Sweet child of mine: Income, health and inequality*

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Abstract. We study the effect of income shocks on child health and strategic investment across siblings using micro data from multiple waves of the Demographic and Health Survey (DHS) spanning 56 developing countries. Variations in the world prices of locally produced crops are used as measures of local income. We find that: (i) temporary variations in income in utero and in the first year of life durably affect child health and long-term health investment; (ii) households allocate more resources to the children born in good times relative to their siblings; (iii) the health of later-born siblings deteriorate and these siblings receive less investments. These within-household reallocations have important implications for child health inequality. At the regional level, aggregate health inequality is found to be larger when children are exposed to more volatile crop prices.

JEL classification: O11, I14, I12.

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1 Introduction

How to 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 these 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, theoretically and empirically, 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 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 health disparities within households (relative to the role of inequalities across households)?

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 deeply alter investment decisions in households subject to severe budget constraints with limited access to financial markets. Furthermore, the lack of effective old-age pension systems may push parents to allocate scarce resources within the family on the basis of efficiency rather than equity concerns. Importantly, asymmetries in parents' investment choices over the health and education of their children affect within-household and hence overall inequality.

We first provide a simple theoretical framework that explains why income earned during pregnancy and first year of life of a child have-long lasting effects on parental investment, health and educational outcomes, and within household advantages. Credit and saving markets plays a crucial role in translating income shocks occurring in-utero and during the early childhood of a child into investment and endowments shocks specific to that child. Our framework emphasises how the child's human capital accumulation process in the presence of shocks may exacerbate intra-household competition on resources, given production functions and budget constraints. We use this model to derive predictions that relate income fluctuations to sibling competition on resources. These predictions are tested in the second part of the paper using household-level data on health investment and outcomes, and education and the price of locally produced commodities.

Then, 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 500 thousands women and 800 thousands 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 health investments, such as vaccinations and provision of health treatments. 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 quantitatively similar when comparing children across families and 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, iron pills 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 price-induced changes in consumption. A demand-side 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 40% 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. We also 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, and similar in magnitude than the one estimated in the specification with household fixed effects.

Parents' preferences, budget constraints and children's health production function can explain an health 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. The estimates indicate that the observed average increase in the regional price index of produced crops might have led to a 36% increase in health disparities across children within the same household.

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. In our sample of DHS countries with data from the 1990s and the 2010s, we observe an average decline in inequalities in child health as measured by height and weight. This is shown in Figure A.1 of the online appendix section B.5. What this Figure shown is also a strong heterogeneity in the 2010s-1990s percent changes across countries.

Similar patterns in child health disparities in developing countries have been already docu-

[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 (GonzÃ¡lez and Rodriguez-Gonzalez, 2018), while it remained stable in France (Currie et al., 2018) and in Canada (Baker et al., 2017).

mented elsewhere (Li et al., 2017; Wang, 2003). These papers attribute the overall inequalities to disparities 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 health 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. Figure A.2 in the online appendix shows the percent change between 2010s and 1990s in the within- and between-households components of child health inequality (as measured by the mean log deviation – other indices display similar trends). Most countries in our sample record a decline in child health disparities both between and within households, consistently with the aggregate patterns. The trends vary however markedly across countries, with some experiencing a doubling in the level of child health inequalities within households.

In our empirical analysis, we will exploit even richer geographical variations across regions within countries and find that the changes in health inequalities within household increase 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-poor and development policies (Brown et al., 2017, 2018). 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 et al. (2017); Duque et al. (2018); and Almond and Mazumder (2013); Almond et al. (2018) for recent reviews of the literature).[2] 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 Almond and Currie (2011) and Currie and Vogl (2013), as well as recent contributions by Groppo and Kraehnert, 2016; Adhvaryu et al., 2017; 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

[2] 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).

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 outlines a theoretical framework that can guide our empirical analysis at the micro level. Section describes the health and price data that we use, and sections 4.1 and discuss the empirical strategy adopted to investigate effects at the child level, and the corresponding results. In section , we then explore the implications of our micro-level evidence for child health inequality within regions. Section concludes.

2 Theoretical Framework

We present a simple theoretical framework that highlights the conditions under which variations in household income occurring in the early life of a child have lasting consequences on the health investments she receives. This framework also allows us to study investment externalities across siblings and their impact on child quality.

2.1 Environment

Consider a representative household consisting of a married couple (the parents) with children. Parents allocate resources across children and over time. To characterise the parents' problem, we build on seminal models of children human capital accumulation, parents' optimal investment decisions, and sibling externalities (Heckman, 2007; Almond and Currie, 2011; Yi et al., 2015; Almond et al., 2018). As our objective is to study the effect of income fluctuations on investment at different stages of children's life, we extend these frameworks in order to incorporate a time dimension in investment decisions.

Assume for now that the parents have two children (we will relax this assumption and extend the model to higher parities), and have no access to credit or saving facilities. We distinguish three stages in the life of a child. Stage 1 represents the in utero period and first year of life: parents need to decide how much income to devote to the child's nutrition and health, given income and competing expenditures. In stage 2 the child still lives with her parents who have to decide how much to invest in her human capital (either health or education). Investments in period 1 and 2 determine the quality of the child that is realized in period 3, when she becomes and adult and does not depend on parents' resources anymore.

Children come in specificied birth order. The first child is alone with the parents during stage 1 of life; in stage 2, she overlaps with the second child, who is in his stage 1. So, overall, the household lives 4 periods – the last one being when the quality of the second child is realized.

The income of the household y_t is uncertain and varies over time. Income is independently drawn from a probability distribution function $f(.)$ over $(0; +\infty)$. The expected value of y_t is denoted $\overline{y}$.

Human capital production function. As in Almond et al. (2018), and following Heckman (2007), the quality of children production technology is given by a two-period Constant Elasticity of Substitution (CES) function:

$$h_c = A\left[\gamma(I_c^{p_1})^{\frac{(s-1)}{s}} + (1-\gamma)(I_c^{p_2})^{\frac{(s-1)}{s}}\right]^{\frac{s}{(s-1)}}$$

where $I_c^{p_1}$ and $I_c^{p_2}$ are the investments parents make into child $c = (c1, c2)$ in period 1 and 2 of their life. Since we are interested in the long-term effect of early life shocks, the parameter s, the elasticity of substitution between $I_c^{p_1}$ and $I_c^{p_2}$ is key. We start deriving results for $s = 0$, implying that the two investments are complements.

If $s = 0$, the production function takes on a Cobb-Douglas form:

$$h_c = A(I_c^{p_1})^{\gamma}(I_c^{p_2})^{1-\gamma}$$

As the Fetal Origin literature has shown since the work of Currie and Hyson (1999) and Costa (2000), health investments during pregnancy and the first year of life are particularly important for further development (see e.g. Almond and Currie, 2011, for a review of this literature). We hence assume that $\gamma > \frac{1}{2}$.

Parents' preferences and budget constraint. Parents value investment as long as it increases quality. Since investment goes also through nutrition, we are implicitly assuming that, in each period, investment is high enough to guarantee survival. Investment is traded-off against parental consumption. In particular, the inter-temporal utility function of the parents has the following form[3]:

$$u_p = log\,(C_1) + log\,(C_2) + log\,(C_3) + h_{c1} + h_{c2}$$

The specific functional form we use embeds some assumptions: first, since $\frac{\partial^2 h_c}{\partial I_c^{p_2} \partial I_c^{p_1}} > 0$ we are assuming dynamic complementarities in investment, meaning that the returns of the second period investment increase with first period investment. Also, since we are interested in how competition on resources affects investment across children, we assume that parents have no inequality aversion in children quality. However, our theoretical predictions hold for a moderate level of inequality aversion.

Parents face the following budget constraints:

$$C_1 + pI_{c1}^{p_1} \leq Y_1$$
$$C_2 + p\,(I_{c1}^{p_2} + I_{c2}^{p_1}) \leq Y_2$$
$$C_3 + pI_{c2}^{p_2} \leq Y_3$$

where p is the aggregate cost of human capital investment in children.

[3]Since we are ruling out savings and credit, we assume the discount factor equals 1.

2.2 Parental optimal investment and realised quality

Optimal Investment without income fluctuations. Assume that income is fixed, i.e. that $y_1 = y_2 = y_3 = \overline{y}$. In this case, when maximizing their utility over time, parents can choose the optimal investment path in period 0. They solve simultaneously the system of first order conditions for interior investment solutions (see Appendix A) and want to equalize marginal returns of investment to the marginal utility of consumption.

Since investment in the first period of life of a child has higher returns and that the first child is alone in his period of life, her realised quality is higher. This is due to the fact that the lower investment in child one in period two in less important than the lower investment in child two in period one. This prediction traces a relationship between investment in a child health and birth rank and refers to the "siblings' rivalry" effect: a child born at later birth order has (by definition) more older siblings and, thus, has to compete more for resources [4].

We now study how income variability affect optimal investment.

Optimal Investment under uncertainty. We allow income to vary over time. Parents maximise their utility equalizing marginal rates of consumption and investment under each state of the world. However, when deciding period 1 investments, they are now uncertain about the level of investment of the second period.

Due to risk-aversion, the uncertainty of period 2 investment for the second child decreases his period 1 investment. This, is turn, decreases the resource constraint faced by the first child in period 2. Due to dynamic complementarities, the increase in period 2 investment should drive period 1 investment up for child 1; however, the income uncertainty pushes period 1 investment down: so the overall effect on period 1 investment for child one is ambiguous.

We now consider the effects of a positive income realization $y_t > \overline{y}$[5] occurring in period 1 on investment in period 1 and 2 for one child, keeping the income of the other period fixed and equal to $\overline{y}$[6]. An increase in income has a direct positive effect on investment for all children living in that period. The increase in investment implies also an indirect effect for the child that is in his first period of life when the increase in income occurs: thanks to dynamic complementarities , a positive income shock increases investment also in period 2.

Proposition 1 *A positive shock occurring in the first period of life of a child increases both first and second period investment on that child. Thus, adult quality increases following a positive income shock.*

Proof. See Appendix.

As shown in the proof of the proposition, the increase in investment is higher for the second child than for the first child.

[4] The "siblings' rivalry" effect has been shown the be particularly detrimental for high birth rank girls (Garg and Morduch, 1998; Pande, 2003)

[5] All the results hold in a symmetric way for a negative shock.

[6] This assumption mimic our main empirical specification that relies on household fixed effects to get rid of unobservables. Once fixed effects are introduced, we study the effects, for each child, of price deviations from mean prices during pregnancy and first year of life of all children

We can further study the 'sibling effect" – the marginal effect of an income shock in the first period (the in utero and first year of life for the older child) on parents' investments in the second and third period on the second child. The "sibling rivalry" mechanism occurring in period 2 is the main channel of transmission of the shock: since investment in child 1 is more profitable, thanks to dynamic complementarities, incentives to devote resources to the second child decrease. Formally:

Proposition 2 *A positive shock occurring in the first period of life of the first child reduces both first and second period investments on the second child. Thus, adult quality of the second child decreases following a positive income shock occurring in the first period of life of the first child.*

Proof. See Appendix.

3 Data

Our first objective is to identify the effects of local income shocks during in utero and early life on child health and parental health investments in poor countries. We therefore primarily need data on (i) health indicators and health investments at the individual (child) level; (ii) income shocks which are exogenous to health and more generally individual behavior. The online appendix section B provides additional details about the sources and the construction of the data.

3.1 Individual data

Our baseline data on child mortality, health and other individual and household characteristics come from the Demographic and Health Surveys (DHS).[7] We restrict our analysis to countries containing information on the geo-location of households. This restriction is crucial as we need the household GPS coordinates to to link the individual data to income shocks. These restrictions leave us with 56 countries, among which 35 are African countries, 8 are in Latin American, 11 in Asia and 2 in (Eastern) Europe. Maps showing the countries covered and the location of the household appear in the online appendix, section B.5. Table A.1 contains the list of countries, as well as the number waves and individuals for each of them.

The data includes information on household members characteristics, primarily the mother and children. Some additional data cover adult men; we will also make use of this data later on, when looking at adult health and educational outcomes. Note that the DHS is not a panel: each household – hence child – appears only once in the data. This however 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 anthropometric indicators (height-for-age, weight-for-age) and child mortality – at birth and in the first year. Anthropometric measures are available only for children under five years old. We therefore restrict

[7] https://dhsprogram.com/Data/.

our sample to these children, i.e. a little more than 1,3 million children born from about 872 thousands 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.[8]

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 (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 a twin dummy. At the mother or household level, we keep information on age, rural/urban status, education and Rohrer's Index, and wealth index.

3.2 Income shocks

Our analysis requires to identify income variations which are exogenous to local conditions and are not expected to impact health directly. The "fetal origin" literature has used exposure to a number of external events (e.g., infectious diseases, extreme weather shocks – see 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 channels other 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 local conflicts (Berman and Couttenier, 2015; McGuirk and Burke, 2017).

We first divide each country of our sample in 5,941 cells of 0.5×0.5 (roughly 55×55km at the equator). For each of these cells, we compute the suitability of the cell to grow each 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.

[8] https://www.who.int/childgrowth/standards/en/.

For each cell and year, we compute the following price shock:

$$\mathrm{P}_{kt} = \sum_p \alpha_{pk} \times P^W_{pt} \quad (1)$$

where α_{pk} is the suitability of cell k to grow crop p and P^W_{pt} is the monthly nominal world price of crop p at time (month) t (relative to its level in January 2010). In our baseline regressions we will average these prices across the months of pregnancy and the first year of life of the child; we will consider later-life prices in our robustness exercises. In these robustness checks we will also 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 and local conditions (although it does not vary over time) than the GAEZ-based *share*, but it could capture better the patterns of agricultural specialisation.

Figure A.4 in the online appendix 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 × 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 income.

3.3 Descriptive statistics

Table 1 reports summary statistics for the main variables used in the child-level empirical analysis. Mothers are 29 years old on average and households are primarily rural (70%). Information on mortality is available for 1.319 million children, while anthropometric indicators are non-missing for about 745 thousands children. Underweight affects 8% of the children, while underheight (stunting) reaches 18 % of the sample.

Table 1 also displays statistics on the health investments variables that we use in our empirical analysis. Breastfeeding duration is long on average, as 84% of children are breastfed at least six months. On the other hand, medications such as deworming or iron pills are much less widespread.

Table 1: Summary statistics

	Obs.	Mean	S.D.	1st Quartile	Median	3rd Quartile
Child-level						
Age	1221185	1.99	1.48	1	2	3
Gender	1319209	1.49	0.50	1	1	2
Birth order	1319209	3.50	2.44	2	3	5
Twin	1319209	0.03	0.17	0	0	0
Underheight	745956	0.18	0.39	0	0	0
Underweight	745956	0.08	0.27	0	0	0
Height (cm)	733508	81.96	14.51	71.80	82.50	93
Weight (kg)	739738	11.88	9.38	8.40	11	13.60
Death Birth	1319209	0.01	0.11	0	0	0
Death First year	1319209	0.03	0.17	0	0	0
Breastfeeding > 6m	1119604	0.84	0.37	1	1	1
# Polio vaccines	814501	2.72	1.36	2	3	4
# DPT vaccines	1013853	2.04	1.28	1	3	3
BCG vaccine (dummy)	1023497	0.82	0.38	1	1	1
Measles vaccine (dummy)	1012648	0.62	0.49	0	1	1
Iron pills in last 3 months	564681	0.14	0.34	0	0	0
Deworm in last 3 months	619010	0.38	0.49	0	0	1
Mother-level						
Education (mother)	1319121	0.90	0.89	0	1	2
Age (mother)	1319209	28.98	6.96	24	28	34
Rural	1319209	0.70	0.46	0	1	1
Cell-level						
ln crop prices (GAEZ)	1275549	4.43	0.31	4.15	4.43	4.69

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

4 Income, child health and early life investment

4.1 Empirical strategy

The model presented in section 2 contains two main testable predictions. A higher income in the early life of a child: (i) increases the investment she receives and therefore her health in subsequent periods (proposition 1); (ii) worsens the investment and health of children born subsequently (proposition 2).

In this section we present our strategy to test these predictions. We focus on health and parental investment during childhood (up to five years of life); section 5 studies longer term effects on health and education.

Income shocks and child health. We first want to study the effect of income variations, proxied by world agricultural commodity prices, on child health – child "quality". Local exposure to agricultural world prices may correlate with household behaviour and characteristics which 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 characteristic – 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:

$$Y_c = \alpha \log \overline{P}_{c,k} + \mathbf{D_c'}\delta + \mu_H + \gamma_{i,t} + \nu_m + \varepsilon_c \tag{2}$$

where Y_c^H is a mortality or health indicator for child c at time t (month-year), sequentially: 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;[9] the continuous measures of height and weight relative to the WHO reference values (in logs); a dummy for death at birth; and a dummy for death in the first year.

$\overline{\mathrm{P}}_{k,t}$ is the average of the monthly prices of crops produced in cell k during the in utero period and in the first year of life (or only during in utero period when the dependent variable is death at birth). Note that we will also separate the in utero and first year of life periods, as well as consider subsequent years. Our results show that in utero and first life prices generally have similar effects, while later years prices have a much lower impact. $\mathbf{D'_{ct}}$ is a vector of child characteristics – age, gender, twin, birth order. μ_H are household fixed effects. $\gamma_{i,t}$ and ν_m are additional fixed effects accounting for country×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. In our sensitivity analysis we will additionally include controls for local weather shocks and other commodity prices shocks (oil and mineral prices in oil or mineral producing regions) that might correlate with $\overline{P}_{c,k}$.

In equation (2), α 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 α 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, α 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

[9]These definition correspond to "severe" underweight and stunting. The results are similar when "moderate" underweight and stunting are considered, i.e. two standard deviations below mean.

the following variant of equation (2):

$$Y_c = \sum_{a=0}^{4} \alpha^a \text{Age}_c^a \times \log \overline{\text{P}}_{k,t} + \mathbf{D_c'}\delta + \mu_H + \gamma_{i,t} + \nu_m + \varepsilon_c \tag{3}$$

where 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 children's life. The profile of the α^a however 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. As in our model, persistence could come from the direct effect of better nutrition on health and/or from other health investments. If, as in our model, health investments in each periods are complements, we would expect parents to spend more on the health of their children born during good times – compared to their siblings –, potentially in a durable way.

We examine the parental investment 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:

$$I_c = \beta \log \overline{P}_{c,k} + \mathbf{D_c'}\delta + \mu_H + \gamma_{i,t} + \nu_m + \varepsilon_c \tag{4}$$

where I_c is either a dummy for durable breastfeeding (longer than 6 months); the count of doses of vaccines against polio, DPT (diphtheria, pertussis and tetanus), tuberculosis (BCG) and measles; or an indicator for provision of iron pills or deworming in the last three months.[10]

A significant β 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_c variables could be seen as 'bad' controls in specification (2) (Pei et al., 2018).

Again, we estimate a variant of (4) where the β 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. This exercise makes little sense in the case of breastfeeding and vaccinations, which are investments typically taking place upon birth or in the first year of life, but it does in the case iron and deworm pills, which are observed at the current age of the child.

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 papers 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

[10] Adhvaryu and Nyshadham (2016) uses a similar set of variables to proxy for investment in child health. The DHS also contains a variable coded one if the child received Vitamin A over the last three months; results are similar.

fixed effects μ_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), which allows us to directly test Proposition 2. 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):

$$Y_c = \alpha \log \overline{P}_{c,k} + \alpha^s \log \overline{P}^s_{c,k} + \mathbf{D'_c}\beta + \mathbf{C'_H}\gamma + \mu_k + \gamma_{i,t} + \nu_m + \varepsilon_c \tag{5}$$

with the s superscript indicating is the average of P across the older siblings of child c. The matrix C collects controls for the mother's age (and its value squared), level of education, and for whether the household is located in an urban area. The μ_k term denote cell k fixed effects. A similar specification is estimated also for health investment outcomes. The coefficient α^s indicates whether having siblings born in 'good' times (high $\overline{\mathrm{P}}^s_{k,t}$) affects the health of child c (conditional on her own price, $\overline{\mathrm{P}}_{k,t}$). Proposition 2 predicts α and α^s to be of opposite signs.

Econometric issues. We estimate all specifications 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. In our robustness we allow the error term to be spatially correlated (within a 500km radius), as well serially correlated.

There are two main threats to identification in equation (2) to (5). The first is omitted variables, which might correlate with world prices and affect child health through channels other than income. In our robustness exercises, we will control for various potential time-varying confounders, such as mineral and oil prices, conflicts and rainfall. The second threat is persistence in prices over time. If early life prices are strongly correlated with later life prices, (2) to (5) might wrongly capture the effect of later price. We will show that our results are similar when controlling for the full sequence of prices, from the in utero period to the current age of the child.

4.2 Results

Income and 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 α 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 the child is a twin. Overall, children's health is positively associated to increases in world prices of locally produced commodities in early life. Children exposed to higher crop prices during pregnancy and the first year of life have higher weight and height relative to standard reference values, and are less likely to be stunted or underwieghted. The size of the coefficients are comparable in Panels A and B, suggesting that we are not only capturing a divergence between kids within households, but also an positive effect of positive income variations in the early life on later health. In our baseline specification, exposed children seem also significantly less likely to die at birth or during the first year of life during high income periods; however, these results on mortality are not robust to alternative specifications and data sources, as discussed in section 4.3.

Table 2: Exposure to world crop prices and child health

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. var.	Underheight	Underweight	ln height	ln weight	—— Death ——	
					At birth	1^{st} year
Panel A						
ln crop price	-0.189^{a}	-0.156^{a}	0.065^{a}	0.129^{a}	-0.009^{b}	-0.021^{a}
	(0.025)	(0.017)	(0.008)	(0.019)	(0.004)	(0.008)
Observations	371419	371419	357106	362237	777288	777288
R^2	0.675	0.687	0.738	0.741	0.522	0.533
Child controls	Yes	Yes	Yes	Yes	Yes	Yes
Household (mother) FE	Yes	Yes	Yes	Yes	Yes	Yes
Panel B						
ln crop price	-0.201^{a}	-0.149^{a}	0.065^{a}	0.138^{a}	-0.002	-0.009
	(0.023)	(0.015)	(0.008)	(0.020)	(0.003)	(0.006)
Observations	371407	371407	357094	362225	777228	777228
R^2	0.171	0.242	0.198	0.160	0.025	0.036
Child controls	Yes	Yes	Yes	Yes	Yes	Yes
Household controls	Yes	Yes	Yes	Yes	Yes	Yes
Cell FE	Yes	Yes	Yes	Yes	Yes	Yes

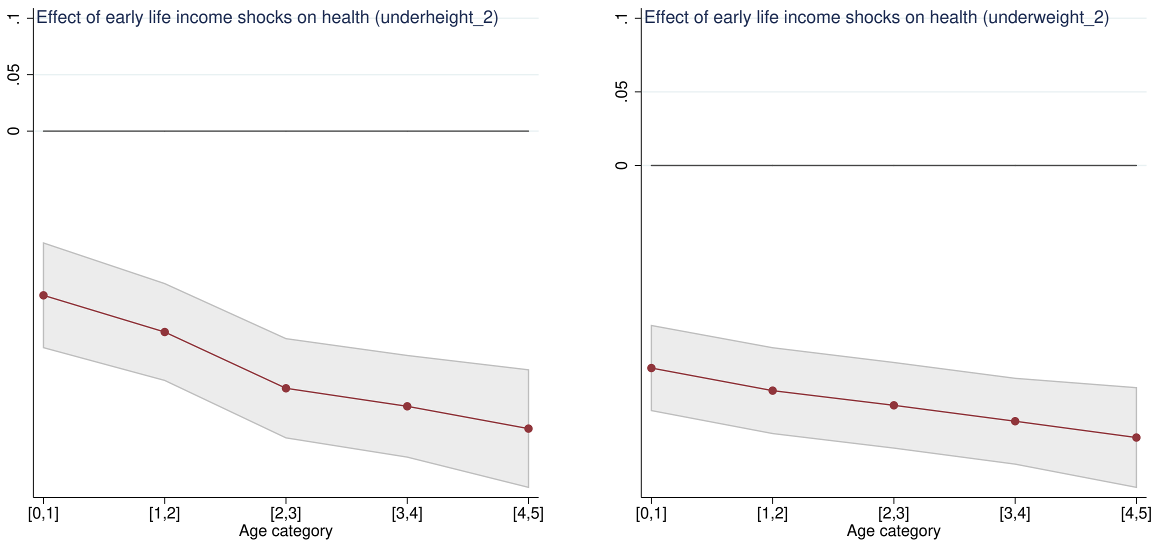
^{c} significant at 10%; ^{b} significant at 5%; ^{a} significant at 1%. OLS estimations. The unit of observation is a child. Standard errors clustered at the cell level in parentheses. All estimations include country × year and month dummies. Child controls include: gender, birth order, twin dummy, and age in month. Household controls include: mother's age and age square, education dummies, rural/urban dummy. 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. 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. Death is a dummy which equals 1 if the child dies at birth (col. 5) or in her/his first year (col. 6), 0 otherwise.

The estimated coefficients imply sizeable effects of differences in the local level of world prices. Consider the effects on children's weight (column (4)). In the estimation sample, the healthiest child in the family has on average a 22% higher weight than the 'lightest' one (weight is standardised by age and sex). The estimated elasticity in column (4) thus suggests that the least healthy sibling could have achieved a 60% reduction in the weight gap if she would have received a 100% higher crop price than the one received by the healthiest sibling (conditional on the crop prices received by the other siblings). The average within-household spread in the crop price variable being 19%, our estimates predict that price-related income fluctuations could explain up to 11% 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%).

These baseline estimates may reflect short-lived effects, i.e. the impact of price variations at birth and in the first year of life, not necessarily in the subsequent years. To assess the persistence of the health impact, 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 two binary health indicators (the results for the continuous indicators are shown in section C.1 of the online appendix). The coefficients tend to increase in absolute terms up to five years, which suggests a protracted impact of early life income variations on health. Figure C.1 in the online appendix confirms the persistence of the effect in the case of the continuous height and weight variables. This persistency over such a short time span could be explained by the transmission of the health int the first year of life to the following years, or by the response of parental health investment. We now explore this latter possibility.

Figure 1: Exposure to world crop prices and child health over time

(a) Underheight (b) Underweight



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

Income and health investment. 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 determine wether the estimates found in Table 2 solely reflect better nutrition and persistence in health conditions, or also a behavioral response of parents through investments in health.

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 responding to crop price variations in the early life of the child by investing more in her health.The size of the implied effects is quantitatively important. The largest gap in the number of Polio vaccination doses across siblings (dependent variable in column (2)) is on average 0.8. The estimated crop price coefficient in column (2) suggests that this gap would be 10% lower if the crop price index at birth for the low-polio child were 19% higher – the sample average largest gap in the price index across siblings. The same within-household changes in prices is associated with 2 percentage-point higher likelihood of receiving vaccination against tuberculosis (Bacillus Calmette-Guerin, or BCG), and a 4 percentage-point higher chances of being immunized against measles. A 19% higher crop price early in life is also associated with a 6 percentage-point higher likelihood of being breastfed for at least six months (7% of the sample probability).

Table 3: Exposure to world crop prices and health investments

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dep. var.	Breast.	– Vaccins (# doses) –				Other investments	
		Polio	DPT	BCG	Measles	Iron	Deworm
Panel A							
ln crop price	0.331^a	0.450^a	0.498^a	0.096^a	0.230^a	0.029^c	0.195^a
	(0.020)	(0.066)	(0.061)	(0.016)	(0.031)	(0.015)	(0.024)
Observations	633666	434806	527134	533398	525223	303999	328971
R^2	0.744	0.820	0.826	0.809	0.800	0.826	0.829
Child controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mother FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Panel B							
ln crop price	0.298^a	0.498^a	0.518^a	0.068^a	0.177^a	0.096^a	0.238^a
	(0.019)	(0.068)	(0.055)	(0.015)	(0.027)	(0.017)	(0.024)
Observations	633642	434782	527110	533374	525199	303981	328955
R^2	0.425	0.338	0.397	0.321	0.408	0.152	0.299
Child controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cell FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

^{c} significant at 10%; ^{b} significant at 5%; ^{a} significant at 1%. OLS estimations. In the first column the dependent variable takes the value 1 is the child has been breastfed for at least 6 months, 0 otherwise. In the next two columns the dependent variables are the number of doses taken by the child of Polio (max. 4 doses), and DPT (max. 3 doses). In columns (4) to (7) the dependent variables are dummies taking the value 1 if the child has taken all required doses of particular vaccines (Measles and DPT), iron pills, and deworming drugs (these last two during the three months preceding the survey).

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, in Figure A.6 of online appendix C.1 we split again 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). We do this for the last two indicators, iron pills and deworming (the other investments being typically done in the first year of life). Overall, results suggest that the positive coefficient on crop prices is stable or slightly increasing with age, though it is imprecisely estimated in the case of iron pills.

These results that differential health responses of siblings to income shocks in utero and at birth is partly driven by parental investment response. At this stage, none of the results however shows that the health of the children who are not born during bad times (compared to their siblings) deteriorates, as predicted by Proposition 2. We now test this prediction.

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 (specification (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 and 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.

Table 4: Own and siblings' exposure to world crop prices and health outcomes

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. var.	Underheight	Underweight	ln height	ln weight	—— Death ——	
					At birth	1^{st} year
ln crop price (own)	-0.215^a	-0.159^a	0.069^a	0.147^a	-0.004	-0.011^b
	(0.026)	(0.017)	(0.009)	(0.021)	(0.004)	(0.005)
ln crop price (siblings)	0.044^a	0.024^a	-0.009^a	-0.026^a	0.008^a	0.006^a
	(0.008)	(0.005)	(0.002)	(0.006)	(0.002)	(0.001)
Observations	279704	279704	268498	272015	564947	952876
R^2	0.180	0.257	0.201	0.163	0.030	0.032
Child controls	Yes	Yes	Yes	Yes	Yes	Yes
Household controls	Yes	Yes	Yes	Yes	Yes	Yes
Cell FE	Yes	Yes	Yes	Yes	Yes	Yes

^{c} significant at 10%; ^{b} significant at 5%; ^{a} significant at 1%. 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 age square, education dummies, rural/urban dummy. 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. ln crop price (siblings) is the price faced on average by all elder siblings during in utero and during their first year of life. 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. Death is a dummy which equals 1 if the child dies at birth (col. 5) or in her/his first year (col. 6), 0 otherwise.

Table 5: Own and siblings' exposure to world crop prices and health investments

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dep. var.	Breast.	– Vaccins (# doses) –				Other investments	
		Polio	DPT	BCG	Measles	Iron	Deworm
ln crop price (own)	0.310^a	0.486^a	0.524^a	0.075^a	0.185^a	0.103^a	0.263^a
	(0.020)	(0.076)	(0.061)	(0.018)	(0.028)	(0.019)	(0.027)
ln crop price (siblings)	0.004	-0.106^a	-0.117^a	-0.026^a	-0.020^a	-0.012	0.001
	(0.004)	(0.026)	(0.021)	(0.007)	(0.008)	(0.008)	(0.010)
Observations	477902	331501	395113	399417	393598	228477	246938
R^2	0.432	0.335	0.393	0.322	0.398	0.158	0.303
Child controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cell FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

^{c} significant at 10%; ^{b} significant at 5%; ^{a} significant at 1%. OLS estimations. ln crop price (siblings) is the price faced on average by all elder siblings during in utero and during their first year of life. In the first column the dependent variable takes the value 1 is the child has been breastfed for at least 6 months, 0 otherwise. In the next two columns the dependent variables are the number of doses taken by the child of Polio (max. 4 doses), and DPT (max. 3 doses). In columns (4) to (7) the dependent variables are dummies taking the value 1 if the child has taken all required doses of particular vaccines (Measles and DPT), iron pills, and deworming drugs (these last two during the three months preceding the survey.

4.3 Sensitivity analysis

In this section, we show that our main results – Panels A in Tables 2 and 3 – are robust to a large battery of sensitivity checks. Most of the Tables are relegated to the online appendix (section C), in which we discuss these results more extensively.

Full sequence of prices. Price are persistent over time. This persistence is an issue in our case, as it implies that we might be capturing the effect of prices in subsequent years on subsequent health and not the effect of early life prices on subsequent health. To solve this problem, we can include the full sequence of prices in our estimations. The results are shown and discussed in section C.2 of the online appendix. We find that (i) our results are statistically robust; (ii) pregnancy and first year prices have quantitatively similar effects; (iii) later life prices, while being generally significant, have a much more limited impact on health indicators.

Additional controls. Crop prices could correlate with other time-varying, cell level variables. For instance, Berman and Couttenier (2015) and Burke and McGuirk (2018) show that they impact local conflict. In section C.3 we show that our estimates are virtually unchanged when we control for other time-varying local variables such as exposure to world prices of locally produced minerals, weather conditions, and incidence of conflicts.

Cash/staple crops. 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. In section the online appendix section C.4 we report 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. The estimates on the cash crop variables are generally significant but more imprecisely estimate; this reflects the fact that cash crop account for a small part of our sample. Overall, 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).

Other robustness. In section C.5 we use an alternative measure of agricultural specialization from M3-Crop (Monfreda et al., 2008). Prices are in this case weighted by the share of harvested area in 2000 in the cell. The results are quite similar, except in the case of mortality, for which the estimates become statistically insignificant. In section C.6 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, except in the case of columns 4-7 of Tabe A.11. As another check on the validity of our results, we replicate in section C.7 the baseline results on the sample of rural households (70% of the sample); the results are slightly reinforced.

5 Adult health and education

Our model could in principle be interpreted as providing predictions on the long-term impact of early life price changes on health, and could as well be used to look at educational investment. In this section we consider these two extensions. As discussed below, this exercise has to be taken with caution because attrition is likely to affect our results: we do not observe health or education of adult members of the family who have left the household.

We first study long-term persistence, i.e. whether the effects of early life shocks impact are still visible when the individual has become an adult. We consider health information on adults contained in the DHS. For all waves, we have anthropometric data (Rohrer index, BMI, haemoglobin levels) on women living in the households. For the most recent DHS waves (DHS7) we also have information for men, for part of the countries (only on BMI and haemoglobin level). We first identify siblings, within each household; these can be the household heads or heads' partner's siblings, children of the head or grand children. We then look at how early life shocks affect current health, controlling for either cell fixed effects or sibling fixed effects, as in our baseline regressions.

Table 6: Early exposure to world crop prices on individual health, adult data

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dep. var.	Rohrer	BMI	Underweight		ln hemogl.	No anemia	Education	
Measure			(BMI)	(Rohrer)			>Primary	4 cat.
Panel A								
ln crop price	0.097	0.406	-0.054^c	-0.040	0.025	0.096	0.025	0.053
	(0.260)	(0.327)	(0.029)	(0.041)	(0.020)	(0.060)	(0.023)	(0.038)
Observations	126588	137087	137087	126588	72216	72215	276740	276740
Individual & HH controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sibling FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Panel B								
ln crop price	0.274^a	0.760^a	-0.044^a	-0.038^a	0.033^a	0.052^a	0.072^a	0.156^a
	(0.101)	(0.107)	(0.008)	(0.012)	(0.005)	(0.015)	(0.010)	(0.017)
Observations	404981	433242	433242	404981	250273	250273	804889	804889
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cell FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

^{c} significant at 10%; ^{b} significant at 5%; ^{a} significant at 1%. OLS estimations. The unit of observation is an adult individual. Standard errors clustered at the cell level in parentheses. All estimations include country × year of birth and month of birth dummies. Individual controls include gender and age dummies. Household controls a rural dummy. 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. Rohrer index, BMI, hemoglobin are the individual's Rohrer index, BMI and level of hemoglobin at the time of the survey. Underweight (BMI) is a dummy taking the value 1 if the BMI of the respondent is lower than 25; Underweight (Rohrer) is a dummy that takes the value 1 if the Rohrer index of the respondent is lower than 12.

The results are shown in Table 6. We find positive and significant effects of early life shocks on adult health[11] in cell fixed effects estimations (Panel B of Table 6 below, columns (1)-(6)). When sibling FE are included, the coefficients remain positive but much more imprecisely estimated, and are statistically insignificant in most cases (Panel A, columns (1)-(6)).

In Table 6, columns (7) and (8) we perform a similar exercise, but use education as a dependent variable. For the most recent DHS wave, we have information on educational attainment for all members of the households. We do find positive effects of early life shocks on education, though the coefficients are again statistically more significant when sibling fixed effects are included.

Note that the results from these estimations – especially the ones with sibling fixed effects – have to be taken with care. Information is available only for adults who still are in the households, and women are over-represented, especially in the case of the health indicators. All individuals who left the households are not observed, as are most men. Similarly, over such a long period of time, migration is likely; but information on migration is unavailable for most of the individuals of these regressions. These elements might create measurement error and blur especially the within-siblings comparisons.

[11]The average/median age is 28/25 in this sample.

6 Child health inequality

By comparing health outcomes within households, across siblings, the results of the child-level regressions have important implications for aggregate inequalities in child health. In particular, health disparities should increase within households with variations in prices in utero and at birth, as these fluctuations widen the health and health investment gaps across siblings. At the aggregate level however, whether this translate into larger child health inequalities remains an open question. It depends on the effect of price volatility on health and health investment both within and across households.

We start by interacting our price variables with proxies for income at the household level, to infer their effect on child health inequality across household. We then aggregate our data and construct child health inequality indicators which are easily decomposable into within and a between households components, and study how crop price volatility affect inequality through both these channels.

6.1 Income and child health 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.

We augment our baseline specifications with interaction terms between our price variable and three indicators which correlate positively with household income: the education level of the mother; her Rohrer index – a measure of corpulence that in poor countries should proxy for wealth –; and a categorical wealth index available in the DHS. The health literature usually refers to this type of variables to identify the socio-economic (SE) gradient in health outcomes.

Table 7: Exposure to world crop prices and child health across households

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. var.	Underheight	Underweight	ln height	ln weight	—— Death	——
					At birth	1^{st} year
ln crop price	-0.428^a	-0.243^a	0.139^a	0.213^a	-0.020^c	-0.061^a
	(0.046)	(0.031)	(0.017)	(0.038)	(0.011)	(0.019)
× education	0.028^a	0.004	-0.006^b	0.007	-0.007^a	-0.005
	(0.010)	(0.006)	(0.003)	(0.008)	(0.002)	(0.004)
× Rohrer index	0.084^a	0.043^a	-0.027^a	-0.051^a	0.007	0.025^b
	(0.022)	(0.016)	(0.009)	(0.020)	(0.006)	(0.010)
× Wealth index	0.020^a	0.003	-0.005^a	0.002	0.001	0.000
	(0.005)	(0.004)	(0.002)	(0.004)	(0.001)	(0.002)
Observations	270460	270460	264677	267379	354946	354946
R^2	0.653	0.615	0.747	0.698	0.528	0.538
Child controls	Yes	Yes	Yes	Yes	Yes	Yes
Household (mother) FE	Yes	Yes	Yes	Yes	Yes	Yes

^{c} 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. Child controls include: gender, birth order, twin dummy, and age in month. Household controls include: mother's age and age square, education dummies, rural/urban dummy. 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. 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. Death is a dummy which equals 1 if the child dies at birth (col. 5) or in her/his first year (col. 6), 0 otherwise.

Table 8: Exposure to world crop prices and health investments across households

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dep. var.	Breast.	– Vaccins (# doses) –				Other investments	
		Polio	DPT	BCG	Measles	Iron	Deworm
Panel A							
ln crop price	0.431^a	0.286^b	0.935^a	0.050^c	0.530^a	0.043	0.396^a
	(0.036)	(0.126)	(0.109)	(0.030)	(0.051)	(0.030)	(0.045)
× education	0.005	0.022	-0.083^a	-0.014^b	-0.101^a	0.003	-0.072^a
	(0.006)	(0.023)	(0.022)	(0.006)	(0.010)	(0.006)	(0.009)
× Rohrer index	-0.018	0.134^b	-0.001	0.017	-0.061^a	-0.004	-0.033
	(0.015)	(0.062)	(0.051)	(0.015)	(0.022)	(0.017)	(0.021)
× Wealth index	-0.009^b	-0.003	-0.074^a	0.012^a	-0.042^a	-0.005	-0.035^a
	(0.004)	(0.015)	(0.012)	(0.004)	(0.005)	(0.003)	(0.006)
Observations	345365	255733	290131	293041	289261	218027	232622
R^2	0.759	0.824	0.832	0.821	0.808	0.821	0.828
Child controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mother FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

^{c} significant at 10%; ^{b} significant at 5%; ^{a} significant at 1%. OLS estimations. In the first column the dependent variable takes the value 1 is the child has been breastfed for at least 6 months, 0 otherwise. In the next two columns the dependent variables are the number of doses taken by the child of Polio (max. 4 doses), and DPT (max. 3 doses). In columns (4) to (7) the dependent variables are dummies taking the value 1 if the child has taken all required doses of particular vaccines (Measles and DPT), iron pills, and deworming drugs (these last two during the three months preceding the survey).

The results are displayed in Tables 7 and 8. Though the significance of the coefficients varies across indicators and specifications, the coefficients on the interaction variables generally exhibit the opposite sign of the price variable. Put differently, while prices increases tend to improve child health and trigger parental investments, this is less the case in high-SE households. These findings accord well with increases in crop prices alleviating budget constraints, which should be more severe in low-SE households. However, the lack of significance of some interaction coefficients in Tables 7 and 8 indicate that between-household heterogeneity in the health effects of crop prices is rather weak.

6.2 Within-household adjustment and aggregate child health inequality

We now study the relationship between price variability and aggregate child health inequality. To do so, we compute aggregate indicator of child health inequality at level of the administrative region (Admin2). Given that we want to look at changes in inequality over time, we concentrate on the countries for which at least two surveys are available. We are left with 31 countries and 3383 regions in total, observed on average for 3 years. We then compute various versions of General Entropy (GE) and Atkinson (A) indexes of inequality in height and weight. We choose to concentrate on these indexes for two reasons. First, contrary to Gini for instance, they are decomposable into their within and between households components. Second, the GE index has a straightforward interpretation: with a weight parameter of zero, it equals the mean log deviation; with a parameter of 1, it equals the Theil index; and with a parameter of 2 it is half the squared coefficient of variation.

To study the impact of price fluctuations on changes in aggregate inequality, we estimate the following specification:

$$\Delta \log \mathrm{Ineq}_{rt}^{D} = \alpha^{D} |\Delta \log \overline{P}_{r,t}| + \mathbf{D'_{rt}}\beta + \mu_t + \varepsilon_{rt} \tag{6}$$

where the unit of observation is now an administrative region r at time t. Δ denotes 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), computed across children of the same five-year cohort. The superscript D denotes overall, between or within inequality indicator.

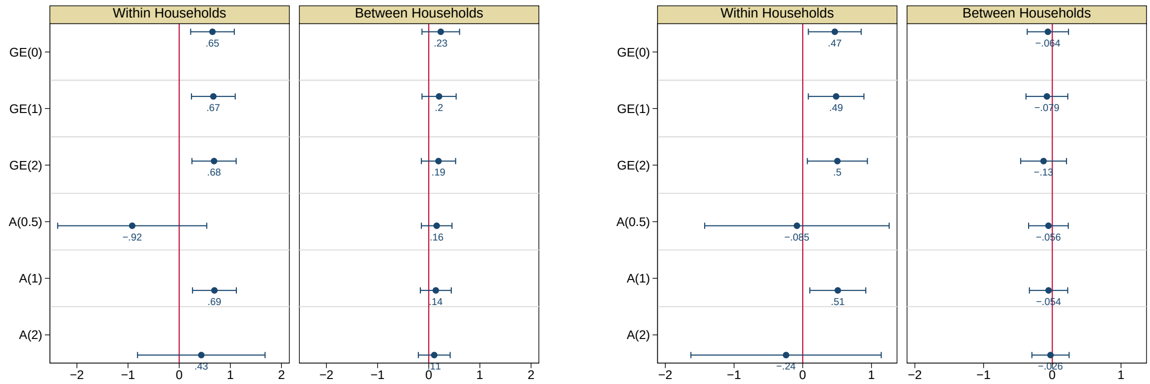
The main variable of interest, $|\Delta \log \overline{P}_{r,t}|$ is the absolute value of the average price faced by the cohort of children born in region r in the previous 5 years during the in utero period and their first year of life (first-differenced). The coefficient α^{D} captures the association 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)).

Table A.2 in online appendix B.6 reports summary statistics for the log changes in the mean log deviation (GE(0)) and Theil index (GE(1)), and in their within- and between-households components for regions within countries – i.e., the dependent variables in regression (6). In our sample, disparities in child health narrow on average over time. The decline is visible both within and between households. As for country-level health inequalities (see Figures A.1 and A.2), these patterns however mask substantial heterogeneity across regions, which is particularly marked within households. Regions and periods in the bottom quartile of the distribution experience declines in within-household child health disparities between 80 and 90%, whereas observations in the top quartile record 80% or higher increases in health disparities across siblings.

In the regression equation (6), we thus see whether variations in utero and at birth exposure to crop prices across regions and over time correlates with the rich patterns of disparities in child health between and within households. The two inequality components are considered separately as dependent variables.

Figure 2: Exposure to world crop prices on child health inequality

(a) Height (b) Weight



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.

Figure 2 plots the α^D coefficients and their 95% confidence interval for each 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.

The estimated elasticities indicate a robust and sizeable effect, at least for the within-household components of inequality coming from General Entropy indexes. The observed average percent change in the regional producer price index between the first and last year a region is observed in our sample equals 56%.[12] Our estimated elasticities thus suggest that this average variation could lead to a 36% higher value of the within-household component of disparities in child health.

7 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 56 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

[12]The average region is observed three times throughout the sample. The average (in absolute value) first-difference in the crop the price index at the regional level is approximately 34% at the price index in the initial period (see the descriptive statistics in Table A.2 in the online appendix.

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.

References

Adhvaryu, A., Fenske, J., Nyshadham, A., 2017. Early Life Circumstance and Adult Mental Health. Journal of Political Economy Forthcoming.

Adhvaryu, A., Nyshadham, A., 2016. Endowments at Birth and Parents' Investments in Children. The Economic Journal 126(593), 781–820.

Almond, D., Currie, J., 2011. Killing Me Softly: The Fetal Origins Hypothesis. Journal of Economic Perspectives 25(3), 153–72.

Almond, D., Currie, J., Duque, V., 2018. Childhood Circumstances and Adult Outcomes: Act II. Journal of Economic Literature Forthcoming.

Almond, D., Mazumder, B., 2013. Fetal origins and parental responses. Annual Review of Economics 5(1), 37–56.

Baird, S., Friedman, J., Schady, N., 2011. Aggregate income shocks and infant mortality in the developing world. The Review of Economics and Statistics 93(3), 847–856.

Baker, M., Currie, J., Schwandt, H., 2017. Mortality Inequality in Canada and the U.S.: Divergent or Convergent Trends? NBER Working Paper 23514.

Benshaul-Tolonen, A., 2018. Local Industrial Shocks and Infant Mortality. The Economic Journal Forthcoming.

Berman, N., Couttenier, M., 2015. External shocks, internal shots: The geography of civil conflicts. Review of Economics and Statistics 97(4), 758–776.

Brown, C., Calvi, R., Penglase, J., 2018. Sharing the Pie: Undernutrition, Intra-household Allocation, and Poverty. Working Paper.

Brown, C., Ravallion, M., van de Walle, D., 2017. Are Poor Individuals Mainly Found in Poor Households? Evidence using Nutrition Data for Africa. NBER Working Paper 24047.

Cogneau, D., Jedwab, R., 2012. Commodity price shocks and child outcomes: The 1990 cocoa crisis in cÃ´te d?ivoire. Economic Development and Cultural Change 60(3), 507–534.

Costa, D.L., 2000. Understanding the twentieth-century decline in chronic conditions among older men. Demography 37(1), 53–72.

Currie, J., Hyson, R., 1999. Is the impact of health shocks cushioned by socioeconomic status? the case of low birthweight. American Economic Review 89(2), 245–250.

Currie, J., Schwandt, H., 2016a. Inequality in mortality decreased among the young while increasing for older adults, 1990–2010. Science .

Currie, J., Schwandt, H., 2016b. Mortality Inequality: The Good News from a County-Level Approach. Journal of Economic Perspectives 30(2), 29–52.

Currie, J., Schwandt, H., Thuilliez, J., 2018. PauvretÃ©, EgalitÃ©, MortalitÃ©: Mortality (In)Equality in France and the United States. NBER Working Paper 24623.

Currie, J., Vogl, T., 2013. Early-Life Health and Adult Circumstance in Developing Countries. Annual Review of Economics 5(1), 1–36.

Dercon, S., Porter, C., 2014. Live aid revisited: Long-term impacts of the 1984 ethiopian famine on children. Journal of the European Economic Association 12(4), 927–948.

Duque, V., Rosales-Rueda, M., Sanchez, F., 2018. How Early-life Shocks Interact with subsequent Human Capital Investments? Evidence from Administrative Data. Working Paper.

Ferreira, F.H.G., 2009. Aggregate Economic Shocks, Child Schooling, and Child Health. World Bank Research Observer 24(2), 147–181.

Garg, A., Morduch, J., 1998. Sibling rivalry and the gender gap: Evidence from child health outcomes in ghana. Journal of Population Economics 11(4), 471–493.

GonzÃ¡lez, L., Rodriguez-Gonzalez, A., 2018. Changes in Inequality in Mortality: New Evidence for Spain. Working Papers 1050. Barcelona Graduate School of Economics.

Groppo, V., Kraehnert, K., 2016. Extreme Weather Events and Child Height: Evidence from Mongolia. World Development 86(C), 59–78.

Heckman, J.J., 2007. The economics, technology, and neuroscience of human capability formation. Proceedings of the National Academy of Sciences 104(33), 13250–13255.

Li, Z., Li, M., Subramanian, S.V., Lu, C., 2017. Assessing levels and trends of child health inequality in 88 developing countries: from 2000 to 2014. Global Health Action 10(1), 1408385.

McGuirk, E., Burke, M., 2017. The Economic Origins of Conflict in Africa. Technical Report 23056.

Miller, G., Urdinola, B.P., 2010. Cyclicality, Mortality, and the Value of Time: The Case of Coffee Price Fluctuations and Child Survival in Colombia. Journal of Political Economy 118(1), 113–155.

Monfreda, C., Ramankutty, N., Foley, J.A., 2008. Farming the planet: 2. Geographic distribution of crop areas, yields, physiological types, and net primary production in the year 2000. Global Biogeochemical Cycles 22(1).

Pande, R.P., 2003. Selective gender differences in childhood nutrition and immunization in rural india: The role of siblings. Demography 40(3), 395–418.

Pei, Z., Pischke, J.S., Schwandt, H., 2018. Poorly Measured Confounders are More Useful on the Left than on the Right. Journal of Business & Economic Statistics Forthcoming, 1–12.

Rosenzweig, M.R., Zhang, J., 2009. Do population control policies induce more human capital investment? twins, birth weight and china's "one-child" policy. The Review of Economic Studies 76(3), 1149–1174.

Venkataramani, A.S., 2012. Early life exposure to malaria and cognition in adulthood: Evidence from mexico. Journal of Health Economics 31(5), 767 – 780.

Vogl, T.S., 2018. Dynamics of child mortality inequality. AEA Papers and Proceedings 108, 348–52.

Wang, L., 2003. Determinants of child mortality in ldcs: Empirical findings from demographic and health surveys. Health Policy 65(3), 277 – 299.

Yi, J., Heckman, J.J., Zhang, J., Conti, G., 2015. Early Health Shocks, Intra-household Resource Allocation and Child Outcomes. The Economic Journal 125(588), F347–F371.

Sweet child of mine:
Income shocks, health and inequality

Online Appendix

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A Theoretical Appendix

Optimal Investment without income fluctuations. When income is certain, the parents solve simultaneously the system of first order conditions for interior investment solutions:

$$\begin{array}{rcl} -\frac{1}{Y-I_{c1}^{p_1}}+\gamma A(I_{c1}^{p_1})^{\gamma-1}(I_{c1}^{p_2})^{1-\gamma} & = & 0 \\ -\frac{1}{Y-I_{c1}^{p_2}-I_{c2}^{p_1}}+(1-\gamma)A(I_{c1}^{p_1})^{\gamma}(I_{c1}^{p_2})^{-\gamma} & = & 0 \\ -\frac{1}{Y-I_{c1}^{p_2}-I_{c2}^{p_1}}+\gamma A(I_{c2}^{p_1})^{\gamma-1}(I_{c2}^{p_2})^{1-\gamma} & = & 0 \\ -\frac{1}{Y-I_{c2}^{p_2}}+(1-\gamma)A(I_{c1}^{p_1})^{\gamma}(I_{c1}^{p_2})^{-\gamma} & = & 0 \end{array} \tag{7}$$

Since income is constant, $\gamma > \frac{1}{2}$ and the two children overlap in period 2, it follows immediately that $I_{c1}^{p_1} > I_{c2}^{p_1} > I_{c2}^{p_2} > I_{c1}^{p_2}$. Moreover, $\frac{I_{c1}^{p_1}}{I_{c2}^{p_1}} > \frac{I_{c2}^{p_2}}{I_{c1}^{p_2}}$. This implies that the human capital of the first child is higher than the human capital of the second child (for a given level of income). This prediction traces a relationship between investment in a child health and birth rank

Optimal Investment under uncertainty. Income uncertainty modifes the FOCs of the parents problem for the first year investment in the following way:

$$\begin{array}{rcl} -\frac{1}{Y_1^j-I_{c1}^{p_1,j}}+\gamma A(I_{c1}^{p_1,j})^{\gamma-1}[p_L(I_{c1}^{p_2,L})^{1-\gamma}+p_M(I_{c1}^{p_2,M})^{1-\gamma}+p_H(I_{c1}^{p_2,H})^{1-\gamma}] & = & 0 \\ -\frac{1}{Y_2^k-I_{c1}^{p_2,k}-I_{c2}^{p_1,k}}+(1-\gamma)A(I_{c1}^{p_1,j})^{\gamma}(I_{c1}^{p_2,k})^{-\gamma} & = & 0 \\ -\frac{1}{Y_2^k-I_{c1}^{p_2,k}-I_{c2}^{p_1,k}}+\gamma A(I_{c2}^{p_1,k})^{\gamma-1}[p_L(I_{c2}^{p_2,L})^{1-\gamma}+p_M(I_{c2}^{p_2,M})^{1-\gamma}+p_H(I_{c2}^{p_2,H})^{1-\gamma}] & = & 0 \\ -\frac{1}{Y_3^l-I_{c2}^{p_2,l}}+(1-\gamma)A(I_{c2}^{p_1,k})^{\gamma}(-I_{c2}^{p_2,l})^{-\gamma} & = & 0 \end{array} \tag{8}$$

where Y_1^j, Y_2^k and Y_3^l are income realizations in periods 1, 2 and 3 respectively, and $I_c^{p,j}$ the corresponding investment for child c in period p, with j, k and l in L, M, H.

A.1 Proofs

Proof Proposition 1. We start with a shock to the first child: the income realization in the first period is $y_1 > \overline{y}$ while, in the following periods, income realisations are equal to $\overline{y}$.

The effect of a positive income shock on investment in the first and second period for child 1 is the following:

$$\begin{array}{rcl} \frac{\partial I^{p_1,j}{c1}}{\partial Y_1} & = -\frac{\frac{\partial U^P}{\partial Y_1}}{\frac{\partial U^P}{\partial I^{p_1}}} = & \frac{h_{c1}}{(Y_1^j-I_{c1}^{p_1,j})I_{c1}^{p_1,j}} > 0 \\ \frac{\partial I_{c1}^{p_2,j}}{\partial Y_1} & = \frac{\partial I^{p_2,j}}{\partial I^{p_1,j}}\frac{\partial I^{p_1,j}}{\partial Y_1} = & \frac{\partial I^{p_2,j}}{\partial I^{p_1,j}}\frac{h_{c1}}{(Y_1^j-I_{c1}^{p_1,j})I_{c1}^{p_1,j}} > 0 \end{array} \tag{9}$$

The second derivative is positive because $\frac{\partial I^{p_2,j}}{\partial I^{p_1,j}} > 0$ – $I^{p_1,j}$ increases the return of investing in period 2 for the same child, as the first order conditions show.

Turning to the second child, an income shock occurring in his first period of life correspond to a shock to y_2: we assume now that the income realization in the second period is $y_2 > overliney$ while, in periods 1 and 3, income realizations are going to be equal to $\overline{y}$.

The effect of a positive income shock on investment in the first and second period for child 2 is the following:

$$\begin{array}{rcl} \frac{\partial I^{p_1,j}{c2}}{\partial Y_2} & = -\frac{\frac{\partial U^P}{\partial Y_2}}{\frac{\partial U^P}{\partial I^{p_1,j}{c2}}} = & \frac{h_{c2}}{(Y_2^k-I_{c1}^{p_2,k}-I_{c2}^{p_1,k})I_{c2}^{p_1,k}} > 0 \\ \frac{\partial I_{c2}^{p_2,j}}{\partial Y_2} & = \frac{\partial I^{p_2,j}}{\partial I^{p_1,j}}\frac{\partial I^{p_1,j}}{\partial Y_2} = & \frac{\partial I^{p_2,j}}{\partial I^{p_1,j}}\frac{h_{c2}}{(Y_2^k-I_{c1}^{p_2,k}-I_{c2}^{p_1,k})\partial I^{p_2,j}} > 0 \end{array} \tag{10}$$

To understand whether the effect of a symmetric shock is bigger for the first or the second child, assuming that prior to the shock $Y_1 = Y_2 = Y^M$, we compare the effect of an increase in income in the first and the third equation in (8). Since, prior to the shock $C_1 > C_2$, thanks to the convexity of the marginal utility of consumption, we know that for a symmetric increase, the increase in the left hand part of the FOC for second period income is always bigger than the increase for first period income:

$$\left| \frac{1}{Y_2^H - I_{c1}^{p_2,M} - I_{c2}^{p_1,M}} - \frac{1}{Y_2^M - I_{c1}^{p_2,M} - I_{c2}^{p_1,M}} \right| > \left| \frac{1}{Y_1^H - I_{c1}^{p_1,M}} - \frac{1}{Y_1^M - I_{c1}^{p_1,M}} \right| \tag{11}$$

implying that an increase in total investment for a shock in period 2 is always higher than for a shock in period 1. We also have that $\frac{\partial I^{p_1,j_{c2}}}{\partial Y_2} > \frac{\partial I^{p_1,j_{c1}}}{\partial Y_1}$, leading to $\frac{\partial I^{p_2,j_{c2}}}{\partial Y_2} > \frac{\partial I^{p_2,j_{c1}}}{\partial Y_1}$ since $\frac{\partial I_{c2}^{p_2,j}}{\partial I_{c2}^{p_1,j}} = \frac{\partial I_{c1}^{p_2,j}}{\partial I_{c1}^{p_1,j}}$.

Proof Proposition 2 The effect of an increase in investment in the first child on the second child investment are given by:

$$\begin{aligned} \frac{\partial I_{c2}^{p_1,j}}{\partial Y_1} &= -\frac{\frac{\partial U^P}{\partial I_{c1}^{p_2,j}} \frac{\partial I_{c1}^{p_2,j}}{\partial Y_1}}{\frac{\partial U^P}{\partial I_{c2}^{p_1,j}}} = -\frac{h_{c2}}{(Y_2^k - I_{c1}^{p_2,k} - I_{c2}^{p_1,k}) I_{c2}^{p_1,k}} \frac{\partial I_{c1}^{p_2,j}}{\partial Y_1} < 0 \\ \frac{\partial I_{c2}^{p_2,j}}{\partial Y_1} &= \frac{\partial I^{p_2,j}}{\partial I^{p_1,j}} \frac{\partial I_{c2}^{p_1,j}}{\partial Y_1} \frac{\partial I^{p_1,j}}{\partial Y_2} = \frac{\partial I^{p_2,j}}{\partial I^{p_1,j}} \frac{\partial I_{c2}^{p_1,j}}{\partial Y_1} \frac{h_{c2}}{(Y_2^k - I_{c1}^{p_2,k} - I_{c2}^{p_1,k}) \partial I^{p_2,j}} < 0 \end{aligned} \tag{12}$$

B Additional data description

B.1 DHS data

DHS data, child level and adult level

Table A.1: Country-level statistics

Country	Waves	# households	(with children)	# children	(0-5 years)	Country	Waves	# households	(with children)	# children	(0-5 years)
Albania	1	7584	4817	12766	1616	Kenya	3	53112	37838	134537	37744
Angola	1	11561	8070	25261	10781	Kyrgystan	1	8208	5555	16024	4312
Armenia	2	12038	7862	17195	3183	Lesotho	3	21340	14231	39872	10585
Bangladesh	4	68685	61394	185466	36487	Liberia	4	64102	49409	181217	55854
Benin	3	41752	31460	124036	35363	Madagascar	4	61959	37678	97912	43887
Bolivia	1	16939	11720	41061	8809	Malawi	4	78303	59775	223506	65202
Burkina Faso	4	50474	36760	151157	47044	Mali	4	55318	43583	186154	59017
Burundi	1	14538	8864	30528	12244	Moldova	1	7440	4948	9903	1552
Cambodia	3	68506	44036	151348	32303	Morocco	1	16798	8660	32494	6180
Cameroon	3	29953	21350	88469	25719	Mozambique	2	24957	10624	41930	12931
Central African Republic	1	5884	4388	17591	4995	Myanmar	1	12885	7796	22989	4815
Chad	1	17719	14156	71929	20117	Namibia	3	26577	17748	53779	14809
Colombia	1	38718	25373	62368	11608	Niger	2	14080	10989	56971	19811
Comoros	1	5329	2934	11497	3150	Nigeria	4	103112	71622	310240	91164
Congo Democratic Republic	2	28822	20046	87271	28102	Pakistan	1	10023	8670	38545	9053
Cote d'Ivoire	2	21199	15444	65203	19163	Peru	3	83850	57440	184627	37373
Dominican Republic	2	38274	27454	80764	15884	Philippines	2	27227	17315	58683	13661
Egypt	5	107138	94688	340930	77754	Rwanda	3	45802	28824	111245	30988
Ethiopia	3	61635	40037	169250	42701	Senegal	4	73270	49156	206024	58933
Gabon	1	8422	6383	23457	6211	Sierra Leone	2	24032	18185	69711	18054
Ghana	6	34558	23203	85272	26199	Swaziland	1	4987	3488	11874	2952
Guatemala	1	25914	17178	55970	12644	Tajikistan	1	9656	6172	19938	5013
Guinea	3	23849	18520	81895	21617	Tanzania	4	75593	32524	121377	39855
Guyana	1	4996	3484	10929	2178	Timor-Leste	1	13137	7969	35998	9806
Haiti	3	35203	21348	79181	19686	Togo	3	21409	15746	65357	18452
Honduras	1	22757	15854	49674	10970	Uganda	3	55648	23377	99994	32556
Indonesia	2	58609	11569	35207	6859	Zambia	2	23557	17790	76128	22453
Jordan	3	28234	25636	110697	26768	Zimbabwe	4	33940	24062	76450	22042

Source: Authors' computations from DHS data.

B.2 Agricultural specialization and producer prices

Price data, GAEZ and M3crop data

B.3 Other data

Rainfall, conflict, mining prices, etc.

B.4 Extended sample statistics

Sample statistics including control/secondary variables

B.5 Data description: figures

Figure A.1: Percent change in child health inequality (2010s - 1990s)

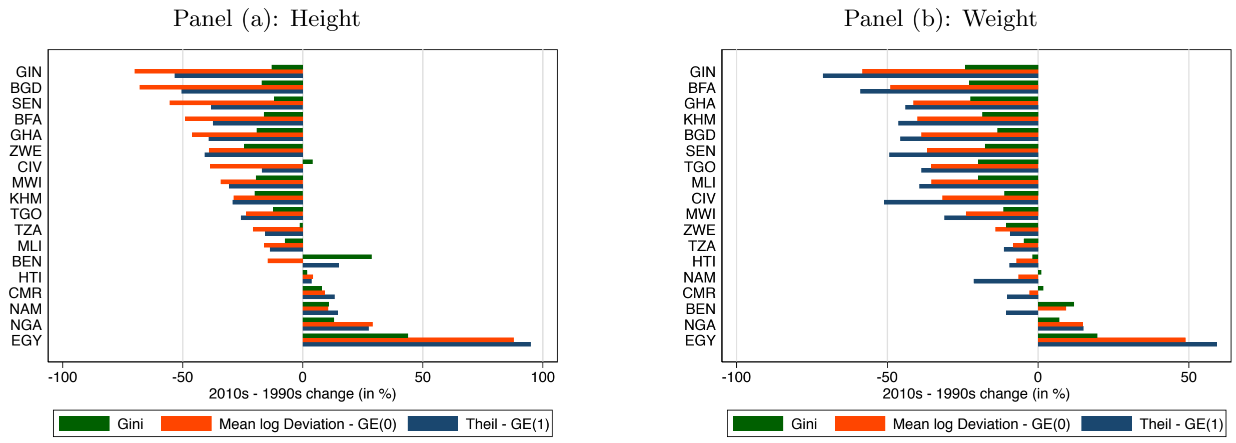


Figure A.2: Percent change in child health inequality within and between households (2010s - 1990s) – Mean log deviation (GE(0))

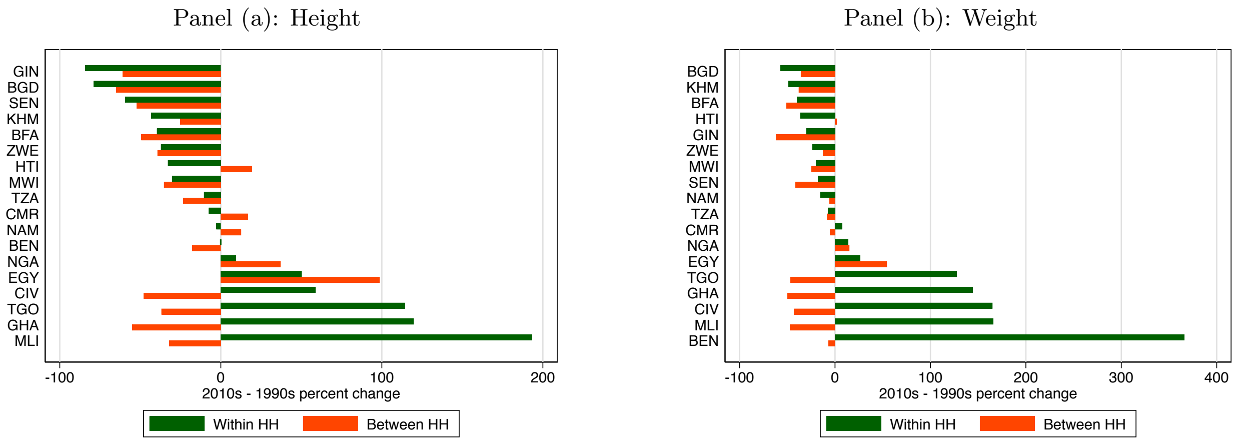


Figure A.3: Location of DHS households

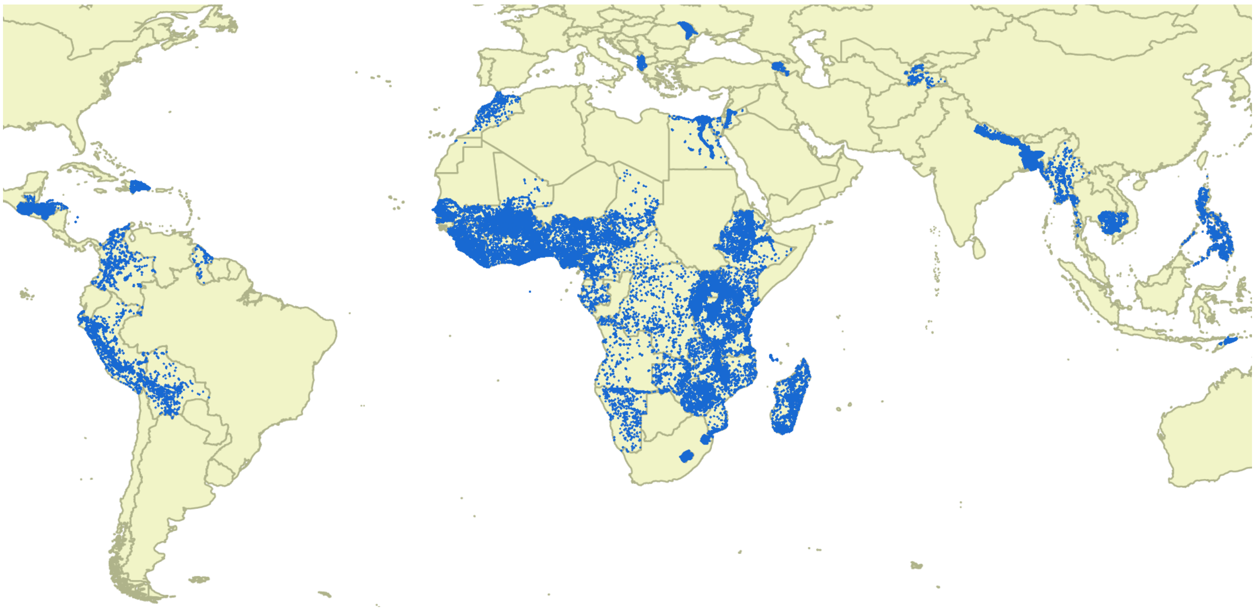
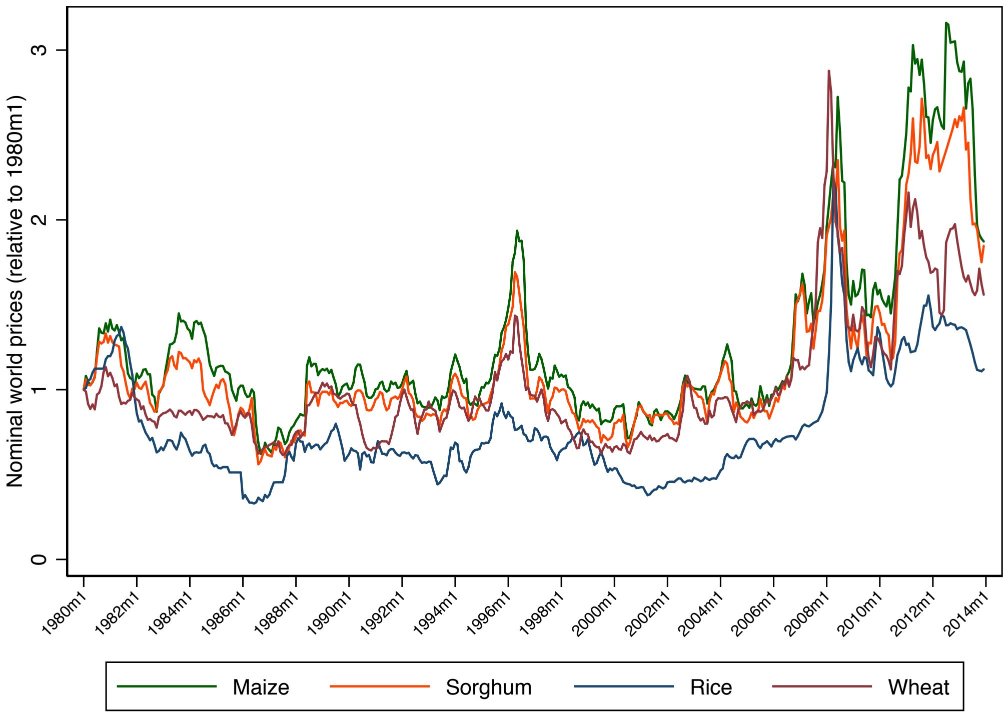


Figure A.4: World prices of the most produced crops



B.6 Inequality: descriptive statistics

Table A.2: Inequality, descriptive statistics

	Obs.	Mean	S.D.	1^{st} Quartile	Median	3^{rd} Quartile
Height:						
Δ log GE(0)	4894	-0.079	1.50	-0.66	-0.086	0.50
Δ log GE(0) Within	4540	-0.087	1.78	-0.98	-0.090	0.80
Δ log GE(0) Between	4885	-0.065	1.59	-0.66	-0.088	0.53
Δ log GE(1)	4891	-0.077	1.27	-0.65	-0.087	0.49
Δ log GE(1) Within	4540	-0.080	1.78	-0.97	-0.088	0.80
Δ log GE(1) Between	4881	-0.070	1.32	-0.65	-0.088	0.53
Weight:						
Δ log GE(0)	4891	-0.059	1.27	-0.61	-0.049	0.51
Δ log GE(0) Within	4540	-0.052	1.69	-0.91	-0.067	0.79
Δ log GE(0) Between	4882	-0.061	1.40	-0.63	-0.051	0.53
Δ log GE(1)	4888	-0.057	1.06	-0.65	-0.047	0.54
Δ log GE(1) Within	4540	-0.052	1.78	-0.99	-0.052	0.85
Δ log GE(1) Between	4880	-0.052	1.30	-0.66	-0.049	0.56
Covariates:						
Δ ln crop price (absolute value)	4952	0.34	0.19	0.20	0.33	0.46
Δ Age (in months)	4952	1.53	12.3	-2.29	0.51	3.43
Δ Gender	4952	-0.00036	0.15	-0.077	0.00021	0.077
Δ Twin	4952	0.0023	0.098	-0.024	0	0.033

Source: Authors' computations from DHS on the estimation sample. GE(0) is the mean log deviation, and GE(1) is the Theil index. See main text for data sources.

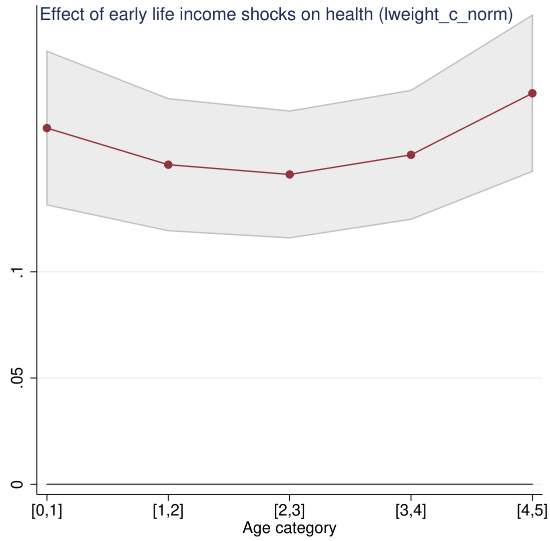
C Additional results

C.1 Child health and health investment: additional figures

Figure A.5: Exposure to world crop prices on health over the age profile (continuous health measures)

(a) log height

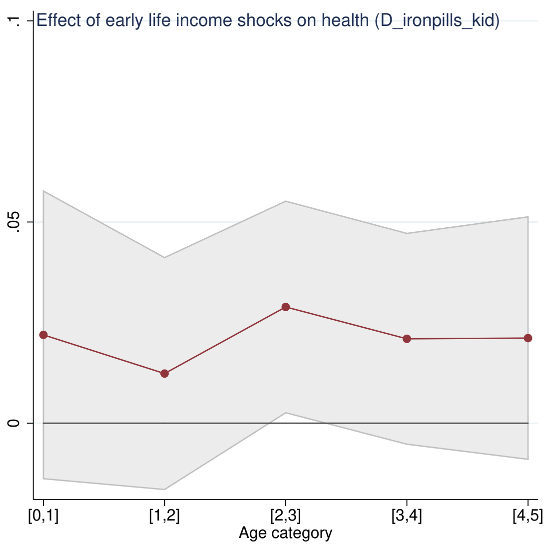
(b) log weight



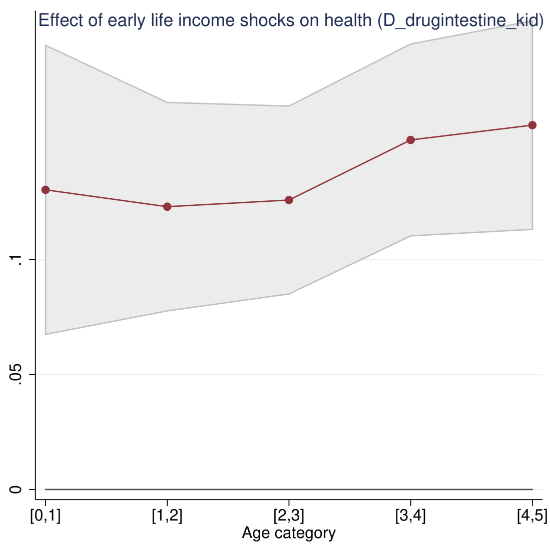
Source: These figures report the coefficient on the ln crop price variables price, split by child age in years, based on the estimation of equation (3). Shaded areas are 90% confidence bands.

Figure A.6: Exposure to world crop prices on health investment over the age profile

(a) Iron pills



(b) Deworming



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

C.2 Robustness: full sequence of prices

Price are persistent over time. This persistence is an issue in our case, as it implies that we might be capturing the effect of prices in subsequent years on subsequent health and not the effect of early life prices on subsequent health. To solve this problem, we can include the full sequence of prices in our estimations, i.e. control for the prices observed when the child is 2, 3 or 4 years old. Equation (2) becomes:

$$Y_c = \alpha \log \overline{P}_{c,k} + \sum_{a=2}^{4} [\beta_1^a \log \overline{\mathrm{P}}_k^a + \beta_2^a \ln \overline{\mathrm{P}}_k^a \times I_k^a] + \mathbf{D_c'}\delta + \mu_H + \gamma_{i,t} + \nu_m + \varepsilon_c \tag{13}$$

Equation (13) includes the full sequence of prices $\overline{\mathrm{P}}_k^a$ for children in their second, third and fourth years. Because not all children reached that age, we interact $\overline{\mathrm{P}}_k^a$ with an indicator variable which equal 1 if child k is aged a or more. The set of coefficient β_2^a represents effect of prices variations in later life. β_1^a, on the other hand, should generally be insignificant.

The results on health are shown in Table A.3. Four elements are worth mentioning. First, prices during pregnancy and first year remain significant, which means we were not picking up the effect of price persistence. Second, prices during pregnancy and in the first year have quantitatively similar effects. Third, prices in later years, while being generally significant, have a quantitatively much more limited impact on health indicators. Fourth, the non interacted prices are in most cases insignificant, which is in line with expectations.

Finally, in Figures A.7 to A.9 we show that the results on the effect of early life price variations on health and health investment over time are robust to the inclusion of the full sequence of prices.

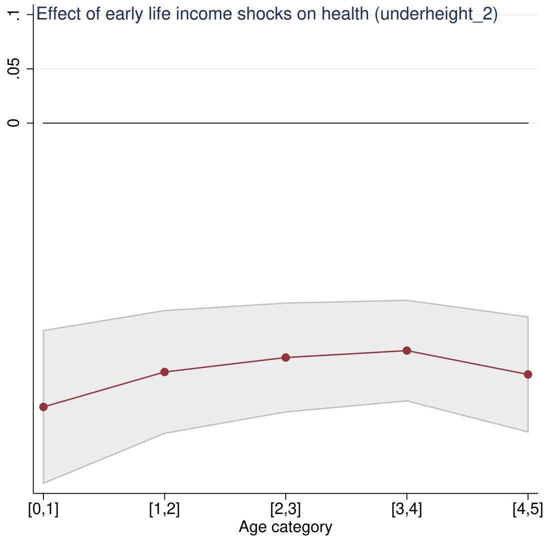
Table A.3: Exposure to world crop prices on health – By year of the price shock

	(1)	(2)	(3)	(4)
Dep. var.	Underheight	Underweight	ln height	ln weight
Prices observed before time of the survey:				
ln crop price (pregnancy)	-0.102[a]	-0.088[a]	0.028[a]	0.079[a]
	(0.022)	(0.014)	(0.008)	(0.019)
ln crop price year 1	-0.129[a]	-0.073[a]	0.056[a]	0.096[a]
	(0.021)	(0.014)	(0.007)	(0.016)
ln crop price year 2 × age ≥ 1	-0.065[a]	-0.023[b]	0.003	-0.030[b]
	(0.015)	(0.010)	(0.006)	(0.015)
ln crop price year 3 × age ≥ 2	-0.082[a]	-0.021[b]	0.016[a]	0.004
	(0.016)	(0.010)	(0.004)	(0.010)
ln crop price year 4 × age ≥ 3	-0.039[b]	-0.019[c]	0.002	0.011
	(0.016)	(0.010)	(0.005)	(0.012)
ln crop price year 2	-0.002	-0.022	0.016	0.086[a]
	(0.027)	(0.018)	(0.010)	(0.026)
ln crop price year 3	0.016	0.017	0.001	0.045[b]
	(0.024)	(0.015)	(0.008)	(0.019)
ln crop price year 4	0.012	-0.028[b]	0.007	0.037[b]
	(0.017)	(0.013)	(0.006)	(0.015)
Observations	362523	362523	348272	353350
R^2	0.668	0.686	0.723	0.732
Child controls	Yes	Yes	Yes	Yes
Household (mother) FE	Yes	Yes	Yes	Yes

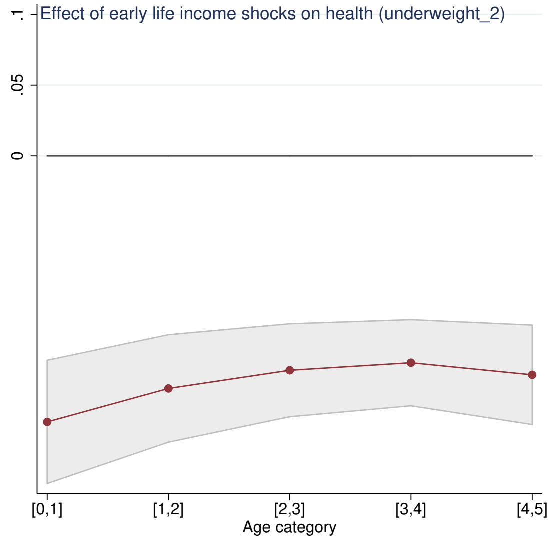
[c] significant at 10%; [b] significant at 5%; [a] significant at 1%. OLS estimations. The unit of observation is a child. Standard errors clustered at the cell level in parentheses. All estimations include country × year and month dummies. Child controls include: gender, birth order, twin dummy, and age dummies (one for each year). 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. 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. Age refers to the age of the child (in years) at the time of the survey – e.g., "age≥1" includes all children that are 1 or older at the time of the survey (i.e., they are in their second year of life).

Figure A.7: Exposure to world crop prices and child health over time (full price sequence)

(a) Underheight



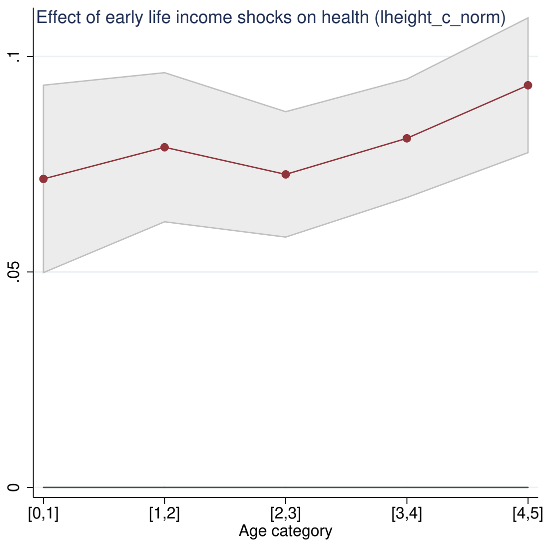
(b) Underweight



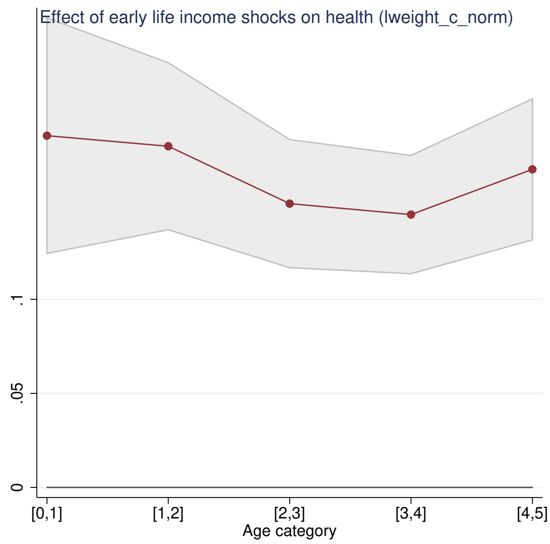
Source: These figures report the coefficient on the ln crop price variables price, split by child age in years, based on the estimation of equation (3), but including the full sequence of later life prices are in equation 13. Shaded areas are 90% confidence bands.

Figure A.8: Exposure to world crop prices on health over the age profile (continuous health measures, full price sequence)

(a) log height



(b) log weight

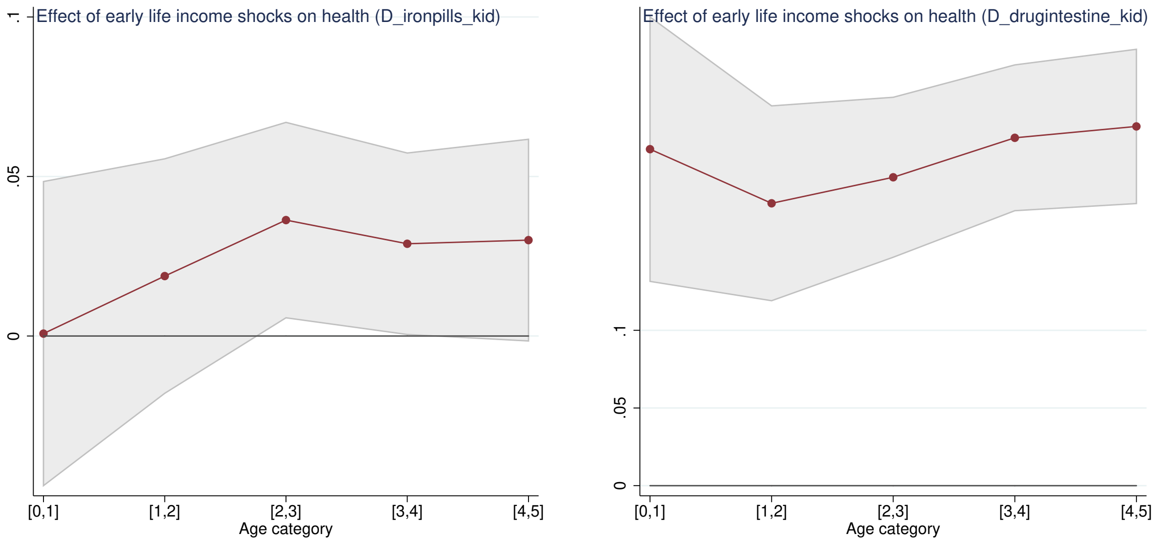


Source: These figures report the coefficient on the ln crop price variables price, split by child age in years, based on the estimation of equation (3), but including the full sequence of later life prices are in equation 13. Shaded areas are 90% confidence bands.

Figure A.9: Exposure to world crop prices on health investment over the age profile (full price sequence)

(a) Iron pills

(b) Deworming



Source: These figures report the coefficient on the ln crop price variables price, split by child age in years, based on the estimation of equation (3), but including the full sequence of later life prices are in equation 13. Shaded areas are 90% confidence bands.

C.3 Time-varying controls

In this section we add to our baseline estimations a number of time-varying, cell-specific controls that might correlate with crop prices: prices of minerals produced in the regions (as computed by Berman *et al.*, 2017); the occurrence of conflict events from UCDP-GED; rainfall. All variable are taken during pregnancy and first year of life.

Table A.4: Exposure to world crop prices on mortality and health – Cell-level controls

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. var.	Underheight	Underweight	ln height	ln weight	Death	
					At birth	1^{st} year
Panel A						
ln crop price	-0.207^a	-0.165^a	0.071^a	0.141^a	-0.008^c	-0.019^b
	(0.026)	(0.017)	(0.008)	(0.019)	(0.004)	(0.008)
Observations	351375	351375	340053	345017	738107	738140
R^2	0.668	0.663	0.741	0.742	0.525	0.537
Child controls	Yes	Yes	Yes	Yes	Yes	Yes
Household (mother) FE	Yes	Yes	Yes	Yes	Yes	Yes

^{c} 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, rainfall, and the incidence of conflicts at the cell level (all during the same period as crop price, ie. in utero and first year of life). 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 A.5: Exposure to world crop prices on health investments – Cell-level controls

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dep. var.	Breast.	– Vaccins (# doses) –				Other investments	
		Polio	DPT	BCG	Measles	Iron	Deworm
ln crop price	0.314^a	0.443^a	0.435^a	0.086^a	0.195^a	0.026^c	0.195^a
	(0.021)	(0.066)	(0.060)	(0.016)	(0.030)	(0.015)	(0.024)
Observations	603751	430348	501213	507126	499335	303999	328971
R^2	0.747	0.819	0.827	0.811	0.803	0.826	0.829
Child controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household (mother) FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

^{c} significant at 10%; ^{b} significant at 5%; ^{a} significant at 1%. OLS estimations. All estimations include country × year and month dummies, and time-varying controls for exposure to world prices of minerals, rainfall, and the incidence of conflicts at the cell level (all during the same period as crop price, ie. in utero and first year of life). In the first column the dependent variable takes the value 1 is the child has been breastfed for at least 6 months, 0 otherwise. In the next two columns the dependent variables are the number of doses taken by the child of Polio (max. 4 doses), and DPT (max. 3 doses). In columns (4) to (7) the dependent variables are dummies taking the value 1 if the child has taken all required doses of particular vaccines (Measles and DPT), iron pills, and deworming drugs (these last two during the three months preceding the survey).

C.4 Cash vs food crops

Table A.6: Exposure to world crop prices on mortality and health – 'Cash' vs. 'food' crops

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. var.	Underheight	Underweight	ln height	ln weight	—— Death ——	
					At birth	1^{st} year
ln crop price (food)	-0.245^{a}	-0.189^{a}	0.078^{a}	0.131^{a}	-0.009^{c}	-0.025^{a}
	(0.029)	(0.019)	(0.009)	(0.023)	(0.005)	(0.009)
ln crop price (cash)	-0.116^{c}	-0.136^{a}	0.051^{a}	0.146^{a}	-0.013	-0.013
	(0.060)	(0.046)	(0.018)	(0.049)	(0.010)	(0.017)
Observations	350150	350150	336094	340987	749313	749313
R^2	0.677	0.689	0.738	0.739	0.522	0.533
Child controls	Yes	Yes	Yes	Yes	Yes	Yes
Household (mother) FE	Yes	Yes	Yes	Yes	Yes	Yes

^{c} 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. Child controls include: gender, birth order, twin dummy, and age in month. 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 A.7: Exposure to world crop prices on health investments – 'Cash' vs. 'food' crops

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dep. var.	Breast.	– Vaccins (# doses) –				Other investments	
		Polio	DPT	BCG	Measles	Iron	Deworm
ln crop price (food)	0.362^{a}	0.492^{a}	0.641^{a}	0.116^{a}	0.286^{a}	0.019	0.283^{a}
	(0.024)	(0.081)	(0.076)	(0.019)	(0.040)	(0.019)	(0.030)
ln crop price (cash)	0.404^{a}	0.354^{b}	0.117	0.063	0.102^{c}	0.047	-0.173^{a}
	(0.043)	(0.160)	(0.133)	(0.043)	(0.058)	(0.036)	(0.063)
Observations	606419	419189	502556	508483	500456	298381	323256
R^2	0.747	0.819	0.826	0.810	0.801	0.827	0.829
Child controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household (mother) FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

^{c} significant at 10%; ^{b} significant at 5%; ^{a} significant at 1%. OLS estimations. In the first column the dependent variable takes the value 1 is the child has been breastfed for at least 6 months, 0 otherwise. In the next two columns the dependent variables are the number of doses taken by the child of Polio (max. 4 doses), and DPT (max. 3 doses). In columns (4) to (7) the dependent variables are dummies taking the value 1 if the child has taken all required doses of particular vaccines (Measles and DPT), iron pills, and deworming drugs (these last two during the three months preceding the survey).

C.5 Alternative agricultural specialization measure

Table A.8: Exposure to world crop prices on mortality and health – M3 crop data

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. var.	Underheight	Underweight	ln height	ln weight	—— Death ——	
					At birth	1^{st} year
ln crop price	-0.107^a	-0.094^a	0.035^a	0.052^a	-0.002	-0.007
	(0.018)	(0.012)	(0.005)	(0.013)	(0.003)	(0.005)
Observations	380015	380015	365673	370850	783023	783023
R^2	0.674	0.687	0.736	0.741	0.522	0.533
Child controls	Yes	Yes	Yes	Yes	Yes	Yes
Household (mother) FE	Yes	Yes	Yes	Yes	Yes	Yes

^{c} 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. Child controls include: gender, birth order, twin dummy, and age in month. 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 A.9: Exposure to world crop prices on health investments – M3 crop data

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dep. var.	Breast.	– Vaccins (# doses) –				Other investments	
		Polio	DPT	BCG	Measles	Iron	Deworm
ln crop price	0.208^a	0.317^a	0.376^a	0.052^a	0.145^a	0.011	0.102^a
	(0.015)	(0.048)	(0.045)	(0.012)	(0.023)	(0.011)	(0.018)
Observations	641273	437280	535936	542412	534274	301482	326530
R^2	0.742	0.820	0.825	0.808	0.799	0.825	0.829
Child controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household (mother) FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

^{c} significant at 10%; ^{b} significant at 5%; ^{a} significant at 1%. OLS estimations. In the first column the dependent variable takes the value 1 is the child has been breastfed for at least 6 months, 0 otherwise. In the next two columns the dependent variables are the number of doses taken by the child of Polio (max. 4 doses), and DPT (max. 3 doses). In columns (4) to (7) the dependent variables are dummies taking the value 1 if the child has taken all required doses of particular vaccines (Measles and DPT), iron pills, and deworming drugs (these last two during the three months preceding the survey).

C.6 Migration

Table A.10: Exposure to world crop prices on mortality and health – Excluding migrants

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. var.	Underheight	Underweight	ln height	ln weight	—— Death ——	
					At birth	1^{st} year
ln crop price	-0.191[a]	-0.189[a]	0.086[a]	0.176[a]	-0.005	-0.025[b]
	(0.035)	(0.024)	(0.010)	(0.028)	(0.007)	(0.012)
Observations	183966	183966	174001	176485	350444	350444
R^2	0.689	0.723	0.746	0.744	0.524	0.535
Child controls	Yes	Yes	Yes	Yes	Yes	Yes
Household (mother) FE	Yes	Yes	Yes	Yes	Yes	Yes

[c] 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. Child controls include: gender, birth order, twin dummy, and age in month. 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 A.11: Exposure to world crop prices on health investments – Excluding migrants

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dep. var.	Breast.	– Vaccins (# doses) –				Other investments	
		Polio	DPT	BCG	Measles	Iron	Deworm
ln crop price	0.150[a]	0.195[b]	0.319[a]	0.003	-0.017	0.021	0.040
	(0.029)	(0.093)	(0.081)	(0.020)	(0.035)	(0.030)	(0.037)
Observations	532482	365742	464692	467672	463654	158254	186113
R^2	0.399	0.336	0.398	0.315	0.419	0.175	0.307
Child controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mother FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

[c] significant at 10%; [b] significant at 5%; [a] significant at 1%. OLS estimations. In the first column the dependent variable takes the value 1 is the child has been breastfed for at least 6 months, 0 otherwise. In the next two columns the dependent variables are the number of doses taken by the child of Polio (max. 4 doses), and DPT (max. 3 doses). In columns (4) to (7) the dependent variables are dummies taking the value 1 if the child has taken all required doses of particular vaccines (Measles and DPT), iron pills, and deworming drugs (these last two during the three months preceding the survey).

C.7 Rural sample

Table A.12: Exposure to world crop prices on mortality and health – Rural sample

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. var.	Underheight	Underweight	ln height	ln weight	—— Death ——	
					At birth	1^{st} year
ln crop price	-0.186[a]	-0.183[a]	0.061[a]	0.112[a]	-0.012[b]	-0.024[a]
	(0.029)	(0.019)	(0.008)	(0.021)	(0.005)	(0.009)
Observations	272093	272093	262065	265094	580546	580546
R^2	0.675	0.683	0.740	0.737	0.521	0.532
Child controls	Yes	Yes	Yes	Yes	Yes	Yes
Household (mother) FE	Yes	Yes	Yes	Yes	Yes	Yes

[c] 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. Child controls include: gender, birth order, twin dummy, and age in month. 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 A.13: Exposure to world crop prices on health investments – Rural sample

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dep. var.	Breast.	– Vaccins (# doses) –				Other investments	
		Polio	DPT	BCG	Measles	Iron	Deworm
ln crop price	0.282[a]	0.472[a]	0.516[a]	0.068[a]	0.170[a]	0.089[a]	0.256[a]
	(0.017)	(0.065)	(0.051)	(0.014)	(0.021)	(0.017)	(0.021)
Observations	754778	561668	672949	678205	671146	380278	427086
R^2	0.440	0.350	0.408	0.332	0.409	0.148	0.303
Child controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mother FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

[c] significant at 10%; [b] significant at 5%; [a] significant at 1%. OLS estimations. In the first column the dependent variable takes the value 1 is the child has been breastfed for at least 6 months, 0 otherwise. In the next two columns the dependent variables are the number of doses taken by the child of Polio (max. 4 doses), and DPT (max. 3 doses). In columns (4) to (7) the dependent variables are dummies taking the value 1 if the child has taken all required doses of particular vaccines (Measles and DPT), iron pills, and deworming drugs (these last two during the three months preceding the survey).

C.8 Conley standard errors

TBC

C.9 Child mortality and selection bias

Our results show a small but at times statistically significant effect of early life crop price variations on mortality at birth and in the first year of life. In this section we examine whether this selective mortality affects our baseline results on child health and parental investments in child health. We perform two different tests, which both suggest that such selection bias is unlikely to be driving our findings.

First, we estimate our baseline specifications (2) and (4) on sub-samples defined according to the survival probability. This is an application of the "identification-at-infinity" method (Chamberlain, 1986; Mulligan and Rubinstein, 2008). The general idea is to restrict the estimation sample to children that are most likely to survive, the selection bias being lower for children with high survival probability. As a first step, we estimate the following equation:

$$\text{Alive}_c = \alpha \log \overline{P}_{c,k} + \mathbf{D_c'}\delta + \mu_H + \gamma_{i,t} + \nu_m + \varepsilon_c \quad (14)$$

where Alive_c is a dummy taking the value 1 if the child is alive at the time of the survey, and the others terms have been defined in section 4.1. Based on the predictions from the estimation of 14, we allocate children in 5 bins of survival probability and estimate (2) and (4) on sub-samples that include only children above the 20th, 40th, 60th and 80th percentiles of survival probability. The results depicted graphically in Figures A.10 and A.11 below. As we move toward the right along the x-axis, the sample gets more and more restricted to children with high predicted survival probability, i.e. we progressively drop the quintiles of observations with the highest exit probabilities from the sample. Accordingly, the fifth point estimate only includes the quintiles of observations with the lowest exit probabilities (i.e. the highest survival probability). If selective mortality were driving our results, we would expect the patterns depicted in Figures A.10 and A.11 to substantially differ across samples. On the contrary, the coefficients are generally stable, except in Figure A.10.d , where the coefficients are very imprecisely estimated.

These results suggest that selective mortality does not bias our results. We can go further and try to account for a potential selection bias by including a correction term in our estimations. Given the structure of our selection equation (which includes two high dimensional sets of fixed effects, we cannot use probit or other maximum likelihood estimators to implement a standard Heckman procedure. The variables being the same in our baseline equations and in the selection equation, we have to rely on some nonlinear transformation of the predicted probabilities to correct for selection. We first follow Cosslett (1991), who proposes a semi-parametric estimator in which the selection correction is approximated through indicator variables computed from the predictions obtained from equation (14). In Tables **??** and A.15, we include in our baseline specifications 100 bins corresponding to each centile of the predicted survival probabilities as correction terms. Alternatively, in Tables **??** and A.15the predicted probability of exit is introduced directly when estimating equation (2) and (4) in the form of a 10 degree polynomial. In all cases, the results are very close from the benchmark ones.

Table A.14: Crop prices and child health: selection on mortality

	(1)	(2)	(3)	(4)
Dep. var.	Underheight	Underweight	ln height	ln weight
Panel A (bins)				
ln crop price	-0.207[a]	-0.153[a]	0.069[a]	0.133[a]
	(0.026)	(0.017)	(0.008)	(0.019)
Observations	325272	325272	316377	321183
R^2	0.630	0.601	0.717	0.726
Child controls	Yes	Yes	Yes	Yes
Household (mother) FE	Yes	Yes	Yes	Yes
Panel B (polynomials				
ln crop price	-0.207[a]	-0.153[a]	0.069[a]	0.133[a]
	(0.026)	(0.017)	(0.008)	(0.019)
Observations	325272	325272	316377	321183
R^2	0.630	0.601	0.717	0.726
Child controls	Yes	Yes	Yes	Yes
Household (mother) FE	Yes	Yes	Yes	Yes

[c] 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. Child controls include: gender, birth order, twin dummy, and age in month. Household controls include: mother's age and age square, education dummies, rural/urban dummy. 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. 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. Death is a dummy which equals 1 if the child dies at birth (col. 5) or in her/his first year (col. 6), 0 otherwise. The estimations in Panel A include as correction terms 100 bins corresponding to each centile of the predicted survival probabilities, estimated from equation (14). The estimations of Panel B include directly the predicted survival probability in the form of a 10 degree polynomial.

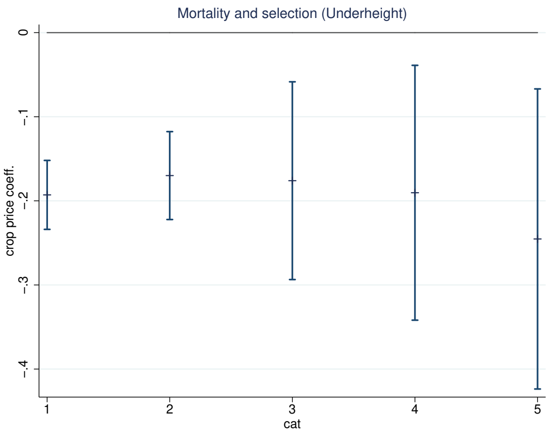
Table A.15: Crop prices and health investments: selection on mortality

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dep. var.	Breast.	– Vaccins (# doses) –				Other investments	
		Polio	DPT	BCG	Measles	Iron	Deworm
Panel A (bins)							
ln crop price	0.331^a	0.450^a	0.498^a	0.096^a	0.230^a	0.029^c	0.195^a
	(0.020)	(0.066)	(0.061)	(0.016)	(0.031)	(0.015)	(0.024)
Observations	633666	434806	527134	533398	525223	303999	328971
R^2	0.744	0.820	0.826	0.809	0.800	0.826	0.829
Child controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Mother FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Panel B (polynomials							
ln crop price	0.298^a	0.498^a	0.518^a	0.068^a	0.177^a	0.096^a	0.238^a
	(0.019)	(0.068)	(0.055)	(0.015)	(0.027)	(0.017)	(0.024)
Observations	633642	434782	527110	533374	525199	303981	328955
R^2	0.425	0.338	0.397	0.321	0.408	0.152	0.299
Child controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Household controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cell FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

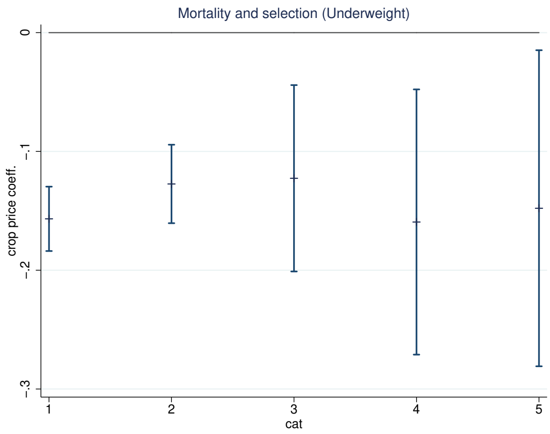
^{c} significant at 10%; ^{b} significant at 5%; ^{a} significant at 1%. OLS estimations. In the first column the dependent variable takes the value 1 is the child has been breastfed for at least 6 months, 0 otherwise. In the next two columns the dependent variables are the number of doses taken by the child of Polio (max. 4 doses), and DPT (max. 3 doses). In columns (4) to (7) the dependent variables are dummies taking the value 1 if the child has taken all required doses of particular vaccines (Measles and DPT), iron pills, and deworming drugs (these last two during the three months preceding the survey). The estimations in Panel A include as correction terms 100 bins corresponding to each centile of the predicted survival probabilities, estimated from equation (14). The estimations of Panel B include directly the predicted survival probability in the form of a 10 degree polynomial.

Figure A.10: Selective mortality: sub-samples (1/2)

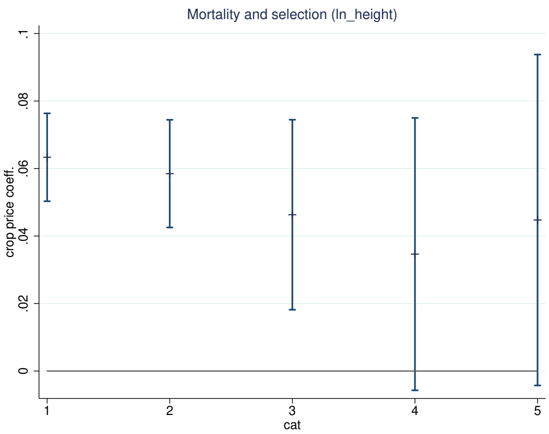
(a) Underheight



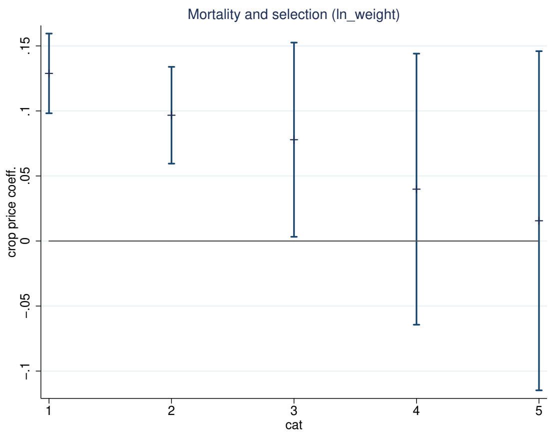
(b) Underweight



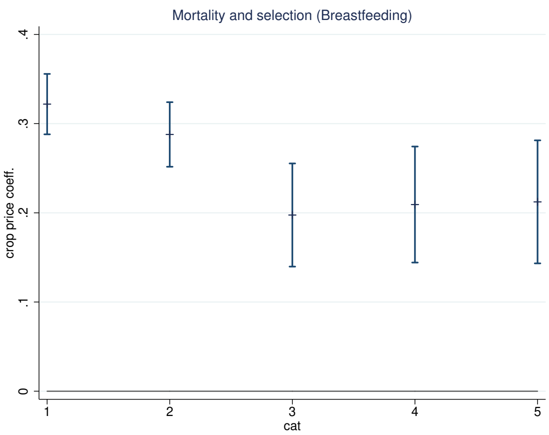
(c) ln height



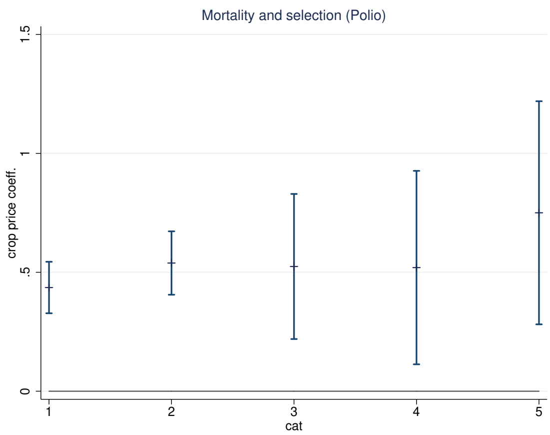
(d) ln weight



(f) Breastfeeding$> 6m$



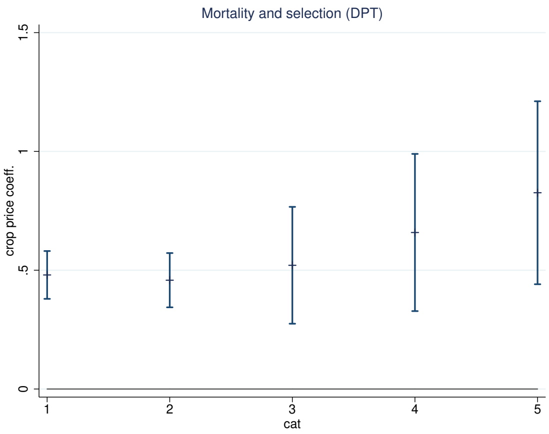
(f) # Polio vaccines



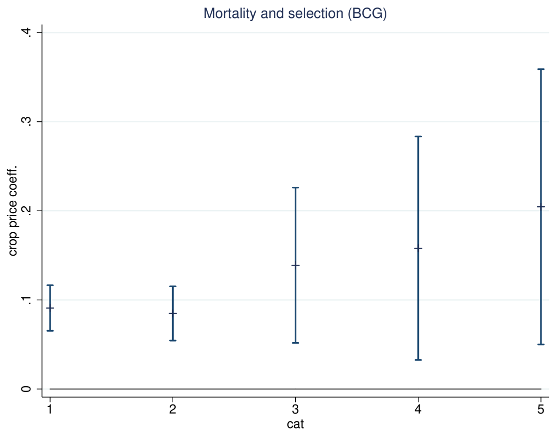
Note: These figures plot the coefficients and 90% confidence intervals obtained when equations (2) and (4) are estimated on subsamples defined according to the child-specific predicted survival probability. As we move toward the right along the x-axis, the sample gets more and more restricted to children with high predicted survival probability, i.e. we progressively drop the quintiles of observations with the highest exit probabilities from the sample. For instance, the fifth point estimate in each figure is from a regression that only includes the quintiles of observations with the lowest exit probabilities (i.e. the highest survival probability). Predicted survival probabilities are estimated from equation 14.

Figure A.11: Selective mortality: sub-samples (2/2)

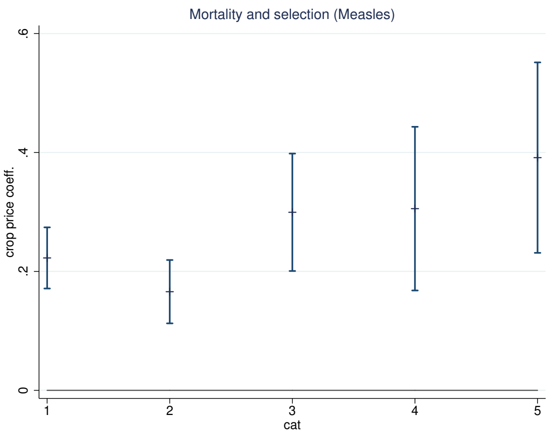
(a) # DPT vaccines



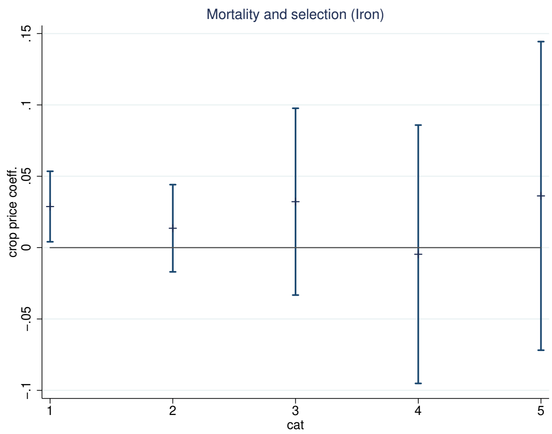
(b) BCG Vaccine



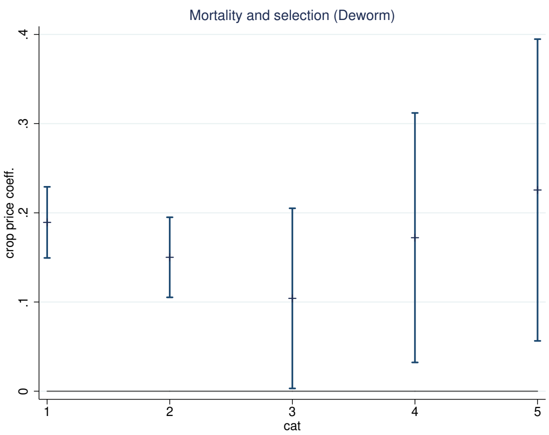
(c) Measles vaccine



(d) Iron pills last 3m



(f) Deworm last 3m



Note: These figures plot the coefficients and 90% confidence intervals obtained when equations (2) and (4) are estimated on subsamples defined according to the child-specific predicted survival probability. As we move toward the right along the x-axis, the sample gets more and more restricted to children with high predicted survival probability, i.e. we progressively drop the quintiles of observations with the highest exit probabilities from the sample. For instance, the fifth point estimate in each figure is from a regression that only includes the quintiles of observations with the lowest exit probabilities (i.e. the highest survival probability). Predicted survival probabilities are estimated from equation 14.