \Gamma_{yv}(dh_{24})
\]

This implies that the means and standard deviations of reference point distributions are a function of \( \Gamma_{yv} \): \( \mu_{R_{y+1,v}}(\Gamma_{yv}) \) and \( \sigma_{R_{y+1,v}}(\Gamma_{yv}) \). In this setting, static individual choices have dynamic aggregate effects: Month 24 heights for the cohort born in period \( y \) are realized in period \( y+1 \) and determine the reference point distribution for the cohort born in \( y+1 \); subsequently, height at month 24 for the cohort born in period \( y+1 \) are realized in period \( y+2 \) and determine the reference point for the cohort born in \( y+2 \).

For children born in period \( y \) in village \( v \), given \( p_{yv}^N \) and \( \mu_{R_{y-1,v}}(\Gamma_{y-1,v}) \), \( \sigma_{R_{y-1,v}}(\Gamma_{y-1,v}) \), we have the optimal nutrition decision rule:

\[
N \left( Y, X, \epsilon; p_{yv}^N, \mu_{R_{y-1,v}}(\Gamma_{y-1,v}), \sigma_{R_{y-1,v}}(\Gamma_{y-1,v}) \right) = N \left( Y, X, \epsilon; p_{yv}^N, \Gamma_{y-1,v} \right)
\]

Using this decision rule and given some joint distribution of \( F_{yv}(Y, X, \epsilon) \), we can write the following equation describing the transition from height at month 24 distribution for the birth cohort born in period \( y-1 \), \( \Gamma_{y-1,v} \), to the height at month 24 distribution for the birth cohort born in period \( y \), \( \Gamma_{y,v} \):

\[
\Gamma_{yv}(H) = \int_{Y \times X \times \epsilon} 1 \left( h_{24} \left( N \left( Y, X, \epsilon; p_{yv}^N, \Gamma_{y-1,v} \right), X, \epsilon \right) \in H \right) dF_{yv}(Y, X, \epsilon)
\]

27. By definition, the CDF for \( h_{24} \) is \( F_{yv}(h) = \Gamma_{yv}(\{h_{min}, h\}) \).
where 1 is again the indicator function. Given the optimal-nutrition decision rule, some initial distribution $\Gamma_{\text{initial},v}$ realized before period $y_{\text{min}}$, and a sequence of price and income and covariate distributions $(p_{yv}^N, F_{yv}(Y, X))_{y=y_{\text{min}}}^{y_{\text{max}}}$ from year $y_{\text{min}}$ to year $y_{\text{max}}$, we can iteratively solve for a sequence of heights at month 24 distributions across cohorts $(\Gamma_{y_{\text{min}}}^{y_{\text{max}}})_{y_{\text{min}}}^{y_{\text{max}}}$. 

The implication of this process of updating the reference point distribution is that if a policy subsidizes $p^N$ or provides transfers to increase $Y$ starting in period $y$, the distribution of heights at month 24 for the cohort born in period $y$ initially shifts just due to the change in budgets. In period $y + 1$ households would also face a different reference point distribution, which induces additional changes in choices and realized height at month 24 for successive cohorts.

3.1.7 Stationary Height Distribution

In a setting in which the nutritional price $P^N$ and the distribution of $F(Y, X, \epsilon)$ are fixed over periods, given $P^N$, $F(Y, X, \epsilon)$, and the nutrition decision rule $N(Y, X, \epsilon; \Gamma)$ we can define a stationary distribution for heights at month 24 $\Gamma$:

$$\Gamma (\mathcal{H}) = \int_{Y \times X \times \epsilon} 1 (h_{24} (N(Y, X, \epsilon; \Gamma), X, \epsilon) \in \mathcal{H}) dF(Y, X, \epsilon)$$

Equation 9 describes the fixed point for $\Gamma$, which exists here given the concavity of the production function. As discussed earlier, households in our model do not distinguish between uncertainty with respect to reference points and with respect to own children’s realized $h_{24}$. This implies that even if mean village height is known with certainty, as might be the case if a stationary distribution is reached, it still is rational for households to consider some level of $\sigma_R > 0$ that captures remaining uncertainty in the gap between own realized height and the average of village reference heights.

3.2 Model Estimation

3.2.1 Measurement Error and Likelihood

The household observes $\Omega = (Y, p^N_{yv}, X)$, and the distributions of $R_{yv}$. In terms of choices and outcomes, the econometrician only observes $F^*$ and $N^*$, which differ from the true optimal nutritional choice $N$ by measurement error $\eta$ and true height outcome $h_{24}$ by $\iota$:

$$\log(N^*) = \log(N(Y, X, \epsilon; p^N_{yv}, \mu_{R_{yv}}, \sigma_{R_{yv}})) + \eta$$

$$\log(h^*_{24}) = \log(h_{24}(N(Y, X, \epsilon; p^N_{yv}, \mu_{R_{yv}}, \sigma_{R_{yv}}), X, \epsilon)) + \iota$$
We assume that $\eta$ and $\iota$ are normally distributed, and that $\epsilon$, $\eta$, and $\iota$ are independent. The standard deviation of $\eta$ is $\sigma_{\eta}$ and the mean is $\mu_{\eta} = -\frac{\sigma_{\eta}^2}{2}$. The standard deviation for $\iota$ is $\sigma_{\iota}$ with mean $\mu_{\iota} = -\frac{\sigma_{\iota}^2}{2}$. The log likelihood is based on the difference between model optimal nutritional choices and observed nutritional choices, as well as the model height outcome and observed heights at 24 months of age:

$$
\max_{\theta \in \Theta} \sum_{y=1970}^{1975} \sum_v \left\{ \sum_i \log \left( \int \phi_i(\ln h_{24,i}^* - \ln h_{24}(Y_i, X_i, \epsilon_i; \theta, \mu_{Ryv}, \sigma_{Ryv})) \cdot \phi_{\eta}(\ln N_i^* - \ln N(Y_i, X_i, \epsilon_i; \theta, \mu_{Ryv}, \sigma_{Ryv}))dF(\epsilon_i) \right) \right\}
$$

where

$$
\theta = \{ \rho, \gamma, \lambda, \delta, A, \alpha, \beta, \sigma_{\epsilon}, \sigma_{\eta}, \sigma_{\iota} \}
$$

Equation 12 is determined by $\theta$ as well as a set of $(\mu_{Ryv}, \sigma_{Ryv})$ that are village- and time-specific. This means that in estimating the model, we do not impose assumptions about where the current height distribution is with respect to the stationary height distribution. We solve for optimal choices given the observed individual specific $\Omega_i$ and the observed $\mu_{Ryv}, \sigma_{Ryv}$ for each year $y$ in village $v$.

We solve the model using the solution method described in Appendix Section A.1. To find the $\theta$ that minimizes the likelihood, we search across parameter space using Quasi-Newton methods, and initiate the likelihood with a range of parameter values to find the global maximum.\(^{28}\) We obtain standard errors from the approximated inverse Hessian.

### 3.2.2 Identification of the Key Parameters

In Appendix Section A.2, we describe how we match the data described in Section 2.2 to model variables and values. In this section, we discuss aspects of the data that help identify key parameters. Parameter $\rho$ for the quadratic term of non-child-nutrition consumption $c$ determines the concavity of preferences with respect to $c$. If income does not matter, then the model is quasilinear in income with $\rho = 0$. Hence, $\rho$ is identified by the effect of income on choices.

In terms of the linear preference parameters for height, if parameter $\gamma = 0$ (and $\lambda = 0$), that would lead to zero nutritional choices. Given positive nutritional choices,

\(^{28}\) Initial values of the parameters: for preference parameters, we try $\rho$ equals to or less than 0, and we test a range of $\gamma$ values, with corresponding $\lambda$ values that makes preference in height linear, or have different degrees of concavity. For the Atole discount $\delta$ parameter, we test from 10 to 90 percent discounts at 10 percent intervals. We start production function parameters at the same values always, which are parameters estimated from a instrumental variable regression in which the Atole dummy is an instrument for protein intakes.
we have $\gamma > 0$. If average nutritional choices are high, $\gamma$ is higher to reflect higher preferences for height, and vice-versa.

In Figure 1, we show the nutritional-choice and height gaps between Atole and Fresco villages. If the Atole price discount parameter $\delta = 0$, that implies that Atole and Fresco villages have the same protein prices. The protein supplementation policy experiment works through the $\delta$ parameter. We can adjust $\delta > 0$ to help match the overall nutritional gap between Atole and Fresco villages shown in Figure 1.

Crucial to our model is the reference point parameter $\lambda$. If $\lambda = 0$, reference points have no impact on nutritional choices and heights. We discussed in Section 2.2 that there is no statistically significant differences in incomes, prices, gender and initial heights between Atole and Fresco villages. Therefore, if $\lambda = 0$, the nutritional choices and height gaps between Atole and Fresco villages across cohorts of children at 24 months of age should be constant. In Figure 1, however, as discussed in Section 2.2, we see increasing height and nutritional gaps between Atole and Fresco villages. $\lambda$ is identified by these increasing gaps.

Our production function parameters are identified from the relationship between nutritional inputs, $X$ variables, and height outcomes. The productivity shocks impact both nutritional choices and height outcomes. If we increase $\sigma_\epsilon$, that increases both the standard deviation of nutritional choices as well as height outcomes. $\sigma_\epsilon$ is identified by the positive covariance between the height at month 24 and nutritional choices that is not captured by income, price or components of $X$.

4 Estimation Results

4.1 Parameter Estimates

We present estimated parameters in Table 2, with standard errors shown in brackets. For preferences, $\rho$ is estimated to be -0.0725, indicating concavity in preferences for $c$. $\gamma$ is estimated to be 0.0347, and $\lambda$ is $-0.041$. Given these parameters, we show the consumption and height possibility frontier along with indifference curves for an individual in Figures 3 and 4. Given these parameters, parents prefer taller children, but do not wish for their child to be taller than the mean height of the reference group. The price discount parameter $\delta$ is 0.3756, representing a 38% discount in protein prices in Atole villages. The production function parameters are $\beta = 0.075$, $\alpha_{h0} = 0.034$, $\alpha_{male} = 0.0074$, $A = 4.10$, and $\sigma_\epsilon = 0.010$. For the measurement error coefficients, $\sigma_\eta = 0.38$ and $\sigma_\iota = 0.04$.

29. The effect of $\epsilon$ on height is less than its effects on nutrition because households with more negative shocks will choose higher levels of protein intakes, thus dampening the negative effects of negative shocks on height.
Table 2: Estimated Model Parameters with Standard Errors

<table>
<thead>
<tr>
<th>Parameter Estimates (s.e.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price Discount</td>
</tr>
<tr>
<td>( \rho )</td>
</tr>
<tr>
<td>(-0.0725)</td>
</tr>
<tr>
<td>((0.0038))</td>
</tr>
<tr>
<td>( \gamma )</td>
</tr>
<tr>
<td>(0.0347)</td>
</tr>
<tr>
<td>((0.0039))</td>
</tr>
<tr>
<td>( \lambda )</td>
</tr>
<tr>
<td>(-0.041)</td>
</tr>
<tr>
<td>((0.0065))</td>
</tr>
<tr>
<td>Price Discount</td>
</tr>
<tr>
<td>( \delta )</td>
</tr>
<tr>
<td>(0.3756)</td>
</tr>
<tr>
<td>((0.026))</td>
</tr>
<tr>
<td>Production Function</td>
</tr>
<tr>
<td>( A )</td>
</tr>
<tr>
<td>(4.1036)</td>
</tr>
<tr>
<td>((0.020))</td>
</tr>
<tr>
<td>( \alpha_{H0} )</td>
</tr>
<tr>
<td>(0.0344)</td>
</tr>
<tr>
<td>((0.016))</td>
</tr>
<tr>
<td>( \alpha_{male} )</td>
</tr>
<tr>
<td>(0.0074)</td>
</tr>
<tr>
<td>((0.0026))</td>
</tr>
<tr>
<td>( \beta )</td>
</tr>
<tr>
<td>(0.0753)</td>
</tr>
<tr>
<td>((0.016))</td>
</tr>
<tr>
<td>( \sigma_e )</td>
</tr>
<tr>
<td>(0.0100)</td>
</tr>
<tr>
<td>((0.0011))</td>
</tr>
<tr>
<td>Measurement Error</td>
</tr>
<tr>
<td>( \sigma_\eta )</td>
</tr>
<tr>
<td>(0.3830)</td>
</tr>
<tr>
<td>((0.013))</td>
</tr>
<tr>
<td>( \sigma_\iota )</td>
</tr>
<tr>
<td>(0.0425)</td>
</tr>
<tr>
<td>((0.0013))</td>
</tr>
</tbody>
</table>

4.2 Model Fit

Given estimated parameters, we solve for optimal protein choices for each household. Table 3 compares simulated and actual average protein choices in Fresco and Atole villages, and average height outcomes at month 24 in Fresco and Atole villages. From Panel A, overall, the observed average Fresco village protein choice is 18.78 grams per day and the model simulated average is 19.29 grams. The observed average Atole protein choice is 25.84 grams per day, and the simulated Atole choice is 25.47 grams. For heights, the observed average heights in Fresco and Atole villages are 76.97 cm and 78.30 cm at 24 months of age; the corresponding simulated values are 76.77 cm and 78.39 cm.

Panel B of Table 3 compares simulated and actual averages across gender. Reference points for girls and boys differ by a constant, and there is also a gender-specific coefficient in the production function. With these two gender-related coefficients, we are able to match fairly well the gender gaps in nutritional choices and height outcomes. In Atole villages, observed average proteins for boys and girls are 26.43 grams and 25.19 grams and the simulated results are 26.60 grams and 24.24 grams. In Fresco villages, observed average proteins for boys and girls are 20.12 grams and 17.31 grams and the simulated results are 20.30 grams and 18.15 grams.

Panel C of Table 3 compares simulated and actual averages across calendar year
Table 3: The Fit of the Estimated Model’s Simulated Choices with Data

<table>
<thead>
<tr>
<th></th>
<th>Average Protein Choices</th>
<th>Average Height Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fresco</td>
<td>Atole</td>
</tr>
<tr>
<td></td>
<td>simu-</td>
<td>observed</td>
</tr>
<tr>
<td></td>
<td>lated</td>
<td></td>
</tr>
</tbody>
</table>

Panel A: Average

|                | 19.29  | 18.78  | 25.47  | 25.84  | 76.77  | 76.97  | 78.39  | 78.30  |

Panel B: Averages Across Genders

<table>
<thead>
<tr>
<th></th>
<th>Female</th>
<th>Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>18.15</td>
<td>20.30</td>
</tr>
<tr>
<td></td>
<td>17.31</td>
<td>20.10</td>
</tr>
<tr>
<td>Average</td>
<td>24.24</td>
<td>26.60</td>
</tr>
<tr>
<td></td>
<td>25.19</td>
<td>26.43</td>
</tr>
<tr>
<td>Average</td>
<td>76.11</td>
<td>77.35</td>
</tr>
<tr>
<td></td>
<td>76.19</td>
<td>77.67</td>
</tr>
<tr>
<td>Average</td>
<td>77.81</td>
<td>78.93</td>
</tr>
<tr>
<td></td>
<td>77.69</td>
<td>78.86</td>
</tr>
</tbody>
</table>

Panel C: Averages Across Years

<table>
<thead>
<tr>
<th></th>
<th>1970-71</th>
<th>1972-73</th>
<th>1974-75</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>18.61</td>
<td>19.25</td>
<td>19.69</td>
</tr>
<tr>
<td></td>
<td>18.17</td>
<td>18.97</td>
<td>18.96</td>
</tr>
<tr>
<td>Average</td>
<td>23.46</td>
<td>24.92</td>
<td>27.46</td>
</tr>
<tr>
<td></td>
<td>24.19</td>
<td>25.68</td>
<td>27.15</td>
</tr>
<tr>
<td>Average</td>
<td>76.57</td>
<td>76.79</td>
<td>76.85</td>
</tr>
<tr>
<td></td>
<td>76.83</td>
<td>76.73</td>
<td>77.24</td>
</tr>
<tr>
<td>Average</td>
<td>77.88</td>
<td>78.27</td>
<td>78.87</td>
</tr>
<tr>
<td></td>
<td>77.18</td>
<td>78.57</td>
<td>78.77</td>
</tr>
</tbody>
</table>

Standard deviations are in parenthesis.

birth cohorts. Income, price, and initial height variations over the years impact the average height and protein choices in each year; however, only the differentially trended reference point sequence can explain the differential nutritional trends. Average protein choices increased rapidly in Atole villages, from 24.19 in 1970 to 1971 to 25.68 grams in 1972-1973, and then to 27.15 grams in 1974-1975. The corresponding simulated averages are 23.46, 24.92 and 27.46. In comparison, protein choices in Fresco villages increased from 18.17 grams in 1970-1971 to 18.97 grams in 1972-1973, and then to 18.96 in 1974-1975. The corresponding simulated results are 18.61, 19.25 and 19.69 grams, which are increasing at a slightly faster pace than the observed outcomes.

For the height outcomes across the years, the match is very close as can be seen from columns 4 through 8 in Panel C of Table 3. Average heights in Atole villages for 1970-71, 72-73, and 74-75 are 77.18 cm, 78.57 cm, and 78.77 cm respectively. Corresponding simulated heights in Atole villages are 77.88 cm, 78.27 cm and 78.87 cm. Average heights in Fresco villages for 1970-71, 72-73, and 74-75 are 76.83 cm, 76.73 cm, and 77.24 cm respectively. Corresponding simulated heights in Fresco villages are 76.57 cm, 76.79 cm and 76.85 cm.
5 Counterfactual Policy Experiments

Using the estimated model, we conduct four sets of counterfactual exercises. First, we decompose the relative contributions of prices and reference points to the height differences between Atole and Fresco villages in the actual INCAP experiments. Second, we focus on the one-period effects of the model, and evaluate the impacts of changing reference heights exogenously on heights in comparison with the effects of one-period changes in income and price.

In our third and fourth sets of counterfactuals, we exploit dynamic features of our model to distinguish among three possible effects of protein-price-subsidy policies in a context where reference points play important roles affecting household decisions: 1, the direct impact of subsidies on the treated children; 2, the indirect effect of subsidies via shifting reference points on the treated children; 3, the indirect impact of shifting reference points on the untreated children. For the third set of counterfactual policy experiments, we compare poor-targeted and universal policy experiments. In the fourth set of policy experiments, we compare concentrated and distributed policies, where we distribute subsidies to a fixed number of children who receive subsidies in just one or multiple villages.

5.1 Decomposition

In the model, the initial height gap between Atole and Fresco villages is driven by the price reduction in nutritional inputs in Atole villages. This price reduction has a direct and immediate impact on the budget constraint that the households face. Additionally, the initial price reduction induces changes in reference heights in the following periods that lead to further increases in nutritional intakes and height outcomes. We decompose the total impact of the price discount policy on the height gaps between Atole and Fresco villages into shares that are driven by the immediate and sustained protein price discount, and shares that are driven by subsequent changes in reference heights.

We show in Table 4 and Figures 5 and 6 counterfactual simulations that close the protein and height gaps between Atole and Fresco villages. In the first column of the first panel on Table 4, we summarize, for households in Fresco villages, the simulated average height outcomes and protein choices. In column five, we show these for households in Atole villages. Comparing these two columns, the height gaps between Atole and Fresco villages for 1970-71, 1972-73 and 1974-75 are 1.31cm, 1.48cm and 2.02cm, respectively.

In the second column, we simulate counterfactuals in which Fresco households receive the 38% Atole protein price discount. This reduces the height gaps, by 72mm
Figure 5: Giving Fresco Villages Atole Price and Atole Reference Points

Figure 6: Decompose Height Gaps Between Atole and Fresco Villages
Table 4: Decompose Protein Gaps between Atole and Fresco Villages

Average Protein Choice Across Birth Years

<table>
<thead>
<tr>
<th>Year</th>
<th>Fresco</th>
<th>Fresco Counterfactuals</th>
<th>Atole</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>simulated without counterfactuals</td>
<td>Fresco with Atole Price Discount</td>
<td>Fresco with Atole Ref. Point</td>
</tr>
<tr>
<td>1970-71</td>
<td>76.57</td>
<td>77.29</td>
<td>77.09</td>
</tr>
<tr>
<td>1972-73</td>
<td>76.79</td>
<td>77.54</td>
<td>77.47</td>
</tr>
<tr>
<td>1974-75</td>
<td>76.85</td>
<td>77.69</td>
<td>77.70</td>
</tr>
</tbody>
</table>

Panel A: Height Across Birth Cohorts

<table>
<thead>
<tr>
<th>Year</th>
<th>Fresco</th>
<th>Fresco with Atole Price Discount</th>
<th>Fresco with Atole Ref. Point</th>
<th>Atole</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970-71</td>
<td>76.57</td>
<td>77.29</td>
<td>77.09</td>
<td>77.86</td>
</tr>
<tr>
<td>1972-73</td>
<td>76.79</td>
<td>77.54</td>
<td>77.47</td>
<td>78.29</td>
</tr>
<tr>
<td>1974-75</td>
<td>76.85</td>
<td>77.69</td>
<td>77.70</td>
<td>78.63</td>
</tr>
</tbody>
</table>

Panel B: Protein Across Birth Cohorts

<table>
<thead>
<tr>
<th>Year</th>
<th>Fresco</th>
<th>Fresco with Atole Price Discount</th>
<th>Fresco with Atole Ref. Point</th>
<th>Atole</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970-71</td>
<td>18.61</td>
<td>20.96</td>
<td>20.37</td>
<td>23.12</td>
</tr>
<tr>
<td>1974-75</td>
<td>19.69</td>
<td>22.63</td>
<td>22.85</td>
<td>26.56</td>
</tr>
</tbody>
</table>

(55%) in 1970-71, 75mm (51%) in 1972-73 and 84mm (42%) in 1974-75. In Figure 6, we show these decompositions for each of the 6 years separately. Both the table and the chart show that the 38% price discount contributes significantly to closing the height gaps; its impact is stable at around 79mm to 92mm over time, and its share of the total impact decreases overtime. The small changes in this impact overtime are due to price and income fluctuations.

Column three presents counterfactuals in which we replace the reference points in Fresco villages by the Atole reference points but do not change prices. Under these counterfactuals, height gaps decrease by 52mm (40%) in 1970-71, 68mm (46%) in 1972-73 and 85mm (42%) in 1974-75. In the lower panel of Figure 6, we show the impacts of these reference point changes on each of the 6 years separately, and observe a substantial rise of the impacts from 62mm in 1970 to 1.03cm in 1975. The impacts increase substantially over time due to the steeper cumulative rise in reference points in Atole villages.

In column four of Table 4, we provide Fresco households with both protein price discounts and the Atole schedule of reference heights. The resulting nutritional choices and height outcomes closely approximate the simulated results from Atole villages shown in column five. The gaps in heights between columns four and five are 0.02cm for 1970-71, -0.02cm for 1972-73 and 0.24cm for 1974-75. Given that other state vari-
ables do not vary significantly between Atole and Fresco villages as seen in Table 1, it is not surprising that equating the two factors that differentiated Atole and Fresco villages lead to the homogenization of height outcomes and protein choices.

Overall, the price discount and the changes in reference points each contributed to about half of the height gaps between Atole and Fresco villages. From 1970 to 1975, the relative contribution of the price discount to the height gaps decreases from 62% to 43%, and the impacts of reference points on heights increase from 48mm to 1.03cm. It is important to note that the decomposition exercise does not imply that changes in reference points and price discounts could be imposed independently. For the Guatemalan case that we study, a change in the price discount brought about the changes in reference points, and we have decomposed the relative roles of these two interactive components.

5.2 Exogenously Shifting Reference Points

In this section, we conduct counterfactual policy experiments in which we impose exogenous changes to reference points. We focus only on the immediate one-period effects of the change. We first compare effects across different levels of exogenous one-period reference point shifts (to WHO reference levels). Second, we compare the effects of exogenous one-period reference point shifts to the one-period effects of protein price discounts and income subsidies. Overall, we find that a 1 cm increase in reference points corresponds to about 0.7 cm increase in height. We also find that a price discount of 37 percent and income increase of 60 percent would induce similar increases in mean heights as the 1 cm increase in reference points.

In our decomposition exercise earlier and the targeted and universal counterfactuals that we discuss later, there is always a change in the budget constraint first that induces later changes in reference points. For those counterfactuals, the effects of reference-points changes in later periods are always interacting with the effects of budget-constraint changes that persist across periods. The counterfactuals of this section allow us to illustrate the effects of shifting policies just along the reference points dimension alone, holding the other variables constant.

An exogenous one-period shift in reference points also has real economic implications: this would happen if individuals moved to a different locality where the reference population is distributed differently (Bottan and Perez-Truglia 2017; Liu and Zuppann 2016). In our model, we assume that reference points could shift when households observe actual changes in heights within the village. Without relocation or observing real within-village changes, it might be difficult to convince households that they should make choices based on reference populations that they do not reside within. There is, however, recent experimental evidence that growth charts based on
external populations could be effective in promoting height growth (Fink et al. 2017). 30

5.2.1 Exogenous Shift of Reference Points to WHO Levels

We conduct our counterfactuals focusing on a specific subgroup of children: boys born in Atole villages in 1974 and 1975. Our results are shown in Figure 7. We pick this group because among the cohorts of boys and girls, this group is the closest to WHO median reference heights.

The left panel of Figure 7 shows changes in average heights induced by exogenous shifts of the reference height from 79.46cm—specific to Atole boys from 1974 to 1975—to other points; the right panel shows the levels of average heights given shifts in reference points. The figures show that if we shift reference heights to 85.8cm—which is the 10th percentile of the WHO height distribution for well-nourished 24 month year olds—average heights increase by about 4.4cm to 83.8cm. If we exogenously impose reference heights to be 87.2cm—which is the median WHO height distribution for well-nourished 24 month olds—average heights increase by 5.4cm to 84.8cm. These reference points changes are large and their impacts are significant. Realized average heights are still below WHO levels, but gaps between Atole boys and WHO levels significantly decrease without the injection of cash-transfers or price discounts.

---

30. As discussed earlier, Marini, Rokx, and Gallagher (2017) and Fink et al. (2017) find that growth chart could promote height growth. Earlier literature on growth charts, however, as discussed by Ben-Joseph, Dowshen, and Izenberg (2007), showed that parents often could not easily understand the possible relevance of growth charts for their children.
Overall, figure 7 shows that going from a reference height of 70 cm to a reference height of 90 cm would change average heights for 24-month-old children by 13.7 cm, increasing average height for this group of children from 72.4 cm to 86.2 cm, without changes in the prices and incomes that affect households’ budgets. The marginal impacts of additional increments in reference points are decreasing due to the concavities of the utility and production functions. We should note that in the data, the change in reference height that was induced by the introduction of protein supplement in Atole villages was only over 1.8 cm in the span of 5 years. Reference height changes that are driven by changes in protein prices and income changes are small and accumulate slowly, but perhaps it is only through the process of slowly changing the actual heights of children in villages that parents of new-borns will be convinced that reference heights should be changing.

5.2.2 Relative Effects of Price, Income and Reference Points Changes

In this section, to better understand the mechanism of reference point changes, we compare the impact of one-period exogenous reference point changes and one-period effects of shifting prices and incomes. We find that substantial price discount and income subsidies are required to produce the same mean height changes as can be induced by reference points shifts. Price discounts can be considered to be a type of conditional transfer policy where transfers are conditional on purchases. Income transfers are unconditional. We find that because most income is not spent on child nutrition, much larger unconditional income transfers are required than the subsidies for price discounts to achieve the same shift in height outcomes.

We simulate here based on the distribution of Atole village children, starting from 1970 reference points. Our results are shown in Panels A and B of Table 5. In both panels there are four rows, each row corresponds to results when reference point shifts up by 0.5, 1.0, 1.5 and 2.0 cm respectively. These four levels are indicated in the first column of Table 5.

In the second and third columns of Table 5, we show that average heights increase by 0.36, 0.71, 1.05, and 1.39 cm when the reference point distribution shifts up by 0.5, 1.0, 1.5 and 2.0 cm. The incremental mean height gains, for each additional 0.5 cm increase in mean reference points, are 0.36, 0.35, 0.35 and 0.34 cm, so that each additional cm of reference point increase induces about 0.70 cm increase in mean realized heights at month 24. The marginal rate of change is slightly smaller for higher levels of reference point increases.

In Panel A, we present price-discount policies\(^\text{31}\) that would lead to equivalent changes in mean heights as induced by reference-points changes. We find that, in terms of

\(^{31}\) Here we are considering a universal price discount that all children receive.
Table 5: One-Period Exogenous Reference Point Change vs Price and Income Changes

### Panel A: Compare to One-Period Percentage Decrease in Price Discount
Simulate from 1970 Atole Distribution

<table>
<thead>
<tr>
<th>Total Increase in Mean Reference Points</th>
<th>Cumulative Total Hgt Increase</th>
<th>Impact of additional 0.5 cm Ref. Inc</th>
<th>Price Discounts (Universal) that Induce Same Mean Height Change As Ref. Points Changes</th>
<th>Equivalent Price Discount</th>
<th>Additional perc. points</th>
<th>Avg Cost Per Person Per Day in Grams</th>
</tr>
</thead>
<tbody>
<tr>
<td>+0.5 cm</td>
<td>+ 0.36</td>
<td>+0.357</td>
<td>20%</td>
<td>-20 pp</td>
<td>4.1 g</td>
<td></td>
</tr>
<tr>
<td>+1.0 cm</td>
<td>+ 0.71</td>
<td>+0.349</td>
<td>37%</td>
<td>-17 pp</td>
<td>8.4 g</td>
<td></td>
</tr>
<tr>
<td>+1.5 cm</td>
<td>+ 1.05</td>
<td>+0.346</td>
<td>51%</td>
<td>-14 pp</td>
<td>12.5 g</td>
<td></td>
</tr>
<tr>
<td>+2.0 cm</td>
<td>+ 1.39</td>
<td>+0.338</td>
<td>64%</td>
<td>-13 pp</td>
<td>16.7 g</td>
<td></td>
</tr>
</tbody>
</table>

### Panel B: Compare to One-Period Percentage Increase in Income
Simulate from 1970 Atole Distribution

<table>
<thead>
<tr>
<th>Total Increase in Mean Reference Points</th>
<th>Cumulative Total Hgt Increase</th>
<th>Impact of additional 0.5 cm Ref. Inc</th>
<th>Income Increase (Universal) that Induces Same Mean Height Change As Ref. Points Changes</th>
<th>Equivalent Income Increase</th>
<th>Additional perc. points</th>
<th>Fraction of Income Spent on Proteins</th>
</tr>
</thead>
<tbody>
<tr>
<td>+0.5 cm</td>
<td>+ 0.36</td>
<td>+0.357</td>
<td>+32%</td>
<td>+32 pp</td>
<td>11.9%</td>
<td></td>
</tr>
<tr>
<td>+1.0 cm</td>
<td>+ 0.71</td>
<td>+0.349</td>
<td>+60%</td>
<td>+28 pp</td>
<td>10.0%</td>
<td></td>
</tr>
<tr>
<td>+1.5 cm</td>
<td>+ 1.05</td>
<td>+0.346</td>
<td>+86%</td>
<td>+26 pp</td>
<td>9.5%</td>
<td></td>
</tr>
<tr>
<td>+2.0 cm</td>
<td>+ 1.39</td>
<td>+0.338</td>
<td>+107%</td>
<td>+20 pp</td>
<td>9.1%</td>
<td></td>
</tr>
</tbody>
</table>

increasing average heights, increasing mean reference points by 0.5, 1.0, 1.5 and 2.0 cm are equivalent to discounting prices by 20, 37, 51 and 64 percent. We determine the costs of these price-discount policies by multiplying the discount fraction by the amount of protein purchased: they are 4.1, 8.4, 12.5 and 16.7 grams per child per day respectively as shown in Column 6 of Panel A. We should note that despite mean-equivalence for each pair of policies, the policy that shifts reference points will lead to
wider height variance than the price-discount policy.\footnote{32}

In Panel B of Table 5, we present income-subsidy policies\footnote{33} that would lead to equivalent changes in mean heights as induced by reference-points changes. We find that, in terms of increasing average heights, increasing mean reference points by 0.5, 1.0, 1.5 and 2.0 cm are equivalent to increasing incomes by 32, 60, 86 and 107 percent. The large income increase required here is due to Engel’s Curve type mechanisms (Deaton and Muellbauer 1980) in which higher-income households spend smaller fractions of income on food. Specifically, in column 6 of Panel B, we present the shares of income spent on protein: 11.9, 10.0, 9.5 and 9.1 percent of income under each of the four sets of mean-preserving policies. This means that as we double income, for each additional queztal, only about 9 centavos go to protein purchases. These increasingly smaller protein spending shares means incomes need to increase by large amounts to move height outcomes up by small amounts. Additionally, given the large amount of income subsides, the mean-preserving income transfers lead to significantly higher variance in height outcomes and protein consumption.

Combining the results, we find that substantial price-discount and income subsidies are required to produce the same mean height changes as can be induced by plausible reference point shifts.

5.3 Targeted vs Universal Policy Experiments

We evaluate the impacts of counterfactual policy experiments that target protein price discounts towards poorer children and a universal policy that provides common price discounts for all, given a fixed budget. Our outcome of interest remains height reached at 24 months of age. There has been a long debate in the both the development and early childhood literature about the trade-offs between targeted vs universal subsidy policies (Besley and Kanbur 1990; Gelbach and Pritchett 1997; Coady, Grosh, and Hod- dinott 2004). Under universal subsidy policies, the entire population benefits, and under targeted policies, subsidies are generally given to those who are deemed (mean-tested for) the most in need.

Our first key result here is that the universal policy—which is generally considered to be insufficiently beneficial for the poor who have to share subsidies with richer

\footnote{32. For example, under the 2.0 cm mean reference point increase, the standard deviation of height is 0.75. Under the 20 percent price discount, the height standard deviation is 0.40. This difference exists because a one-period exogenous shift in reference point increases the optimal height for all and induces increases in investments by richer and poorer households. The effect of a one-period shift in prices, however, has much larger effects for poorer households and less impacts for richer households who already are at closer to optimal heights.}

\footnote{33. We should note that the effects of income subsidies simulated here do not take into account potential general equilibrium effects that higher income might have on prices. Filmer et al. (2018) find that a targeted cash transfer program in the Philippines led to higher prices of perishable protein-rich foods and negative welfare consequences for non-beneficiary children.}
households—is much better for poorer children in later cohorts whose heights increase substantially due to aggregate increases in reference points. To be sure, policies directly targeting the poor still would induce greater height increases for the poor than the universal policy, but for later cohorts, the gaps between targeted and universal policies on the poor are smaller once we have considered the endogenous evolution of reference points.

Our second key result is that the targeted policy—which would normally only benefit the poor—has substantial positive effects on the non-targeted richer children as well through the externality of reference point changes. After an initial period in which only targeted individuals benefit, later cohorts of both targeted and non-targeted children are impacted by reference point changes.

Both results show that reference points amplify the effects of targeted and universal subsidy policies on all children within the same village. To compare the overall effects of the policies, we analyze the height distribution induced by nine budget equivalent policies that gradually increase the proportion of children receiving price subsides. Overall, we find that within our context, all policies induce similar mean heights. The policies, however, generate substantial differences in height variances: the most targeted as well as most universal policies both increase variances. Within the set of budget-balancing policies we consider, we find that variance in height is minimized when 70 percent of the poor children receive 18 percent price discounts.

5.3.1 Simulation Design–Budget Balancing Targeted to Universal Policies

We compare policies in which increasingly larger fractions of individuals in a village are targeted as subsidy recipients. To keep subsidy costs the same across policies, we reduce the subsidies provided to targeted children as the fraction of children targeted increases. We conduct policy counterfactuals that target children by household annual income.

To simulate the policies, we draw 500 individuals based on the empirical joint distribution of incomes, gender and initial heights of all children from Atole villages. Then we start at the reference point from Atole villages in year 1970 and simulate our model forward. Each model period is 2 years, and we simulate the model 4 times to obtain results for the 1970, 1972, 1974 and 1976 cohorts. The state-space distribution and protein prices facing households are the same across cohorts, but each cohort faces different endogenously evolving reference points, which lead to variations in nutritional choices and height.

34. The goal here is to isolate the effects of price subsidy and reference point changes, and abstract away from other potential observed differences in initial heights, non-protein prices and incomes. If the price discount policy were 38 percent and provided to all individuals, the height path would be similar to the observed height path, but it would not be identical because all of our simulated cohorts
Following the model interpretation of the protein supplementation policy as a price discount, our counterfactuals here involve changing the percentage price discount that households receive.\textsuperscript{35} Under the universal policies, all families receive subsidies through a common price discount. Under the policies that target the poor, we transfer the subsidies that rich children received under the universal policy to the poor by increasing the price discount that the poor receive. We increase the price discount sufficiently that given the optimal choices of the poor, at the new price discount level, the poor purchase sufficient proteins to obtain all subsidies available.

Let $\tau$ be the fraction of poorest children receiving price discounts and $\delta$ be the percentage price discount that children receive. $Z(\tau,\delta)$ is the total cost of a subsidy in grams of protein for 1970, 1972, 1974 and 1976 cohorts, given reference point distribution $\Gamma$ for each cohort:

$$Z(\tau,\delta) = \sum_{\text{cohort}\in\{70,72,74,76\}} \left\{ \delta \cdot \int_{Y_{\min}}^{F_{Y,\text{cuban}}(\tau)} \int_{X} N\left( Y, X, \epsilon; \Gamma_{\text{cohort}} \right) f(X|Y) f(Y) f(\epsilon) \, dX \, dY \, d\epsilon \right\} \tag{14}$$

As described earlier, we fix the joint distribution of the state space across cohorts, and so only the reference point distribution $\Gamma$ is cohort-specific in Equation 14. We start $\Gamma_{1970}$ as mentioned using the actual reference points in year 1970 from Atole villages, and solve for subsequent reference points distributions following Equation 8.

We first solve for $Z(\tau = 0.1, \delta = 0.9)$, when 10 percent of the poorest households out of 500 simulated households are provided with a 90\textsuperscript{36} percent protein price discount. Then, for each $\tau \in (0.2, 0.3, \ldots, 0.9, 1.0)$, we solve for the $\delta$ fraction discount that minimizes the difference between $Z(0.1, 0.9)$ and $Z(\tau, \delta)$:

$$\delta(\tau, Z(0.1, 0.9)) = \arg\min_{\delta \in [0.01, \ldots, 1.00]} \left| Z(\delta, \tau) - Z(0.1, 0.9) \right| \tag{15}$$

Solving for the $\delta$ values following Equation 15, we find that policies that provide 55, 50, 39, 30, 25, 21, 18, 16, 14 and 13 percent price discounts for 20, 30, 40, 50, 60, 70, 80, 90, and 100 percent of children, ranked from the poorest to the richest, cost approximately the same as $Z(0.1, 0.9)$.

The focus here is on comparing the distributional effects of policies that cost the same in terms of total protein subsidized through price discounts.

\textsuperscript{35} Alternatively, we could provide households with different levels of protein transfers, but that involves forcing households to consume a fixed level of subsidy proteins (see footnote 19).

\textsuperscript{36} 90 percent is chosen so that as we increase the fraction of children targeted, the price discounts that households receive will not fall below 10 percent.
5.3.2 Comparing the Effects of Targeted Policies on Bottom Quintile ("Poor") and Top Quintile ("Rich")

We discuss in this section the impact of policies with different degrees of targeting/price-discounts on children from the bottom 20 and top 20 percent of the income distribution. As a shorthand, we use the word "poor" and "rich" to refer to these two groups of children.

Overall, we find that: 1) the height of the subsidized median poor child, when provided with at least a 30 percent price discount under highly targeted policies, would exceed the height of the unsubsidized median rich child. 2) Universal policies have very low initial impacts on poor children compared to policies targeting poor children with high discounts, but over cohorts, reference points changes substantially increase heights for poor children even under the universal policy. 3) Reference point externalities lead to height increases for non-targeted rich children that are at least 48 percent of the height increase for poor children under policies targeting the poor.

Figure 8 presents our main findings. Different levels of targeting—targeting 20, 40, 60, 80 percent of the poorest children along with universal policy—are points along the x-axis. Price discounts at 55, 30, 21, 16 and 13 percent for each of the five policies are calculated based on Equation 15. Poor children receive subsidies under all five policies, but rich children only receive subsidies under the universal policy.

As discussed earlier, we simulate results using the empirical distribution of data from Atole villages. We start the simulation in 1970 with 1970 reference points. Figure 8 presents results for the cohort born in 1970. Figure 10 presents the differences in heights for poor children from the 1970, 1972, 1974 and 1976 cohorts. Figure 9 presents results for poor and rich children from the 1976 cohort. We focus on median heights at 24 months of age. In all Figures, the orange solid line shows median heights for poor children, and the dashed green line shows median heights for rich children. Also, the two flat horizontal lines in the figure show that in the absence of the price discount policy, median heights at month 24 for poor and rich children in the 1970 cohort were 76.7 and 77.4 cm respectively (0.7 cm gap).

Policy Effects on 1970 Cohort  Figure 8 shows that for the 1970 cohort, the immediate direct effects of price discounts could be large enough to induce the median poor child to be taller than the median rich child. Under targeted subsidies, poor children experience a significant increase in heights, with median heights increasing by 1.3, 0.6, 0.4, and 0.3 cm when poor children receive 55, 30, 21, and 16 percent targeted discounts. With a 55 percent price discount, poor children’ median height reaches 77.9 cm and is 0.5 cm higher than the median height for rich children. Under the three other targeted

37. These correspond to median daily average protein intakes of 19.0 grams and 22.1 grams for the poor and rich children.
Figure 8: Effects of Targeted Policies on Rich and Poor Households (1970)

Figure 9: Effects of Targeted Policies on Rich and Poor Households (1976)
policies, the median rich child who does not receive subsidies would still be taller than the subsidized median poor child. When both rich and poor children receive 13 percent price discounts under the universal policy, median height increases more for the poor (+0.25 cm) than the rich (+0.17 cm).

Policy Effects on Poor Children Across Cohorts In Figure 10, we present the impact of policies on successive cohorts of poor children. Overall, aggregate effects of policies increase across cohorts at decreasing rates. We compare heights at month 24 for later cohorts of poor to the heights at month 24 that the 1970 poor cohort would reach without price discounts. With 55 percent price discounts targeted towards the poor, median heights increase by 1.3, 1.9, 2.4, and 2.7 cm for 1970, 1972, 1974, and 1976 cohorts of poor children.\textsuperscript{38} The increasing total effect of the price discount policy for later poor cohorts are driven by endogenous shifts in reference point distributions; the decreasing marginal effects of the policy are due to the concavities in preference and production functions.

Interestingly, Figure 10 also shows that while universal policies provide very small height increases to poor children initially, over cohorts, shifts in reference points significantly amplify the benefits of more universal policies on poor children. Specifically, for the 1970 cohort of poor children, the most targeted policy (55 percent discount) increases the median height by 1.25 cm, which is 4.8 times larger than the 0.26 cm median height increase induced by the universal policy (13 percent price discount). For

\textsuperscript{38} Correspondingly, median protein intake increases by 23, 38, 50 and 58 percent for these cohorts.
the 1976 cohort of poor children, however, the effect of the most targeted policy is only 1.8 times greater than the effect of the universal policy, each of which increases median heights by 2.7 and 1.5 cm respectively. Comparing poor children across cohorts, the increase in median height is 5.8 times larger for the 1976 cohort compared to the 1970 cohort (1.5 vs 0.26 cm). The increase in median height for rich children across cohorts is 2.2 times (2.7 vs 1.25 cm). These patterns happen because in terms of shifting the means of the reference point distributions, the universal policy has similar effects as the highly targeted policy, and overtime, the importance of reference point effects increases relative to first period price discount effects.

**Policy Effects on 1976 Cohort**  Figure 9 presents heights for both poor and rich children from the 1976 cohort. One key result is the substantial externality effects of targeted policies on non-targeted rich children. Here we compare heights for the 1976 cohort to the heights at month 24 for the 1970 poor and rich cohorts without subsidies. Across the five policies from most targeted to universal, heights for the rich children increase by 1.3, 1.3, 1.3, 1.3 and 1.6 cm, equivalent to 48, 65, 76, 81 and 103 percent of the increases in heights for poor children, which are 2.7, 2.0, 1.7, 1.6, and 1.5 cm. Height increases for poor children are induced by one-period price discounts and subsequent reference point changes. The 1.3 cm median height increases for rich children under the four targeted policies, however, are only due to the reference-point externality of the treatments on non-targeted individuals. The increases are substantial enough that under 30, 21 and 16 percent price discounts, the median heights for the rich children— who receive no subsidies—are still 0.1, 0.3 and 0.5 cm higher than median heights for targeted poor children. It is only under the 55 percent price discount policy that poor children reach a higher median height (79.4 cm) than rich non-targeted children (78.8 cm).

**5.3.3 Distributional Effects of Most-Targeted and Universal Policies**

We continue with our analysis on targeted policies in this section. Here, we focus on the height distributions for the 1976 cohort under the policy that targets 20 percent of the poorest households with 55 percent discounts as well as under the universal policy in which all receive 13 percent discounts—we will refer to these two policies as 39. Under the universal policy, everyone’s height shifts up by a small amount; under the highly targeted policy, a subset of individuals’ heights shift up by a larger amount.

40. This is also shown by the fact that for the 1970 cohort of poor children, 100 percent of the increases in height are due to first-period price-discount effects, but for the 1976 cohort of poor children, under 55, 30, 21, 15 and 13 percent price discounts, first-period price discount effects only account for 46, 31, 24, 19, and 16 percent of the total effect of each policy.

41. We should note that across all policies, poor 1976 cohorts do achieve higher median heights than rich 1970 cohorts without subsidies: the gaps are 1.9, 1.2, 1.97, 0.85, and 0.76 cm from most-targeted to universal policies.
Figure 11: Height Distribution Histograms for Targeted and Universal Subsidies

The orange histogram (along with the solid orange density plot) shows the distribution of heights at month 24 for the 1976 cohort under the universal policy. The black dashed density plot shows the overall distribution of height under the highly-targeted policy, and a small black histogram shows just the height distribution for the 20 percent poorest children targeted by the targeted policy.

Overall, height is more tightly distributed under the universal policy and bimodal under the highly targeted policy. Average heights at 78.56 cm and 78.51 cm are almost identical under the two policies. The standard deviation of heights, however, is 0.57 cm under the highly targeted policy and only 0.40 under the universal policy. The wider variance under the highly targeted policy is due to the bimodal distribution induced by the policy. The high mode consists of the 20 percent poorest children who receive large price discounts: their mean height is 79.4 cm with a standard deviation of 0.14 cm. The low mode consists of the remaining 80 percent of children who are only impacted through reference point externalities: their mean height is 78.3 cm (1.1 cm lower) with a standard deviation of 0.43 cm. We should note that these results are specific to this environment in which most children are highly stunted. In a context in which children from rich households are much taller, the height distribution for poor children under highly-targeted policies might still be well below the height distribution for the remaining children.
In our environment, if the objective of the policy maker is to make sure a fraction of children achieve heights above a certain high threshold level, the highly-targeted policy is more effective: for example, under the highly-targeted policy, 26 percent of 1976 cohort children are 79 cm and taller, whereas the fraction is only 9 percent under the universal policy.\footnote{If pushing up the higher tail of the distribution is the objective, a subsidy could target the richest who start from a taller base without the subsidies. That policy, however, would lead to much wider variance than the poor-targeting policies that we consider.} If the objective of the policy maker is to reduce the fraction of children shorter than a certain low threshold level, the universal policy is more effective: specifically, under the universal policy, only 5 percent of the children are shorter than 78 cm, but under the highly-targeted policy, 15 percent of children are below that threshold.

5.3.4 Distributional Effects of Different Levels of Targeted Policies

We now analyze the impacts of a wider range of policies with different targeting levels on average heights and the variation of heights across children. We find that given our sample of individuals, mean heights are relatively constant across targeting levels, and variance is minimized when 70 percent of the poorest children are targeted to receive subsidies.

We show the results graphically in Figure 12. In this Figure, different levels of targeting—targeting from 20 to 90 percent of the poorest children at 10 percent intervals along with a universal policy—are points along the x-axis. Price discounts at 55, 39, 30,
25, 21, 18, 16, 14 and 13 percent for each of the nine policies are calculated based on Equation 15 to be approximately budget constant. We plot the 10, 20, 50, 80, 90 percentile levels of overall—including both targeted and non-targeted children—heights of month 24 distributions under each policy experiment.

**Mean Height across Policies** The dashed black line in Figure 12 shows that the mean heights across policies differ by at most only 0.054 cm. Our policy experiments shift a fixed amount of subsidies from one subset of individuals to another in the form of price discounts. Similar mean heights across policies indicate that given the distribution of state-space values and model parameters, shifts in protein intakes across policies have approximately linear effects. Who receives the transfers and how much they receive change the relative heights among individuals, but not the overall average height significantly.

**Variation in Height across Policies** As policies shift price discount intensity and recipients, there are significant variations in height distributions across policies. One measure of variation is the difference between the 10th and 90th percentiles of heights across policies. This is the difference between the dashed blue lines at the top and bottom of Figure 12. Showing a decreasing pattern, these gaps are 1.5, 1.1, 0.9 and 0.75 cm when 20, 30, 40, and 50 percent of the poorest children receive price discounts; the gaps are the tightest at 0.69, 0.66 and 0.66 cm under policies that provide 60, 70, and 80 percent of poorest children with price discounts; the gaps widen again to 0.8 and 0.9 cm under the two most universal policies.

The minimization of height variation when 70 percent of the poorest children are targeted is driven by a tightening of both the higher and lower percentiles of the heights at month 24 distributions. First, under the most-targeted policies, children from the poorest households receive very large discounts and become the tallest children, driving the 90th percentile of height at month 24 distribution up. Concurrently

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43. The highest mean, 78.58 cm, is achieved under targeting 20 percent of the poorest households, and the lowest mean, 78.52 cm, is achieved under the universal policy.

44. Potentially, one might suspect that the variations in means across policies would be large given the concavity of the production function: all else equal, 1 gram of protein transferred from those with high intake to those with lower intake should lead to a net gain in overall height. Here, however, given that households re-optimize with new price subsidies, the increases in protein intakes are less than the amounts of protein transferred to the poor through price discounts.

45. The standard deviation of heights, at 0.40 cm, is also the smallest for the policy that targets 70 percent of poorest children.

46. For the most-targeted policy that provides 55 percent price discounts to the children in the lowest quintile of income, these poorest children’s heights increase significantly and they move to the highest quintile of the realized height at month 24 distribution. As shown in Figure 8, the median heights of these poorest children under the 55 percent discount policy exceed the median heights of children from the richest quintile of income, hence this pushes the 80 and 90th percentile of the overall height distribution up under the most targeted policies.
many children with below-median income do not receive subsidies under the most targeted policies, and they push down the 10th and 20th percentiles of the height distribution. Second, under the most-universal policies, children from the richest households receive price discounts, and they drive the 90th percentile height distribution up. Concurrently, because subsidies for the poorest households are much lower than under more-targeted policies, they push the 10th and 20th percentiles of the height distribution lower. Consequently, we observe the wider distributions of heights under the most-universal and most-targeted policies, but tighter distribution in the middle of Figure 8.

5.4 Concentrated vs Distributed Subsidies

We compare in this section between what we call "concentrated" and "distributed" subsidy policy experiments. We consider a scenario in which each locality has 500 new-born children per year, and there are 10 localities with identically distributed populations. We assume that parents care about the reference heights in their own locality, but not about the reference heights in the other nine localities. The price discount is 38 percent based on the estimated result from the model. An aid agency is subsidizing nutrition for 500 children in these 10 localities. We conduct two counterfactual simulations for comparison. First, we conduct a concentrated policy experiment in which we assign all 500 protein-subsidy children to 1 of the 10 localities, and new-born children in the 9 other localities receive no treatments. Second, we conduct a distributed policy in which we assign treatment so that there are 50 randomly selected protein-subsidy children in each of the 10 separate localities. These policies

47. As shown in Figure 8, the smaller discount (13 percent discount under the universal policy) given to the richest children allows them to achieve higher heights at month 24 than a larger discount (16 to 21 percent under slightly more-targeted policies) given to children in the lower portions of the income distribution.

48. These simulations allow us to study potential spillover effects that might arise when targeting social policies. Our targeted policies from an earlier section also had spillover effects. Spillover effects can be important, for instance Dupas (2014) finds that in the short run, if a larger fraction of neighbors are randomly assigned to a subsidy for malaria nets, the probability is higher for any neighbor to redeem a voucher for a net. Interestingly, the spillover effect is negative in the long run, though this could happen because of larger health gains of more dense nets in the short run, a result that also shows the relevance of the spillover effects. Similarly, Al-Janabi et al. (2016) finds that a family network faces higher anxiety and depression if one of their members has suffered from meningitis, and this effect is larger for closer family members. This results highlights how information from a random situation can create unexpected effects.

49. Each of the villages in the data set, as mentioned in the data section has between 500 and 900 residents. We simulate significantly more children than exist in each village in order to obtain results that do not put excessive weights on individual draws from the state-space distribution.

50. This is similar to the INCAP experiment in which, all Atole children received protein subsidies each year, and Fresco children did not receive protein subsidies.

51. In our previous section on targeted subsidies, subsets of children in each village who receive subsidies are targeted based on household income, in this section, the 50 children receiving subsidies in each village under distributed policy are randomly selected.
would have identical average impacts if there were no reference points effects.

A priori, we would expect that mean height would be greater under the distributed policy than the concentrated policy because of concavities in both the production technology and the utility function with regard to the marginal utility with changing reference points. In fact we find that under the two policies, mean height is similar for the 5000 children, which reflects that locally both the production technology and preferences are close to linear. But the concentrated policy leads to a 48 percent larger standard deviation in heights. Under the distributed policy, heights increase jointly for all children due to spillover effects of reference point changes. Under the concentrated policy, heights increase significantly in the one village where all children are treated due to the positive self-reinforcing effects of reference points changes in addition to the protein subsidies.

For our policy experiments here, we follow the same overall simulation strategy as used under the targeted and universal policies from the previous section: we simulate results for the 1970, 72, 74 and 76 cohorts. The initial-period effects–determined by initial price-discount effects on the treated–of concentrated and distributed policies are the same. In subsequent periods, the 500 treated children are taller under the concentrated policy: they reinforce their height gains by jointly contributing to shifting the reference point distribution for that one locality. The 4500 untreated individuals are significantly taller under the distributed policy because they benefit from reference points externalities coming from the 50 treated children within each village. Considering the height distribution of all 5000 children, the distributed and concentrated policy generate similar mean effects, but the concentrated policy leads to greater height variance as the gap between treated and untreated children widens across periods.

5.4.1 Distributional Difference of Concentrated and Distributed Policies

Figure 13 shows the main results for our concentrated vs distributed counterfactual policy experiments for the 1976 cohort. The black dashed line in the figure shows the density plot for the distribution of heights at month 24 for children in the 10 localities with the concentrated policy scenario, and the orange solid line shows the density for heights at month 24 for children in the 10 localities experiencing the distributed policy scenario.

For the 1976 cohort, the mean height at 24 months of age for all children across the 10 localities in the concentrated policy experiment and the mean for all children in the distributed policy experiment both are around 77.81 cm. This echoes the result from our targeted and universal policy analysis, where different levels of targeting produced similar means. This is the case because the range of protein intake values shifted by the policies are locally linear with respect to height given the parameters
of the production function, and likewise for the preference function with respect to changes in reference point. The concentrated policy, however, generates a much larger overall standard deviation of 0.65 cm, which is 48 percent larger than the standard deviation of height under the distributed policy environment, which is 0.44 cm.

The higher variance under the concentrated policy is due to the larger gap between the treated village and the other nine villages without price discounts. Under the concentrated policy, average heights for the treated village are high at 79.4 cm with a 0.33 cm standard deviation. The height distribution for these treated children distinctly appears on the far right tail of the dashed black density line in Figure 13. Heights for children in the other 9 villages are on average 1.8 cm less (77.6 cm) with a 0.37 cm standard deviation, and their distributions constitute the left main portion of the dashed black density line.

Under the distributed policy, the height distribution for the 500 protein-subsidy children can be seen distinctly in the right tail of the yellow density line; they are spread across villages, and are on average 78.5 cm tall with a standard deviation of 0.29 cm. This is lower than and more tightly distributed compared to the distribution of treated children under the concentrated policy. The untreated children’s mean height under this policy, with their distribution shown as the left main portion of the yellow density line, is only 0.8 cm less (77.7 cm) with a standard deviation of 0.37 cm.

The positive-reinforcement effects of reference point changes drive these results. In
the concentrated scenario, a 1 percent change in heights for the initially treated cohort due to price discounts translates to a 1 percent change in mean expected reference height for the next cohort in the locality where these treated cohorts all reside. In the distributed scenario, with only 10 percent of the children in each locality receiving protein subsidies, a 1 percent change in mean height for the initially treated children would average to a 0.1 percent change in expected mean reference height for the next child cohort in the same locality. As a result, the positive self-reinforcing effects of reference points on the treated is much smaller under the distributed policy. At the same time, even though reference point changes are small, they are impacting the 4500 non-treated children, so that overall heights under the distributed policy increase sufficiently so that total average heights for the 5000 children are similar under the two polices.

5.4.2 Decomposing Channels of Height Increase

For the distributed policy, we can decompose the relative contribution to total height change from our three key channels: the direct price effects on the treated, the reference-points effects on the treated, and the reference-points-externality effects on the untreated. We compare mean height realized under the distributed policy to the mean height for the simulated 1970 cohort without price discounts, which is 76.9 cm. Given our discounts, for the 1970 cohort, mean height shifts up by 0.74 cm to 77.69 cm for treated children and is unchanged for untreated children. Iterating the policy forward, for the 1976 cohort, mean height shifts up by 1.60 cm for the treated children to 78.54 cm and shifts up by 0.78 cm to 77.73 cm for untreated children. Given these, summing across all individuals in all villages, there is an average height increase of 0.86 cm for the 1976 cohort. 82 percent of this total height increase is accrued to 90 percent of children who were not treated, but were impacted through the externality of reference points. The remaining 18 percent of the total height increase accrued to the 10 percent of the children who were treated, 8.4 percentage points (47 percent of 18 percent) are due to the direct price effect, and 9.6 percentage points (53 percent of 18 percent) are due to subsequent changes in reference points interacting with the price discount.

We now decompose relative contributions of different channels for height change under the concentrated policy. Given our price discounts, for the 1970 cohort, the effects of distributed and concentrated policies are identical: compared to height for the 1970 cohort without discounts, mean height shifts up by 0.74 cm to 77.69 cm for treated children and is unchanged for untreated children. Iterating the policy forward, for the 1976 cohort, mean height shifts up by 2.50 cm for children in the treated village. Comparing these two increases, 30 percent of the increase in heights accrued to the treated individuals is from the initial-period price effects, and the rest is due to subsequent
reference-points changes interacted with the price effects.

Under the concentrated policy, compared to 1970 cohort children, the average height for 1976 cohort children from villages without price discounts shifts up to by 0.69 cm to 77.6 cm. This is equal to 28 percent of the changes experienced by the village where all children experienced price discounts. Whether height changes in untreated villages depends on whether reference points are at steady state levels with respect to the price level and the joint distribution of household state-space. 52 In our targeted and universal counterfactual analysis in the previous section and the distributed policy experiments, all children reside in villages where at least some individuals receive price discounts. Here, under the concentrated experiment, untreated villages do not experience price discounts. The distribution of heights across cohorts shifts up or down depending on if the reference height distribution started out below or above the steady state reference height distribution.53

6 Conclusion

In this paper, we built and estimated a structural model for the parental decision on investing in nutrition for their children. The model considers reference-dependent preferences, where the reference is with respect to the heights of the previous cohort of children who live in the same village. In this model, reference points can shift endogenously until they reach a steady state as households observe the heights of children around them from earlier birth cohorts changing.

For researchers interested in the impact of price subsidies and income transfers on height outcomes, we have introduced a long-term secondary channel—endogenous changes in reference points—that might affect the impacts of these policies. For the protein-supplement experimental policy implemented in Guatemala, which we have interpreted as a price discount policy, by 1975–6 years after the start of the policy–60% of the impact of the policy came through its impact on shifting reference points.

Our paper also shows the significant height increase that could be realized from shifting reference points for populations with many highly stunted children. It is an open question how to exogenously shift these reference points through educational campaigns in the short run, although the Peruvian experience mentioned in the introduction indicates that educational campaigns could be effective on a large scale over

52. For the children in untreated villages, if the 1970 reference point was at steady state level with respect to prices and the joint distribution of incomes, gender and initial heights, then there would be no changes in reference points for these children in untreated villages when we iterate for future cohorts. By using the empirical joint distribution of individuals from Atole villages and 1970 Atole village reference points, we did not impose that the reference points were steady state reference points.

53. If reference points were not at steady state, and we add price discounts to a village, subsequent changes in height will be on a new path from the current point to the new steady state specific to the price discount.
time. The cost of an educational campaign to inform households about alternative reference heights could be lower compared to income transfers and price subsidies.

Reference points create channels of amplifying spillover effects so that the effects of targeted and universal policies are more similar than if reference points did not matter. We showed that targeted policies on the poorer children led also to significant gains for children from richer households over time. We also showed that policies that provide universal subsidies initially benefit the poorer little but these gains increase significantly over time as subsidies induce both richer and poorer children to jointly consume more and push up reference heights. In practice, our results mean that policy makers, in deciding between targeted and universal policies, should consider the size of the communities that the policy impacts and how likely it is that these communities share reference points mechanisms as channels of policy spillovers. If the rich and the poor in a community are segregated, as in some urban contexts, there might be no spillovers between the rich and the poor through reference points changes. In the context of village economies, the probability for spillovers is likely greater.

In addition to targeted and universal policies, we compared between what we called concentrated and distributed polices. A key distinction here is that our concentrated and distributed policies are only different because of reference points effects, whereas targeted and universal policies still have different distributional effects even without reference points. We showed that in an environment in which reference points are relevant, the percentage of children receiving subsidies matters. Under the distributed policy, spillovers within a village from those with subsidies to those without subsidies lead to lower variation in overall height. Under the concentrated policy, children with subsidies positively self-reinforce their height gains across cohorts, leading to larger gains for the group receiving subsidies. We consider the distinction between concentrated and distributed subsidy policies as related to realistic policy alternatives. In practice, a policy maker might weigh the fixed costs and political feasibility of implementing subsidy policies in a small number vs many locations; we do not consider those costs and feasibility constraints here, but focus on how externality effects of reference points impact the distributional outcomes under concentrated and distributed policies.

Thus incorporating local reference points leads to substantial amplification of policy effects and to a number of significant nuances in expected distributional effects of alternative policies.
References


Thompson, Amanda L., Linda Adair, and Margaret E. Bentley. 2014. “‘Whatever Average Is’: Understanding African American Mothers’ Perceptions of Infant Weight, Growth, and Health.” *Current Anthropology* 55, no. 3 (June 1): 348–355.


A Appendices

A.1 Model Solution

Given the model, we solve for optimal choices using an iterative grid search routine that integrates over the two shocks facing the household: $R_{yv}$ and $\epsilon$. First, for each household, given $\Omega = (Y, p_{yv}^N, X)$, we construct a grid with $Q_1$ points of household-specific nutritional choices from the minimum of zero up to the maximum that each household could purchase. Second, assuming that $R_{yv}$ and $\epsilon$ are both normally distributed and are independent from each other, we draw $M$ productivity shocks $\epsilon$ for each household, where $\epsilon \sim N(0, \sigma^2_{\epsilon})$. Third, for each household and each $\epsilon$ shock drawn, we integrate $R_{yv}$ in the reference point component of the utility function analytically as a truncated normal function:

$$
\int_{R_{yv}} (h_{24} - R_{yv}) \mathbb{1}\{h_{24} \geq R_{yv}\} \ dF(R_{yv}) = 
(h_{24} - \mu_{R_{yv}}) \cdot \left(\Phi \left(\frac{h_{24} - \mu_{R_{yv}}}{\sigma_{R_{yv}}}\right)\right) + \sigma_{R_{yv}} \phi \left(\frac{h_{24} - \mu_{R_{yv}}}{\sigma_{R_{yv}}}\right)
$$

(16)

Now each point on the choice grid has an expected utility value associated with it.

Fourth, we find the grid point that has the largest expected utility value. Fifth, we construct a new finer household-specific choice grid with $Q_2$ points around the optimal nutritional choice from the initial $Q_1$ point grid. We repeat steps one through four to evaluate utility and find the maximum as before. The process is iterated for $Z$ iterations until the total difference in optimal nutritional choices between iterations meets a convergence criteria. This solution provides the exact optimal choices for each household. Given our estimation problem, the speed of obtaining the likelihood function given each set of parameters is determined by $M$, the number of productivity shocks that we draw. For $M$ less than 50, each likelihood is obtained within seconds.

A.2 Data for Estimation

We include in the estimation sample children who were born between 1970 and 1975. We showed summary statistics for these children in Sections 2.2 and 2.3. As discussed earlier, we do not observe both initial heights and heights at month 24 information for children born before or after these years.

We use the months 15 to 24 average protein intakes, heights at month 24, protein prices, incomes, gender, and initial height variables shown in Table 1 and described in Section 2.2 as $N$, $H_{24}$, $p_{yv}^N$, $Y$, and components of $X$. For nutritional intakes, we use protein because Puentes et al. (2016) show that proteins rather than non-protein
components of calories matter for height growth in these INCAP data. Ideally, our intake variable should be averaged from month 0 to month 24. However, we do not observe protein values from month 0 to month 12 for close to half of our sample due to the difficulty of calculating the protein component of breast–milk for children who rely on breast feeding in the first year of life.

In terms of reference points, controlling for gender, we use the predicted value of the linear trends across cohorts between 1970 to 1975—the trends and coefficients are shown in Figure 1 and described in Section 2.3—as the reference points for Atole and Fresco villages. Specifically, we use the linear trends from Panels 1.2 and 2.2 of Figure 1 along with a gender adjustment. The trend for Atole villages could also be approximated with a quadratic trend, but switching to quadratic trends has minimal effects on estimated parameters. Potentially, we could also use the local polynomial approximated nonlinear trends as reference points, but the linear trends as shown in Figure 1 closely approximate the local polynomial trends, which further could be fluctuating due to sample variation for each birth cohort group. This provides us with a set of village, cohort calendar year and gender-specific predictions of height at 24 months of age: 

\[ E(H_{24}|\text{year, gender, atole}) = \phi_0 + \phi_1 \cdot \text{year} + \phi_2 \cdot \text{atole} \cdot \text{year} + \phi_3 \cdot \text{gender}. \]

We use the 24 months of age height predictions to obtain \( \mu_{R_{\text{year,gender,atole}}} \). For example, the predicted linear trend value that corresponds to the height at month 24 of those born in 1970 is the mean reference point for the cohort born in 1972: 

\[ \mu_{R_{1972,\text{gender},v}} = E(H_{24}|1970, \text{gender}, v). \]

By construction, if simulated results from our estimated model match the average 24 months of age heights for different cohorts, we will have matched also the mean reference points values. We fix \( \sigma_{R_{\text{year,gender,atole}}} = 3.5 \) for Atole and Fresco villages in all years. We do this because height variances across cohorts and villages do not seem to vary systematically. The standard deviations of heights in Fresco villages are 3.33, 3.34, 3.24 cm for 1970-71, 1972-73, and 1974-75 cohorts. The standard deviation of height in Atole villages are 3.13, 3.73, 3.53 cm for 1970-71, 1972-73, 1974-75 cohorts.