Sweet child of mine:  
Income shocks, health and inequality* 

Nicolas Berman†  Lorenzo Rotunno‡  Roberta Ziparo§ 

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Preliminary and incomplete. Please do not circulate. 

Abstract. Health disparities across children have widened in many developing countries, in spite of general improvements in economic and health conditions. In this paper, we investigate how early exposure to income fluctuations affects child health inequality within households. To this end, we use data on more than a million children from multiple waves of the Demographic and Health Survey (DHS) spanning 34 developing countries. We identify income shocks using information on the variation of the world prices of locally produced commodities. We find that (i) temporary income shocks in utero and in the first year of life positively affect survival, anthropometric indicators and long-term health investment up to five years after the shock; (ii) households allocate more resources to children born in good times relative to their siblings. This within-household reallocation has important implications for child health inequality. In regressions at the regional level, health disparities across siblings are found to be larger when children are exposed to higher crop prices. 

Keywords: health, income, intra-household allocation, inequality. 

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†Aix-Marseille University, Graduate Institute Geneva and CEPR. E-mail: nicolas.berman@univ-amu.fr. 
‡Aix-Marseille University. Email: lorenzo.rotunno@univ-amu.fr 
§Aix-Marseille University. Email: roberta.ziparo@univ-amu.fr
1 Introduction

How parents allocate resources among children is a crucial decision for households in developing countries. While economists have paid attention to intra-household education and health investments in children, the quantitative implications for aggregate inequality are not well-studied. An equalising strategy that neutralizes the effects of negative early shocks should reduce inequality among children, whereas strategies that favour children with positive early shocks should enlarge disparities. Assessing the role of intra-household investment decisions can shed light on the mixed patterns in overall child health inequality observed in the developing world (Li et al., 2017; Vogl, 2018).

In this paper, we investigate the relationship between early-life income shocks, health investments in children and health inequality in a large set of developing countries. We have two main objectives. One is to gauge the impact of exogenous income shocks at birth on household decisions to invest in children’s health. By estimating the effect of income shocks during pregnancy and in early life, we aim to assess whether parents tend to offset or reinforce initial disparities in economic and health conditions. The other objective is to quantitatively assess the role of these intra-household investment decisions in driving child health inequality within developing countries. Put differently, do areas more exposed to income-related shocks experience higher child health inequality? And how do these income shocks affect the significance of within-household health inequality (relative to the role of across-household inequality)?

The importance of in utero and early-life events for long-term health, education and labour market outcomes is now well-established (see Almond et al. (2018) for a recent review of the literature). The mediating role of parental responses to these shocks may be more relevant to the experience of developing countries since income fluctuations can alter investment decisions in households subject to severe budget constraints. Imperfect credit markets and the lack of effective old-age pension systems may lead parents to allocate scarce resources within the family on the basis of efficiency rather than equity concerns. Importantly, parents’ investment choices over the health and education of their children can affect within-household and hence overall inequality.

We empirically trace out the effects of early-life income changes on children’s health and parental health investment. Our analysis uses data on more than 1.6 million women and 4 million children (up to five years old) from multiple waves of the Demographic and Health Survey (DHS). We combine monthly world prices of agricultural commodities with geo-referenced data on land suitability for agriculture (from the Global Agro-Ecological Zones (GAEZ) dataset) in order to measure local exposure to variation in prices of produced crops, which represent a major source of income in many developing countries. We then estimate the effect of this exogenous income-related variation on child mortality, health at birth and during infancy, and investments in children’s health at the individual level using the DHS data.

Our empirical strategy relies on the comparison of health outcomes and investments across siblings. We examine whether child health as measured by weight and height indicators varies systematically with local exposure to the world prices of produced crops. To investigate parental responses, we then estimate the impact of the income-related price variables on various types of health investments, including vaccinations and provision of vitamins. The effect of the price variables is identified under the plausible assumption that siblings’ characteristics, while important in driving health outcomes (Almond and Mazumder, 2013), do not affect exposure to the
world prices of produced crops. By comparing health investment in a given period across siblings who were born at most five years apart, our estimates net out the influence of plausible savings behaviour at the household level – e.g., the possibility that parents can save part of the income coming from a positive shock and spend it later on the health of their children.

We find that child health improves significantly with income-related crop prices during pregnancy and in the first year of life. Our estimates suggest that the variation in early exposure to crop prices observed in the data can explain around 10% of the differences in health across siblings. The effects are stronger when comparing children within the same family than when comparing across children living in the same area.

The magnitudes are specific to a persistent effect of exposure to income-related variation during pregnancy and in the first year of life that survives throughout infancy up to five years of age – i.e., the oldest age for which key health indicators are recorded. Parental responses to the initial exposure to crop prices can explain this persistency. Siblings that experience higher local prices early in life are more likely to receive vaccinations, vitamin and deworming – they are the ‘sweet children’ of their parents. The estimated coefficients imply that differences in early exposure to world crop prices can account for 5 to 10% of the average gap in health interventions across children within the same family.

Our results are confirmed when we control for time-varying confounders at the local level, such as rainfall, conflicts and exposure to world prices of minerals, and when we drop ‘migrant’ mothers (i.e., who were born in a different place from the one of residence at the time of the survey) or urban households. The analysis further confirms the assumption, largely adopted in previous work (Adhvaryu et al., 2017; McGuirk and Burke, 2017; Berman and Couttenier, 2015), that the variation in exposure to the world prices of locally produced crops captures supply-side income variation and not changes in consumption. A demand-side income channel should have the opposite effect on health and parental investment than that of production-side income changes. Instead, we find similar positive health effects across cash and non-cash crops – the latter being more prone to local consumption –, indicating that, if anything, the 15 crops in our sample (representing on average 42% of land suitable for crop production) are primarily for production.

The positive within-household coefficient on the price variable suggests that parents’ health investment decisions reinforce any initial disparity that asymmetric income shocks across siblings might have created. Two additional pieces of evidence corroborate these findings. First, the impacts of price shocks on child health and on parental health investments are weaker when we abandon the baseline empirical specification with family fixed effects (we control instead for effects specific to the local area at which land suitability is defined), indicating that parents’ decisions vary with income-related changes especially within the household. Moreover, we find direct evidence of negative spillover effects across siblings. Child health and parental health investments deteriorate with the price index received at birth by siblings. The coefficient on the child’s own price variable remains positive and significant, but lower in magnitude than the one estimated in the specification with household fixed effects. Children’s health and parental investments increases with their own income-related price at birth and when this price is higher relative to that received by their siblings – the within-household estimates pool together both channels (Adhvaryu and Nyshadham, 2016).
Parents’ preferences, budget constraints and children’s health production function can explain an investment strategy that exacerbates initial differences in income-driven health outcomes across siblings (Duque et al., 2018; Almond et al., 2018; Almond and Mazumder, 2013; Venkataramani, 2012). Our results suggest that the trade-off in resource allocation within the family is particularly salient for households with low socioeconomic status, thus corroborating the idea that parents invest relatively more on the ‘sweet’ child especially when budget constraints are tight. We find that the positive effect of exposure to world crop prices on health investments (and children’s health) is significantly weaker in households where the mother has better education and has a higher Rohrer’s index (a corpulence measure that should proxy for wealth).

Once we estimate the effects of income shocks on health outcomes and parents’ investment at the micro-level, we investigate the aggregate implications of our results. The positive and persistent health effects of crop prices in early life coming from within-household variation across children can have important consequences for the evolution of child health inequality. We thus examine how the variation in exposure to world crop prices affects changes in child health inequality (in height and weight) at the regional level within countries. The micro DHS data allow us to identify the contribution of the within- and between-household components of disparities in child health.

The estimates reveal a strong and quantitatively important effect of variation in world crop prices at birth on child health inequality. Consistent with the micro evidence, this effect is driven by a positive association with changes in within-household disparities in child health. Regions that are more exposed to fluctuations in world crop prices experienced larger increases in health differences across siblings.

Contribution and related literature. In this paper, we provide novel evidence on how income-related shocks affect children’s health within the household. Our results contribute to a better understanding of child health inequality in developing countries, whose reduction is one the United Nations Sustainable Development Goals. Previous work has analysed trends in health inequalities within countries, with a focus on disparities across socioeconomic groups and regions. While disparities across children and teens have been stable or decreasing in developed countries since the 1990s\(^1\), trends in developing countries are rather mixed (Li et al., 2017; Wang, 2003). These papers explore inequalities across households or groups with different socioeconomic characteristics (e.g., income, race and gender), but neglect possible disparities within the household. Vogl (2018) examines the evolution of overall (rather than between-group) inequality in child mortality and finds that children’s deaths have become more concentrated on a few mothers over time. We contribute to this line of work by documenting for the first time the role of within-household inequality in driving changes in overall disparities within poor countries.

In our sample of developing countries, the within-household component accounts on average for around 20% of the overall inequality in child health and it increases significantly with exposure to income-related world prices early in life. Recent papers have stressed the importance of differences in economic outcomes within households in order to better target anti-poverty and devel-

\(^1\)The literature looks mainly at inequality in mortality rates and life expectancy within age groups. The evidence shows that healthy inequality among the young has been declining in the U.S. (Currie and Schwandt, 2016b,a) and in Spain (González and Rodriguez-Gonzalez, 2018), while it remained stable in France (Currie et al., 2018) and in Canada (Baker et al., 2017).
velopment policies (Brown et al., 2018, 2017). In this paper, we widen the scope of within-household inequalities by looking at child health.

The association between within-household inequality in child health and exposure to world prices at birth is consistent with the evidence at the child level. Our results indicate that parental health investments complement variations in producer prices at birth across siblings. These findings accord well with the existing literature finding that health investments tend to reinforce initial disparities in child endowment especially in developing countries (Rosenzweig and Zhang (2009); Venkataramani (2012); Adhvaryu and Nyshadham (2016); Duque et al. (2018); and Almond and Mazumder (2013); Almond et al. (2018) for recent reviews of the literature). We empirically test for the aggregate implications of reinforcing investments by looking at how the same price variable affecting investments shapes child health inequality.

Our paper contributes also to the “fetal origin” literature, which hypothesizes that early life conditions and in particular early nutrition has long term effects on health, educational attainment and labor market outcomes – see the reviews by the reviews by Almond and Currie (2011) and Currie and Vogl (2013), as well as recent contributions by Groppo and Kraehnert, 2016; Adhvaryu et al., 2015; Dercon and Porter, 2014. In particular, our analysis is close to a recent paper by Adhvaryu et al. (2017) showing that high prices of cocoa in Ghana lead to better adult mental health, and that improved investments in children’s health is an important channel. We extend their empirical approach by consistently exploiting within-households (or mother) variation over time and hence controlling for individual heterogeneity driving, for instance, selection into fertility and health investment decisions.

Finally, our paper relates to empirical work trying to estimate the causal impact of (contemporaneous) income shocks on child survival and health. Overall, the sign of the empirical relationship seems unclear (see the review by Ferreira (2009)). Baird et al. (2011) find that short-term changes in GDP per capita are positively correlated with infant survival in a panel of developing countries – a result that is confirmed by Benshaul-Tolonen (2018) in Africa and Cogneau and Jedwab (2012) in Cote d’Ivoire –, while Miller and Urdinola (2010) find evidence for counter-cyclical survival in Colombia. We also estimate the effects of income-related variation on child health, and further scrutinize the response of parental health investments.

The rest of the paper is organised as follows. Section 2 describes the health and price data that we use in the analysis. Sections 2.3 and 2.3 discuss the empirical strategy adopted to investigate effects at the child level, and the corresponding results. In section 4.2, we then explore the implications of our micro-level evidence for child health inequality with regions. Section 5.1 concludes.

2 Data

We seek to identify the effects of income-related local shocks in utero and at birth on child health and parental health investments in poor countries. We therefore primarily need data on

\footnote{Yi et al. (2015) finds evidence for compensating health investments (i.e., parents investing more in the health of the less healthy child at birth) and for reinforcing education investments using data on twins from China. We connect also to the literature on “dynamic complementarities” (Heckman, 2007), which studies how the returns to investments vary with the baseline health (or cognitive) ‘stock’ of the child. We estimate how early life income shocks affect parental investments, but identification of the “dynamic” aspect of investments would require a separate shock for the investment decision (see Almond et al. (2018, Section 1) for a discussion).}
(i) health indicators and health investments at the individual (child) level; (ii) income shocks that are exogenous to health and more generally individual behavior.

2.1 Individual data

Our baseline data on child mortality and health, and other individual and household characteristics comes from the Demographic and Health Surveys (DHS).3 We restrict our analysis to countries featuring containing information on the geo-location of households, and featuring multiple rounds of survey. The first restriction is crucial as we need the household GPS coordinates to link the individual data to income shocks. The second restriction is not necessary for the first part of the paper where we look at individual responses, but it is in the last section where we aggregate the data at the regional level to study how aggregate child health inequality changes in response to income variability. These restrictions leave us with 33 countries, among which 26 are African countries. The map in figure A1 in the Appendix locates the households in our dataset. The data includes information on household members characteristics, including the children and the parents. Note that the DHS is not a panel: each household – hence child – appears only once in the data. This is not a problem for our purposes, as in most estimations we are interested in the effect of income shocks within household, across children.

Child health. We make use of two types of information: data on child mortality at birth and in the first year) and anthropometric indicators (height-for-age, weight-for-age). Anthropometric measures are available only for children under five years old. We therefore restrict our sample to these children, i.e. a little more than 1 million children born from about 700,000 mothers aged between 15 and 49 at the time of the survey. We use as baseline anthropometric indicators (i) the log of weight (height), divided by age-specific population mean; (ii) under-weight (under-height), defined as weight (height) being at least two standard deviations below the age-specific population mean. Population means come from the WHO.4

Health Investments. The DHS contains detailed information on early-life investments; as for the anthropometric indicators, information is available for all children under five years old at the time of the survey. We use information on vaccines of Polio, DPT, BCG and Measles; data on medication taken over the three months preceding the survey (Vitamins, iron pills and deworming); and data on the duration of breastfeeding.

Other variables. The surveys also contain a rich set of demographic and socio-economic variables, which we use as controls in our analysis. At the child level, we use information on age (in months), gender, birth order and twins. At the mother or household level, we keep information on age, rural/urban status, education and Rohrer’s Index.

2.2 Income shocks

Our analysis requires the computation of income shocks that are exogenous to local conditions and are not expected to impact health directly. The “fetal origin” literature has used exposure

3https://dhsprogram.com/Data/
4https://www.who.int/childgrowth/standards/en/
to a number of external events (e.g., infectious diseases, extreme weather shocks (Almond and Currie, 2011)), usually within a single country and at a specific point in time. Given our focus on poor, agriculture-oriented countries, a possibility would have been to use rainfall or other weather-related shocks. These, however, might impact health directly through the spread of diseases; they also might also impact health indirectly through other channels than income, e.g. infrastructures. Instead of weather shocks, we exploit local exposure to changes in world prices of agricultural commodities, as predicted by agro-ecological land characteristics, to identify variation in available income. This type of instrument enhances the validity of the empirical strategy for a wide set of developing countries where agriculture is still a major source of household income. Previous work has indeed successfully applied a similar strategy to test for the effects of income shocks on localised conflicts (Berman and Couttenier, 2015; McGuirk and Burke, 2017).

We first divide each country of our sample in 4,000 cells of 0.5×0.5 (roughly 55×55 km at the equator). For each of these cells, we compute the suitability of the cell to grow any of the crops for which we have world prices. Land suitability is taken from the FAO’s Global Agro-Ecological Zones (GAEZ). This data is constructed from models that use location characteristics such as climate information (for instance, rainfall and temperature) and soil characteristics. This information is combined with crop characteristics in order to generate a global GIS raster of the suitability of a grid cell for cultivating each crop. The main advantage of this data is that crop suitability is exogenous to changes in local conditions and world demand, as it is not based on actual production. We focus on the 15 ‘crops’ for which world price data is available from the World Bank: banana, barley, cocoa, coconut, coffee, cotton, maize, palm oil, rice, sorghum, soybean, sugar, tea, tobacco, wheat. For each cell and year, we compute the following price shock:

$$P_{kt} = \sum_{p} \text{share}_{pk} \times P_{pt}^W$$ (1)

where $\text{share}_{p}$ is suitability of cell $k$ to grow crop $p$ and $P_{pt}^W$ is the monthly nominal world price of crop $p$ at time $t$ (relative to its level in January 2010). In our regression we will average these prices across the months of pregnancy and the first year of life of the child.

In our robustness checks we use alternative data from the M3-CROPS database (Monfreda et al., 2008), which measures the share of total harvested area in a cell going to the production of crop $p$ around the year 2000. By proxying actual production, this measure is less exogenous to world prices (although it does not vary over time) than the GAEZ-based $\text{share}$, but it could better capture the patterns of agricultural specialisation.

Both components of the constructed price index in (1) contribute to variation across products, areas, and over time. Only 26% of the overall variation in crop shares is due to variation in average shares across crops, the remaining part being due to differences in a given crop share across cells. Within countries, the role of across-crop variation becomes more important (on average, it explains 66% of the variance in $\text{share}_{pk}$), but differences across areas within countries maintain a non-negligible weight for most countries (see figure A2 in the appendix). Movements in world prices $P^W$ provide variation over time. Figure A3 plots the evolution of world prices of the four most popular (potentially ‘produced’) crops in our data. There are considerable fluctuations over time – e.g., the two recent spikes related to the 2007-2008 and 2011-2012 world food price crises –, and the prices of different commodities, while being clearly correlated, do diverge substantially.
during certain periods (e.g., during the 2011-2012 crisis). The ensuing analysis exploits this rich variation to identify the causal effects of income-related variation in world prices on child health across siblings in developing countries.

Throughout our analysis, we interpret variations in $P_{kt}$ as positively correlated to local agricultural and individual income. This is the common interpretation in the literature (e.g. Berman and Couttenier, 2015, McGuirk and Burke, 2017, Dube and Vargas, 2014); McGuirk and Burke (2017) provide direct evidence of the effect of such shocks on farmers’ income and self-declared poverty using individual data from the Afrobarometer; Berman and Couttenier, 2015 show that these variations are positively correlated with GDP per capita at the sub-national level. Yet, if production and consumption patterns are correlated in space, increases in $P_{kt}$ could instead be interpreted as negative real income shocks (increase in consumption prices). This is however unlikely, for several reasons. First, all our estimations will control for country $\times$ year fixed effects; to the extent that consumption patterns do not vary too much within countries, these fixed effects will capture changes in consumption prices. Second, our results will be hard to reconcile with this consumption side interpretation. Third and more importantly, we will show that our results hold when we split $P_{kt}$ into two indexes, computed for food crops and for cash crops only. As cash crops are not consumed, we will interpret these results as further evidence that our shocks are indeed positively correlated with shocks.

2.3 Descriptive statistics

Table 1 reports summary statistics for the main variables used in the child-level empirical analysis. Information on mortality is available for 1.1 million children, while anthropometric indicators are non-missing for about 600 thousands children. Underweight affects 7% of the children, while underheight (stunting) reaches 17% of the sample. There is also a great deal of heterogeneity in terms of vaccinations and other health expenditures.
Table 1: Summary statistics for the main variables

<table>
<thead>
<tr>
<th></th>
<th>Obs.</th>
<th>Mean</th>
<th>S.D.</th>
<th>1st Quartile</th>
<th>Median</th>
<th>3rd Quartile</th>
</tr>
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<td>Death Birth</td>
<td>1110210</td>
<td>0.01</td>
<td>0.12</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<td>Death First year</td>
<td>1110210</td>
<td>0.03</td>
<td>0.17</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>ln crop prices (GAEZ)</td>
<td>1070217</td>
<td>4.42</td>
<td>0.31</td>
<td>4.15</td>
<td>4.40</td>
<td>4.68</td>
</tr>
<tr>
<td>ln crop prices (M3-crop)</td>
<td>1085844</td>
<td>4.43</td>
<td>0.36</td>
<td>4.14</td>
<td>4.43</td>
<td>4.72</td>
</tr>
<tr>
<td>Age (child)</td>
<td>1029081</td>
<td>1.95</td>
<td>1.42</td>
<td>1.00</td>
<td>2.00</td>
<td>3.00</td>
</tr>
<tr>
<td>Gender (child)</td>
<td>1110210</td>
<td>1.49</td>
<td>0.50</td>
<td>1.00</td>
<td>1.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Birth order (child)</td>
<td>1110210</td>
<td>3.49</td>
<td>2.43</td>
<td>2.00</td>
<td>3.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Twin (child)</td>
<td>1110210</td>
<td>0.05</td>
<td>0.28</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Education (mother)</td>
<td>1110133</td>
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<td>0.88</td>
<td>0.00</td>
<td>1.00</td>
<td>2.00</td>
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<tr>
<td>Age (mother)</td>
<td>1110210</td>
<td>28.92</td>
<td>6.94</td>
<td>24.00</td>
<td>28.00</td>
<td>34.00</td>
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<tr>
<td>Rural</td>
<td>1110210</td>
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<td>1.00</td>
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<tr>
<td>Underheight</td>
<td>616100</td>
<td>0.17</td>
<td>0.38</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Underweight</td>
<td>616100</td>
<td>0.07</td>
<td>0.25</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
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<tr>
<td>Weight (kg)</td>
<td>609929</td>
<td>11.83</td>
<td>9.18</td>
<td>8.40</td>
<td>11.00</td>
<td>13.60</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>606212</td>
<td>81.96</td>
<td>14.54</td>
<td>71.90</td>
<td>82.50</td>
<td>93.00</td>
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<tr>
<td># Polio vaccines</td>
<td>702838</td>
<td>2.75</td>
<td>1.33</td>
<td>2.00</td>
<td>3.00</td>
<td>4.00</td>
</tr>
<tr>
<td># DPT vaccines</td>
<td>828448</td>
<td>2.06</td>
<td>1.27</td>
<td>1.00</td>
<td>3.00</td>
<td>3.00</td>
</tr>
<tr>
<td># total vaccines</td>
<td>691769</td>
<td>6.23</td>
<td>3.07</td>
<td>4.00</td>
<td>8.00</td>
<td>9.00</td>
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<tr>
<td>BCG vaccine (dummy)</td>
<td>836407</td>
<td>0.82</td>
<td>0.38</td>
<td>1.00</td>
<td>1.00</td>
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<tr>
<td>Measles vaccine (dummy)</td>
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<td>0.49</td>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
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<tr>
<td>Vit. A in last 3 month</td>
<td>644403</td>
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<td>0.50</td>
<td>0.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Iron pills in last 3 months</td>
<td>431630</td>
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<td>0.32</td>
<td>0.00</td>
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<tr>
<td>Deworm in last 3 months</td>
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<td>0.38</td>
<td>0.49</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
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<tr>
<td>Breastfeeding &gt; 6m</td>
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<td>0.37</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Source: Authors’ computations from DHS, GAEZ, M3-CROP and World Bank data. See main text for data sources.

3 Empirical strategy: child level

In the empirical analysis, we seek to identify the effects of income-related local shocks in utero and at birth on child health and on parental health investments. Economic events early in life can have long-term consequences on health and well-being. The response of parents to these early-life shocks is all the more important in poor countries where budget constraints are particularly binding and market failures (e.g. in credit markets and social security) are widespread. We then test the implications of the individual-level analysis for the evolution of child health inequality within countries, distinguishing between disparities within households and across households.

Income shocks and child health. We first want to study the effect of income variations, proxied by world agricultural commodity prices, on child health. Local exposure to agricultural world prices may correlate with a number of household characteristics and behaviour that can in turn affect children’s health later in life. To control for the influence of time-invariant confounders, our baseline and preferred specifications include mother (or family) fixed effects. Despite the fact
that each mother – and child characteristics – is observed only once in our data, the presence of multiple children per mother allows us to control for unobserved household characteristics. We therefore focus on within-mother variation in exposure to world commodity prices over time. Denote by $c$ a child, located in cell $k$ and born in year $t$, month $m$. We estimate a specification of the form:

$$
Y_c = \alpha \log P_{c,k} + D'_c \delta + \mu_H + \gamma_{i,t} + \nu_m + \varepsilon_c
$$

(2)

where $Y_c^H$ is a mortality or health indicator for child $c$ at time $t$ (month-year), sequentially: a dummy for death at birth; a dummy for death in the first year; a dummy for under-height, which equals 1 if the height-for-age ratio is at least 3 standard deviations below the corresponding $z$-score from WHO; a dummy for under-weight, which equals 1 if the weight-for-age ratio is at least 3 standard deviations below the corresponding $z$-score from WHO; and the continuous measures of height and weight relative to the WHO reference values (in logs).

$P_{k,t}$ is the average monthly prices of crops produced in cell $k$ during the in utero period and the first year of life (or only during in utero period when the dependent variable is death at birth). $D'_c\delta$ is a vector of child characteristics – age, gender, twin, birth order. $\mu_H$ are household fixed effects, and $\gamma_{i,t}$ and $\nu_m$ are additional fixed effects accounting for country $\times$ year (of birth) and month-of-birth unobserved factors affecting child health that might be correlated with crop prices. $\gamma_{i,t}$ in particular control for all country-wide shocks that might affect health, such as global economic conditions or civil wars. Note that in our sensitivity analysis we will additionally include controls for local weather shocks and other commodity prices shocks (oil and mineral prices) that might correlate with $P_{c,k}$.

In equation (2), $\alpha$ is our coefficient of interest that can be interpreted as the effect of an increase in price on child mortality and health, relative to other children of the same household. Put differently, the coefficient tells us whether children born during periods of high crop prices are in better health than their siblings. Identifying $\alpha$ requires observing at least two children per mother, i.e. the sample is restricted to households with at least two siblings born over the 5 years before the survey.

When $Y_c$ measures child health, $\alpha$ could either reflect a contemporaneous effect – a high family income during pregnancy and the first year of life improves health at birth and in the first year of life –, or a longer-term impact – beyond their contemporaneous effects, early life income fluctuations affect child health after several years. To answer this question, we estimate the following variant of equation (2):

$$
Y_c = \sum_{a=0}^{4} \alpha^a \text{Age}_{c}^a \times \log P_{k,t} + D'_c \delta + \mu_H + \gamma_{i,t} + \nu_m + \varepsilon_c
$$

(3)

where $\text{Age}_{c}^a$ are dummies which equal 1 if the child is aged $a = (0, 4)$ years at the time of the survey. Since we have anthropometric data on children up to five years of age, we cannot test for the significance of early-life income fluctuations later in life. The profile of the $\alpha^a$ informs us about the persistence of early life shocks on health.

**Parental investments in child health.** Specifications (2) and (3) estimate the health effects of early life price shocks, and whether these are persistent. Persistence could either come
from the direct effect of better nutrition on health, or from reinforcing investments. The main question is whether health investments are complements to initial biological endowments, and if later life investments are complement. In either case, we would expect parents to reinforce the direct effect of income shocks on health by spending more on the health of their children born during good times, potentially in a durable way.

We examine the parental responses by looking at whether exposure to the world prices of commodities in utero and during the first year of life affects the parents’ investments in the child’s health, and for how long. Specifically, we run a specification akin to (2), but replace the dependent variable with a health investment measure:

\[ I_c = \beta \log P_{c,k} + D'\delta + \mu_H + \gamma_{i,t} + \nu_m + \varepsilon_c \] (4)

where \( I_c \) is the count of doses or a dummy for provision of vaccines against polio, DPT (diphtheria, pertussis and tetanus), tuberculosis (BCG) and measles, or an indicator for provision of vitamins, iron pills, deworming and durable breastfeeding – Adhvaryu and Nyshadham (2016) uses a similar set of variables to proxy for investment in child health. A significant \( \beta \) coefficient would suggest that at least part of the effects on children’s health that we estimate in (2) is going through parental investments – the \( I_H \) variables could be seen as ‘bad’ controls in specification (2) (Pei et al., 2018).

Again, we estimate a variant of (4) where the \( \beta \) are split by by child age category, similar to what we do for the health indicators in specification (3). This allows us to determine whether the effect of early life shocks on health investment across children is persistent, which itself is an indication of whether early and later life investments are complements.

**Across households estimates and sibling effects.** Equations (2) to (4) feature household fixed effects, i.e. they provide estimates that we can only interpret in relative terms, across children born in the same households. The primary objective of this paper is to study these intra-household adjustments. We might however be interested in the effect across households, in absolute terms. To do so, we will estimate variants of equations (2) to (4) in which household fixed effects \( \mu_H \) are removed and replaced by cell \( k \) fixed effects and by a set of mother / household specific controls.

In these less restrictive specifications we can also isolate sibling effects (Adhvaryu and Nyshadham, 2016). The within-mother estimates exploit variation in the producer price \( P \) received by child \( c \) relative to the average producer price received by all the siblings. Therefore, any effect of exposure to producer prices in early life compounds the effect of the ‘own’ price (received by child \( c \) and that of the siblings’ prices (received by all siblings in the households). To disentangle the contributions of these two components, we estimate specifications of this form (e.g., for health outcomes):

\[ Y_c = \alpha \log P_{c,k} + \alpha^s \log P^{s}_{c,k} + D'\beta + C_H'\gamma + \mu_k + \gamma_{i,t} + \nu_m + \varepsilon_c \] (5)

with the \( s \) superscript indicating is the average of \( P \) across the older siblings of child \( c \). The matrix \( C \) collects controls at the mother (household) level, such as the level of education and wealth (as proxied by a measure of corpulence, the Rohrer index). The \( \mu_k \) term denote cell \( k \) fixed
effects. A similar specification is estimated also for health investment outcomes. The coefficient $\alpha^s$ indicates whether having siblings born in ‘good’ times (high $P^s_{k,t}$) affects the health of child $c$ (conditional on her own price, $F_{k,t}$).

**Econometric issues.** We estimate all specification using least squares; this is the preferred estimator, despite the fact that the dependent variables are often binary or categorical, due to the large dimensions of fixed effects we include. Standard errors are clustered at the cell level in the baseline. We check the robustness of the results allowing the error term to be spatially correlated, and auto-correlated.

### 4 Results: child level

In this section we present the results of the empirical analysis at the child level (specifications (2), (3), (4), (5) and extensions thereof).

#### 4.1 Effects on child health

Table 2 shows the estimates of the effect of exposure to world prices of produced crops on mortality and child health. Panel A reports the estimates of the coefficient $\alpha^H$ in specification (2), exploiting within-mother variation. Panel B shows the result of a less restrictive specification where we compare children within the same cell $k$ (mother fixed effects are replaced with cell fixed effects). All regressions control for the age (in months), gender and birth order of the child, and whether she is a twin. Overall, children’s health is positively associated with exposure to world prices of locally produced commodities. Children exposed to higher crop prices during pregnancy and the first year of life have higher weight and height relative to standard reference values. The effects are larger and more robust in the preferred specification that compares siblings, suggesting that household-level characteristics tend to bias the estimated effect towards zero.\(^5\) In our baseline specification, exposed children seem also significantly less likely to die at birth or during the first year of life; however, results are not robust to alternative specifications and data sources.

The estimated coefficients imply sizeable effects of differences in the local level of world prices. Consider the effects on children’s weight (column (6)). In the estimation sample, the healthiest child in the family has on average a 21% higher weight than the ‘lightest’ one (weight is standardised by age and sex). Our estimates thus suggest that the least healthy sibling could have halved the weight gap if she would have received a 100% higher crop price (conditional on the crop prices received by the other siblings). The average within-household spread in the crop price variable being 18%, our estimates predict that income-related price fluctuations could explain up to 12% of the average differences in weight across siblings. The same calculations lead to very similar magnitudes for the impact on height (the average max-min difference in height across siblings is 9%).

\(^5\) Almond et al. (2009) find a similar patterns in their study of the Chernobyl effect on cognitive performances of Swedish children.
Table 2: Effects of exposure to world crop prices on mortality and health

<table>
<thead>
<tr>
<th>Dep. var.</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Death</td>
<td>Underheight</td>
<td>Underweight</td>
<td>ln height</td>
<td>ln weight</td>
<td></td>
</tr>
<tr>
<td>At birth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st year</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Panel A

<table>
<thead>
<tr>
<th>ln crop price</th>
<th>-0.011&lt;sup&gt;b&lt;/sup&gt;</th>
<th>-0.025&lt;sup&gt;a&lt;/sup&gt;</th>
<th>-0.185&lt;sup&gt;a&lt;/sup&gt;</th>
<th>-0.151&lt;sup&gt;a&lt;/sup&gt;</th>
<th>0.061&lt;sup&gt;a&lt;/sup&gt;</th>
<th>0.136&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0.004)</td>
<td>(0.008)</td>
<td>(0.028)</td>
<td>(0.018)</td>
<td>(0.009)</td>
<td>(0.021)</td>
<td></td>
</tr>
</tbody>
</table>

| Observations  | 619970             | 619970             | 284604             | 284604             | 278037             | 281272             |
| Child controls| Yes                 | Yes                 | Yes                 | Yes                 | Yes                 | Yes                 |
| Household (mother) FE | Yes     | Yes                 | Yes                 | Yes                 | Yes                 | Yes                 |

### Panel B

<table>
<thead>
<tr>
<th>ln crop price</th>
<th>-0.002</th>
<th>-0.001</th>
<th>-0.154&lt;sup&gt;a&lt;/sup&gt;</th>
<th>-0.124&lt;sup&gt;a&lt;/sup&gt;</th>
<th>0.043&lt;sup&gt;a&lt;/sup&gt;</th>
<th>0.105&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>(0.003)</td>
<td>(0.006)</td>
<td>(0.022)</td>
<td>(0.013)</td>
<td>(0.008)</td>
<td>(0.019)</td>
<td></td>
</tr>
</tbody>
</table>

| Observations  | 631698             | 631698             | 519320             | 519320             | 512790             | 513545             |
| Child controls| Yes                 | Yes                 | Yes                 | Yes                 | Yes                 | Yes                 |
| Household controls | Yes    | Yes                 | Yes                 | Yes                 | Yes                 | Yes                 |
| Cell FE       | Yes                 | Yes                 | Yes                 | Yes                 | Yes                 | Yes                 |

<sup>c</sup> significant at 10%; <sup>b</sup> significant at 5%; <sup>a</sup> significant at 1%. OLS estimations. The unit of observation is a child. Standard errors clustered at the cell level in parentheses. All estimations include country × year and month dummies. Child controls include: gender, birth order, twin dummy, and age in month. Household controls include: mother's age and education dummies, rural dummy, and Rohrer index. ln crop price index is the log of the World price of the crops produced in the cell, weighted by the share of each crop in the area. Death is a dummy which equals 1 if the child dies at birth (col. 1) or in her/his first year (col. 2), 0 otherwise. Underheight (respectively underweight) is a dummy which equals 1 if the height-for-age (resp. weight-for-age) ratio is at least 2 standard deviations below the z-score from WHO. ln height (resp. ln weight) are the logs of height (resp. weight) divided by the gender-specific average height (resp. weight) for that particular age in month from WHO.

The positive effect of exposure to world crop prices in early life is robust to a number of extensions and checks. The estimates are virtually unchanged when we control for other time-varying local variables such as exposure to world prices of minerals, local weather conditions, and incidence of conflicts (Table A1). In Table A2 we report the estimates that we obtain after dropping mothers that were born in a place different from the place of residence at the time of the survey. These ‘migrant’ women might create measurement error in our price variable if they moved across our statistically defined cells and if they did so during the previous five years (i.e., when one or more of the siblings were exposed to the world price of produced crops). We however lack information on the timing of migration and on the place of origin. As robustness checks, we thus repeat the baseline estimation dropping all ‘migrant’ women. The sign and statistical significance of the main effects are confirmed. In this restricted sample (we lose almost half of the observations), the effect of exposure to crop prices across siblings is, if anything, slightly weaker than the effect across children within the same cell. This hints at the presence of attenuation bias in the baseline estimates when we rely on within-cell variation. As another check on the validity of our results, we could replicate the baseline results in the sample of rural households (70% of the sample), as shown in table A3.

Our empirical strategy and results are consistent with the interpretation of variation in the
crop price index as a shift in local income. The alternative approach would be to think of our price variable as affecting households as consumers. This would however imply that child health deteriorates with exposure to lower prices of the supposedly ‘consumed’ crops, which does not square well with the overwhelming evidence from the fetal origin literature for a positive relationship between child health and available household resources in utero. Yet, our estimates may provide a ‘net’ effect that masks the counteracting influence of the price of some consumed crops. To check for this possibility, we split our price index (see equation (1)) into the constructed local price of “cash” crops as defined by McGuirk and Burke (2017) (in our sample, cocoa, coffee, cotton, tea and tobacco) – which should be mainly for production –, and the other crops – which could be also consumed. Table A4 reports the results from a specification where the two price variables are included simultaneously as determinants of child health. The coefficients on the ‘food’ crop price variable has the same sign of and is of similar size to the coefficient on the cash crop price variable. These results corroborate our empirical assumption that the set of crops in our sample are mainly produced and hence variation in their prices should be reflected producers’ income (through land suitability).

The baseline effects may differ across the age of the children in the sample. To test for this possibility, we estimate the specification (3) that allows the coefficient on the price variable to vary with the child’s years of age. Figure 1 plots the α’s coefficients for the four health indicators. With the exception of the effect on the continuous weight measure, the coefficients are rather stable or slightly increasing, and precisely estimated at all ages up to five, suggesting a protracted influence of crop prices in utero and at birth. This persistency over such a short time span could be explained by the transmission of the health status at birth to the following years. Parents can also alter the health trajectory of their children, by adopting health investment decisions.
4.2 Effects on parental health investments

Table 3 shows the estimates of specification (4), which assesses the impact of income-related price fluctuations on different forms of health investments in children. The objective is to see whether health interventions by parents respond in a way that reinforces or counteracts the health effect of the income shocks on their children.

The results point to a positive and significant effect of exposure to world prices at birth on vaccinations and other investments in the health of children (controlling for their age, gender, birth order and for twin status). As for the regressions with health outcomes (table 2), the within-mother estimates are stronger than the less restrictive within-cell ones. The evidence is consistent with parents reinforcing the health effects of crop prices in utero and at birth. Siblings who are exposed to higher income-related prices receive also better health investments – they are the ‘sweet’ ones.

The size of the implied effects is quantitatively important. The largest gap in the number of vaccination doses across siblings (dependent variable in column (3)) is on average 1.9. The estimates in column (3) suggest that this gap would be 14% lower if the crop price index at birth
would be 19% higher – the sample average largest gap in the price index across siblings. Doing the same exercise for the other continuous outcome variables in table 3 delivers similar effects – variation in income-related crop price in utero at birth within the family can explain around 15% of the differences in vaccinations. The same within-household changes in prices is associated with 3 percentage-point higher likelihood of receiving vitamins (equivalent to 5% of the sample probability) and 6 percentage-point higher chances of being breastfed for at least six months (7% of the sample probability).

Table 3: Effects of exposure to world crop prices on health investments

<table>
<thead>
<tr>
<th>Dep. var.</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
<th>(9)</th>
<th>(10)</th>
<th>(11)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Vaccins (# doses) -</td>
<td>Polio</td>
<td>DPT</td>
<td>All</td>
<td>BCG</td>
<td>Measles</td>
<td>DPT</td>
<td>Polio</td>
<td>Vitamins</td>
<td>Iron</td>
<td>Deworm</td>
<td>Breast.</td>
</tr>
<tr>
<td>ln crop price</td>
<td>0.404$^a$</td>
<td>0.525$^a$</td>
<td>1.352$^a$</td>
<td>0.083$^a$</td>
<td>0.254$^a$</td>
<td>0.068$^a$</td>
<td>0.034</td>
<td>0.160$^a$</td>
<td>0.038</td>
<td>0.227$^a$</td>
<td>0.315$^a$</td>
</tr>
<tr>
<td>(0.070)</td>
<td>(0.069)</td>
<td>(0.157)</td>
<td>(0.018)</td>
<td>(0.036)</td>
<td>(0.026)</td>
<td>(0.024)</td>
<td>(0.024)</td>
<td>(0.015)</td>
<td>(0.028)</td>
<td>(0.021)</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>347529</td>
<td>403206</td>
<td>338671</td>
<td>401333</td>
<td>408598</td>
<td>352392</td>
<td>314370</td>
<td>22086</td>
<td>245787</td>
<td>493063</td>
<td></td>
</tr>
<tr>
<td>Child controls</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Mother FE</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

Panel B

| ln crop price | 0.395$^a$ | 0.406$^a$ | 0.958$^a$ | 0.012 | 0.106$^a$ | 0.095$^a$ | 0.038 | 0.086$^a$ | 0.144$^a$ | 0.278$^a$ | 0.203$^a$ |
| (0.066) | (0.057) | (0.154) | (0.014) | (0.027) | (0.023) | (0.023) | (0.025) | (0.019) | (0.025) | (0.019) |
| Observations | 475176 | 557937 | 467528 | 561650 | 563831 | 562850 | 479054 | 433477 | 289665 | 319831 | 611762 |
| Child controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Household controls | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Cell FE | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

$^a$ significant at 10%; $^b$ significant at 5%; $^c$ significant at 1%. OLS estimations. In the first three columns the dependent variables are the number of doses taken by the kid of Polio (max. 4 doses), DPT (max. 3 doses) and all vaccines (DPT, Polio, BCG, measles, max. 9 doses). In columns (4) to (7) the dependent variables are dummy taking the value 1 is the child has taken all required doses of a particular vaccines. In columns (8) to (10) dependent variables are dummies taking the value 1 if the child has received Vitamin A, Iron pills and deworming drugs during the three months preceding the survey, zero otherwise. Finally, in column (11) the dependent variable takes the value 1 is the child has been breastfed for at least 6 months, 0 otherwise.

The positive association between health investments in children and exposure to income variation in utero and at birth can be explained by a path-dependency in parents’ behaviour – they had invested more into the child who received a good price in utero and at birth and they kept this behaviour over time. To shed light on this interpretation, we partition the effect of crop prices according to the age of the child at the time of the survey, similarly to what we did for the health outcome specifications (see (3) and the results in figure 1). Overall, results suggest that the positive coefficient on crop prices increases with the age of child, although not significantly so for some of the health investment indicators (see figure A4 for the evolution of the effects on provision of vitamin A and deworming).

The evidence suggest that parents’ health investments reinforce the differential health responses of siblings to income shocks in utero and at birth. Our reduced-form results however cannot tell apart the influence of preferences from that of the health production function, nor the

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6The positive impact of early life crop prices on parental investments on child health is confirmed in the same battery of robustness checks that we deployed for the health outcomes regressions (results available upon request).
quantitative importance of parental investments relative to the biological transmissions of health over time (see the discussions in Almond et al. (2018) and Almond and Mazumder (2013)). If parental preferences are constant across siblings, our empirical evidence is in line with a setting where investments in health and health at birth are complementary. At the very least, what our findings suggest is that parents do not go against the health disparities across siblings coming from early exposure to different income shocks.

**Sibling effects.** Health outcomes and parental investment may react to the crop price received by the child and to the crop prices received by the other siblings. The within-mother coefficients are estimated compound these two types of effect because it relies on deviations in crop prices with respect to the average crop prices across siblings.

In tables 4 and 5, we separate the income-related price of the child from the average income-related price received by her older siblings (the specification in (5)). As in Adhvaryu and Nyshadham (2016), the objective is to identify the contribution of the shock received by the siblings. The results, based on within-cell variation, reveal that sibling effects are significant tend to lower child health and parental investments. Child health decreases significantly with the price in utero and at birth received by the older siblings (table 4). Parents invest less in the health of a child if her older siblings were exposed to a higher prices in utero and at birth. While the own price coefficient has the same sign, it is generally lower than in the baseline estimations (at least on health outcomes), bolstering the idea that at least part of the effects are due to negative spillovers from the siblings.

| Table 4: Effects of own and siblings’ exposure to world crop prices on health outcomes |
|---------------------------------|--------|--------|--------|--------|--------|--------|
|                               | (1)    | (2)    | (3)    | (4)    | (5)    | (6)    |
| Dep. var.                     | Death  | Underheight | Underweight | ln height | ln weight |
| At birth                      |        |          |        |        |        |
| ln crop price (own)           | -0.002 | -0.001   | -0.091  | -0.081  | 0.021   | 0.060   |
| (0.003)                       | (0.005)| (0.018)  | (0.011) | (0.006) | (0.013) |
| ln crop price (siblings)      | 0.005  | 0.008    | 0.020   | 0.007   | -0.002  | -0.006  |
| (0.001)                       | (0.002)| (0.004)  | (0.003) | (0.001) | (0.003) |
| Observations                  | 500138 | 500138   | 415331  | 415331  | 410406  | 410843  |
| Child controls                | Yes    | Yes     | Yes    | Yes    | Yes    |
| Household controls            | Yes    | Yes     | Yes    | Yes    | Yes    |
| Cell FE                       | Yes    | Yes     | Yes    | Yes    | Yes    |

* significant at 10%; ** significant at 5%; *** significant at 1%. ln crop price siblings represents the price faced on average by all elder siblings during in utero and during their first year of life.
Table 5: Effects of own and siblings’ exposure to world crop prices on health investments

<table>
<thead>
<tr>
<th>Dep. var</th>
<th>Vaccins (# doses)</th>
<th>Vaccins (0/1)</th>
<th>Other investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>ln crop price (own)</td>
<td>0.361</td>
<td>0.386</td>
<td>0.907</td>
</tr>
<tr>
<td></td>
<td>(0.072)</td>
<td>(0.060)</td>
<td>(0.164)</td>
</tr>
<tr>
<td>ln crop price (siblings)</td>
<td>-0.060</td>
<td>-0.075</td>
<td>-0.167</td>
</tr>
<tr>
<td></td>
<td>(0.020)</td>
<td>(0.015)</td>
<td>(0.040)</td>
</tr>
</tbody>
</table>

Observations 367361 427819 361327 430552 426619 431567 370371 332556 222549 244591 469478

Child controls Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes
Household controls Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes
Cell FE Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes

5 Local income and child health inequality

By comparing health outcomes across siblings (or across children living in the same area), the results of the child-level regressions can have important implications for aggregate inequality in child health. In particular, health disparities should increase with variation in prices in utero and at birth if children born in good times have significantly better health than others (i.e., if $\alpha$ is positive in regression (2)). In the second part of our empirical analysis, we test explicitly for this aggregate relationship by estimating specifications of the form:

$$\Delta \text{Ineq}_{rt}^D = \alpha^D |\Delta \log P_{r,t}| + D_{rt}^\beta + \mu_t + \varepsilon_{rt}$$

where the unit of observation is now an administrative region $r$ at time $t$. The “$\Delta$” term is the first-difference operator. The dependent variable Ineq$_{rt}^D$ is the change in a decomposable inequality measure of child health indicators (height and weight relative to the respective WHO reference values). We employ the General Entropy and the Atkinson indexes because they can be decomposed into within and between household components – the superscript $D$ denotes overall, between or within inequality indicator. The main variable of interest, $|\Delta \log P_{r,t}|$ is the absolute value of the average price faced by the cohort of children born in region $r$ in the previous 5 years during the in utero period and their first year of life (first-differenced). The coefficient $\alpha^D$ captures the association between changes in child health inequality and changes in the average income-related price shocks in early life across cohorts. The first-difference specification wipes out time-invariant factors that are specific to region $r$. The term $D_{rt}$ collects cohort-averaged characteristics (e.g., age, gender) that are the regional counterparts of the child-specific variables in $D_{ct}$ (e.g., in equation (2)).

5.1 Effects on child health inequality

The results from the child-level regressions illustrate how exposure to different local income shocks at utero can enlarge health disparities across children even within the same family. In this part...
of our empirical analysis, we thus investigate the aggregate implications of changes in crop prices early in life for child health inequality.

**Heterogeneity of the effects across households.** Most of the existing work on child health inequality stresses the role of disparities between groups and households (see Li et al. (2017) for descriptive evidence in developing countries). While our empirical strategy relies on comparisons within the households, our average effects can mask some meaningful heterogeneity across household characteristics that could drive aggregate between-household inequality in child health.

In tables A5 and A6 we interact our price variable with an indicator for the education level of the mother and with her Rohrer index, a measure of corpulence that in poor countries should proxy for wealth. The health literature usually refers to this type of variable to identify the socio-economic (SE) gradient in health outcomes. The coefficients on the interaction variables have often the opposite sign of the price variable. Differences in health outcomes and investments across children because of income shocks tend to be less pronounced in high-SE households.

These findings accord well with increases in crop prices alleviating budget constraints as these should be more severe in low-SE households. However, the lack of significance of some interaction coefficients in tables A5 and A6 indicate that between-household heterogeneity in the health effects of crop prices is rather weak.

**Effects on child health inequality within and between households.** The micro level results point to a relationship between exposure to crop prices at birth and inequality in child health within the household. We thus explore this implication by computing the General Entropy (GE) and the Atkinson (A) indexes of inequality in height and weight, and by decomposing them into their within and between components. Table 6 reports summary statistics for the indexes across administrative regions (3381 in total, observed on average for 3 years) and the share of the index that is account for by the within component. Health disparities across siblings contribute on average as much as 20% of total inequalities in child health.

<table>
<thead>
<tr>
<th>Table 6: Inequality, descriptive statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obs.</td>
</tr>
<tr>
<td>GE(1)(Weight)</td>
</tr>
<tr>
<td>Contrib. within</td>
</tr>
<tr>
<td>A(1)(Weight)</td>
</tr>
<tr>
<td>Contrib. within</td>
</tr>
<tr>
<td>GE(1)(Height)</td>
</tr>
<tr>
<td>Contrib. within</td>
</tr>
<tr>
<td>A(1)(Height)</td>
</tr>
<tr>
<td>Contrib. within</td>
</tr>
</tbody>
</table>

Source: Authors’ computations from DHS. See main text for data sources.

We thus explore the relationship between changes in child health inequality within regions and changes in the average in utero and at birth exposure to crop prices across children of the same five-year cohort (specification (6)). The within- and between-household inequality indexes are considered separately as dependent variables. Figure 2 visualizes the coefficients by type of inequality index. Regions where children are exposed to larger swings in world crop prices display higher inequality in child health. What the figure shows is that this relationship is driven entirely...
by a positive effect of changes in early exposure to crop prices on within-household in children health. Consistently with the documented effects at the micro level, income-related price shocks raise disparities in health outcomes across siblings.

Figure 2: Effect of exposure to world crop prices on child health inequality

These figures report the coefficient on the ln crop price variables price, split by child age in years (see the regression equation (3)). Shaded areas are 90% confidence bands.

6 Concluding remarks

In this paper, we provide novel evidence on how fluctuations in local economic conditions can shape the level and variance of health outcomes for children. Geo-localised survey health data for 34 developing countries are matched with measures of local exposure to world prices of crops, whose variation affects agricultural income, a major source of resources in the developing world. Our empirical analysis relies on variation in crop prices during pregnancy and during the first year of life across siblings within the same household. The results point to strong positive effects of early exposure to high prices on children’s health. Provision of vaccinations, vitamins and other forms of parental investment in children’s health are also increasing in the level of the price received by the child, thus compounding the health effect. The improvements in health and investments received following a positive income shocks are partly at the expense of the other siblings. These findings suggest an effect of income-related price fluctuations on child health inequality acting through a widening of disparities within the household. Results from aggregate regressions at the regional level strongly confirm this presumption – income fluctuations during pregnancy and in the first year of life are an important determinant of child health inequality within the household.

Our findings confirm evidence from the fetal origin literature showing strong and long-lasting effects of economic shocks early in life on education and health outcomes. They are also consistent with empirical studies supporting the idea that parents reinforce the impact of initial shocks to children’s endowments. We show that these micro-level patterns have important aggregate implications for disparities in child health outcomes. The evidence on a representative group of developing countries calls for a greater attention to intra-household dynamics in order to better understand the evolution child health inequalities.
Appendix

Additional Figures

Figure A1: Location of DHS households

Figure A2: Share of variation in \( \text{share}_{kp} \) due to between-crop \((p)\) variation
Figure A3: World prices of the most produced crops

Figure A4: Effect of price shocks on parental investments over time

(a) Vitamins
(b) Deworming

These figures report the coefficient on the ln crop price variables price, split by child age in years. Shaded areas are 90% confidence bands.
### Table A1: Effects of exposure to world crop prices on mortality and health – Cell-level controls

<table>
<thead>
<tr>
<th>Dep. var.</th>
<th>(1) Death At birth</th>
<th>(2) 1st year</th>
<th>(3) Under height</th>
<th>(4) Underweight</th>
<th>(5) ln height</th>
<th>(6) ln weight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ln crop price</td>
<td>-0.010(^b)</td>
<td>-0.026(^a)</td>
<td>-0.189(^a)</td>
<td>-0.150(^a)</td>
<td>0.071(^a)</td>
<td>0.155(^a)</td>
</tr>
<tr>
<td>(0.005)</td>
<td>(0.009)</td>
<td>(0.029)</td>
<td>(0.019)</td>
<td>(0.010)</td>
<td>(0.022)</td>
<td></td>
</tr>
<tr>
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<td>255294</td>
<td>255294</td>
<td>249036</td>
<td>251998</td>
</tr>
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<td>Child controls</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Household controls</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Cell FE</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

\(^a\) significant at 10%; \(^b\) significant at 5%; \(^a\) significant at 1%. OLS estimations. The unit of observation is a child. Standard errors clustered at the cell level in parentheses. All estimations include country × year and month dummies, and time-varying controls for exposure to world prices of minerals, weather conditions, and the incidence of conflicts at the cell level. Child controls include: gender, birth order, twin dummy, and age in month. Household controls include: mother’s age and education dummies, rural dummy, and Rohrer index. ln crop price index is the log of the World price of the crops produced in the cell, weighted by the share of each crop in the area. Death is a dummy which equals 1 if the child dies at birth (col. 1) or in her/his first year (col. 2), 0 otherwise. Underheight (respectively underweight) is a dummy which equals 1 if the height-for-age (resp. weight-for-age) ratio is at least 2 standard deviations below the z-score from WHO. ln height (resp. ln weight) are the logs of height (resp. weight) divided by the gender-specific average height (resp. weight) for that particular age in month from WHO.

### Table A2: Effects of exposure to world crop prices on mortality and health – Excluding migrants

<table>
<thead>
<tr>
<th>Dep. var.</th>
<th>(1) Death At birth</th>
<th>(2) 1st year</th>
<th>(3) Under height</th>
<th>(4) Underweight</th>
<th>(5) ln height</th>
<th>(6) ln weight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel A</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ln crop price</td>
<td>-0.006</td>
<td>-0.028(^b)</td>
<td>-0.219(^a)</td>
<td>-0.202(^a)</td>
<td>0.094(^a)</td>
<td>0.202(^a)</td>
</tr>
<tr>
<td>(0.007)</td>
<td>(0.013)</td>
<td>(0.037)</td>
<td>(0.025)</td>
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<tr>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Cell FE</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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</tbody>
</table>

\(^a\) significant at 10%; \(^b\) significant at 5%; \(^a\) significant at 1%. OLS estimations. The unit of observation is a child. The sample excludes children of mothers who reported living in a place different from the place of birth. Standard errors clustered at the cell level in parentheses. All estimations include country × year and month dummies. Child controls include: gender, birth order, twin dummy, and age in month. Household controls include: mother’s age and education dummies, rural dummy, and Rohrer index. ln crop price index is the log of the World price of the crops produced in the cell, weighted by the share of each crop in the area. Death is a dummy which equals 1 if the child dies at birth (col. 1) or in her/his first year (col. 2), 0 otherwise. Underheight (respectively underweight) is a dummy which equals 1 if the height-for-age (resp. weight-for-age) ratio is at least 2 standard deviations below the z-score from WHO. ln height (resp. ln weight) are the logs of height (resp. weight) divided by the gender-specific average height (resp. weight) for that particular age in month from WHO.
Table A3: Effects of exposure to world crop prices on mortality and health – Rural sample

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<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dep. var.</td>
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<td>Underheight</td>
<td>Underweight</td>
<td>ln height</td>
<td>ln weight</td>
<td></td>
</tr>
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<tr>
<td>Panel A</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ln crop price</td>
<td>-0.015&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.027&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.180&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.179&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.054&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.124&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.010)</td>
<td>(0.032)</td>
<td>(0.021)</td>
<td>(0.010)</td>
<td>(0.023)</td>
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<td>Yes</td>
<td>Yes</td>
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<td>Yes</td>
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<tr>
<td>Household (mother) FE</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Panel B</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ln crop price</td>
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<td>-0.004</td>
<td>-0.168&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.159&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.045&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.116&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
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<td>(0.004)</td>
<td>(0.007)</td>
<td>(0.025)</td>
<td>(0.016)</td>
<td>(0.008)</td>
<td>(0.018)</td>
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<td>355524</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Household controls</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Cell FE</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

<sup>a</sup> significant at 10%; <sup>b</sup> significant at 5%; <sup>c</sup> significant at 1%. OLS estimations. The unit of observation is a child. The sample include only rural households at the time of the survey. Standard errors clustered at the cell level in parentheses. All estimations include country × year and month dummies. Child controls include: gender, birth order, twin dummy, and age in month. Household controls include: mother’s age and education dummies, rural dummy, and Rohrer index. In crop price index is the log of the World price of the crops produced in the cell, weighted by the share of each crop in the area. Death is a dummy which equals 1 if the child dies at birth (col. 1) or in her/his first year (col. 2), 0 otherwise. Underheight (respectively underweight) is a dummy which equals 1 if the height-for-age (resp. weight-for-age) ratio is at least 2 standard deviations below the z-score from WHO. ln height (resp. ln weight) are the logs of height (resp. weight) divided by the gender-specific average height (resp. weight) for that particular age in month from WHO.
### Table A4: Effects of exposure to world crop prices on mortality and health – ‘Cash’ vs. ‘food’ crops

<table>
<thead>
<tr>
<th>Dep. var.</th>
<th>(1) Death At birth</th>
<th>(2) Underheight</th>
<th>(3) Underweight</th>
<th>(4) ln height</th>
<th>(5) ln weight</th>
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</thead>
<tbody>
<tr>
<td><strong>Panel A</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ln crop price (food)</td>
<td>-0.009&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-0.026&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.230&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.189&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.072&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>(0.005)</td>
<td>(0.010)</td>
<td>(0.032)</td>
<td>(0.021)</td>
<td>(0.011)</td>
<td>(0.026)</td>
</tr>
<tr>
<td>ln crop price (cash)</td>
<td>-0.034&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-0.022</td>
<td>-0.121&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-0.124&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.066&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>(0.011)</td>
<td>(0.019)</td>
<td>(0.069)</td>
<td>(0.051)</td>
<td>(0.020)</td>
<td>(0.053)</td>
</tr>
</tbody>
</table>

Observations: 625882, 625882, 284155, 284155, 27784, 280796

Child controls: Yes, Yes, Yes, Yes, Yes, Yes

Household (mother) FE: Yes, Yes, Yes, Yes, Yes, Yes

### Table A5: Heterogeneity across households in the effects of crop prices on child health

<table>
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<tr>
<th>Dep. var.</th>
<th>(1) Death At birth</th>
<th>(2) Underheight</th>
<th>(3) Underweight</th>
<th>(4) ln height</th>
<th>(5) ln weight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel B</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ln crop price (food)</td>
<td>-0.001</td>
<td>-0.001</td>
<td>-0.178&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.141&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.054&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>(0.004)</td>
<td>(0.007)</td>
<td>(0.025)</td>
<td>(0.016)</td>
<td>(0.010)</td>
<td>(0.023)</td>
</tr>
<tr>
<td>ln crop price (cash)</td>
<td>-0.008</td>
<td>-0.012</td>
<td>-0.137&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.181&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.037&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>(0.008)</td>
<td>(0.014)</td>
<td>(0.048)</td>
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<td>(0.016)</td>
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Observations: 503396, 503396, 490297, 490297, 483854, 484526

Child controls: Yes, Yes, Yes, Yes, Yes, Yes

Household controls: Yes, Yes, Yes, Yes, Yes, Yes

Cell FE: Yes, Yes, Yes, Yes, Yes, Yes

*<sup>c</sup> significant at 10%; *<sup>b</sup> significant at 5%; *<sup>a</sup> significant at 1%. OLS estimations. The unit of observation is a child. Standard errors clustered at the cell level in parentheses. All estimations include country × year and month dummies. Child controls include: gender, birth order, twin dummy, and age in month. Household controls include: mother’s age and education dummies, rural dummy, and Rohrer index. ln crop price (food) is the log of the World price of the following products: banana, barley, coconut, maize, palm oil, rice, sorghum, soybean, sugar, wheat; weighted by the share of each crop in the area. ln crop price (cash) is the log of the World price of the following products: cocoa, coffee, cotton, tea and tobacco; weighted by the share of each product in the area. Death is a dummy which equals 1 if the child dies at birth (col. 1) or in her/his first year (col. 2), 0 otherwise. Underheight (respectively underweight) is a dummy which equals 1 if the height-for-age (resp. weight-for-age) ratio is at least 2 standard deviations below the z-score from WHO. In height (resp. In weight) are the logs of height (resp. weight) divided by the gender-specific average height (resp. weight) for that particular age in month from WHO.

### Table A5: Heterogeneity across households in the effects of crop prices on child health

<table>
<thead>
<tr>
<th>Dep. var.</th>
<th>(1) Death At birth</th>
<th>(2) Underheight</th>
<th>(3) Underweight</th>
<th>(4) ln height</th>
<th>(5) ln weight</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Panel B</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ln crop price (food)</td>
<td>-0.012</td>
<td>-0.057&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.377&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.233&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.130&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>(0.011)</td>
<td>(0.018)</td>
<td>(0.045)</td>
<td>(0.031)</td>
<td>(0.017)</td>
<td>(0.044)</td>
</tr>
<tr>
<td>ln crop price (cash)</td>
<td>-0.006&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-0.004</td>
<td>0.033&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.016&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-0.008&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>(0.002)</td>
<td>(0.003)</td>
<td>(0.009)</td>
<td>(0.005)</td>
<td>(0.003)</td>
<td>(0.007)</td>
</tr>
<tr>
<td>ln crop price (food) × education</td>
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<td>0.022&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.088&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.036&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-0.031&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>(0.006)</td>
<td>(0.010)</td>
<td>(0.022)</td>
<td>(0.017)</td>
<td>(0.009)</td>
<td>(0.017)</td>
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Observations: 374896, 374896, 260003, 260001, 254931, 256863

Child controls: Yes, Yes, Yes, Yes, Yes, Yes

Household (mother) FE: Yes, Yes, Yes, Yes, Yes, Yes

<sup>c</sup> significant at 10%; <sup>b</sup> significant at 5%; <sup>a</sup> significant at 1%.
Table A6: Heterogeneity across households in the effects of crop prices on health investments

<table>
<thead>
<tr>
<th>Dep. var.</th>
<th>Vaccins (# doses)</th>
<th>Vaccins (0/1)</th>
<th>Other investments</th>
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</thead>
<tbody>
<tr>
<td>In crop price</td>
<td>0.067** 0.591**</td>
<td>-0.101**</td>
<td>-0.103**</td>
</tr>
<tr>
<td></td>
<td>(0.119) (0.109)</td>
<td>(0.047) (0.046)</td>
<td>(0.050) (0.032)</td>
</tr>
<tr>
<td>× education</td>
<td>0.018 -0.137* -0.273*</td>
<td>0.006 0.005 -0.120**</td>
<td>0.049* 0.006 -0.116**</td>
</tr>
<tr>
<td></td>
<td>(0.022) (0.022)</td>
<td>(0.008) (0.008)</td>
<td>(0.006) (0.006)</td>
</tr>
<tr>
<td>× Rohrer index</td>
<td>0.160* 0.006 0.103 0.014 -0.075*</td>
<td>0.054 0.055* -0.009 0.014 -0.053*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.060) (0.051)</td>
<td>(0.024) (0.026)</td>
<td>(0.024) (0.024)</td>
</tr>
<tr>
<td>Observations</td>
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<td></td>
</tr>
<tr>
<td>Child controls</td>
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<td>Household controls</td>
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<td>Cell FE</td>
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*significant at 10%; **significant at 5%; ***significant at 1%. OLS estimations. In the first three columns the dependent variables are the number of doses taken by the kid of Polio (max. 4 doses), DPT (max. 3 doses) and all vaccines (DPT, Polio, BCG, measles, max. 9 doses). In columns (4) to (7) the dependent variables are dummy taking the value 1 is the child has taken all required doses of a particular vaccines. In columns (8) to (10) dependent variables are dummies taking the value 1 if the child has received Vitamin A, Iron pills and deworming drugs during the three months preceding the survey, zero otherwise. Finally, in column (11) the dependent variable takes the value 1 is the child has been breastfed for at least 6 months, 0 otherwise.
References


