Early Health Shocks, Parental Responses, and Child Outcomes *

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Abstract

This paper studies how early health shocks affect child's human capital formation. We first formulate a theoretical model to understand how early health shocks affect child outcomes through parental responses. We nest a dynamic model of human capability formation into a standard intra-household resource allocation framework. By allowing multidimensionality of child endowments, we allow parents to compensate and reinforce along different dimensions. We then test our main empirical predictions using a large-scale Chinese child twins survey, which contains detailed information on child- and parent-specific expenditures. We can differentiate between investment in money and investment in time. On the one hand, we find evidence of compensating investment in child health but of reinforcing investment in education. On the other, we find no change in the time spent with the child. We confirm that an early health insult negatively affects the child under several different domains, ranging from later health, to cognition, to personality. We also show that early health shocks negatively affect parental expectations, but do not change the child's perceptions of parental behavior. This suggests that the effects of early health shocks mainly operate through the budget constraint, not through preferences.

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1 Introduction

The longlasting effects of early childhood conditions on a variety of adult outcomes have spanned a great deal of research by economists in the last decade. There is now consolidated evidence that an insult occurred early in life can have a causal adverse effect on many long-term outcomes. However, much less is known about the role of intervening inputs – in particular, parental responses – in reinforcing or mitigating the effects of preexisting conditions. What parents do to affect the life chances of their children is still not well understood. This paper is an attempt to advance this literature. We recognize the multidimensionality of human capital and move beyond the traditional assumption that parents can *either* compensate *or* reinforce. We formulate a novel theoretical model and provide empirical support to our predictions: parents adopt a strategy of compensating investment in child health but of reinforcing investment in education, in response to an early health shock.

The rest of the paper is organized as follows. The literatures our work refers to are briefly reviewed in section 2. Section 3 outlines our theoretical framework, and section 4 presents our econometric strategy. The data is described in section 5, and the results discussed in section 6. Section 7 concludes.

2 Literature Review

This paper combines two strands of literature: the burgeoning literature on the effects of early-life conditions on later-life outcomes, and the more consolidated literature on intrahousehold allocation of resources. By merging the two literatures through a dynamic model of human capability formation, we are able to model the mechanisms – parental responses – through which early-life conditions affect later-life outcomes under a variety of dimensions.

Understanding how parents allocate resources across children has been researched in economics since the seminal work of Becker and Tomes (1976) and Behrman, Pollak, and Taubman (1982). Since neither the wealth model nor the separable earnings-transfer model makes unequivocal predictions regarding parental investment strategies, whether parents exhibit a reinforcing, compensating or neutral behavior has been ultimately an empirical question. Most studies have found evidence of reinforcing behavior (see, for example, Rosenzweig and Schultz (1982), Behrman, Rosenzweig, and Taubman (1994) and Rosenzweig and Wolpin (1988)), while a few studies have found empirical support for a compensation strategy adopted by the parents (Pitt, Rosenzweig, and Hassan, 1990). This literature usually assumes the existence of only one dimension for parents to compensate or reinforce; moreover, it frequently uses measures of children's outcomes, such as educational attainment and test scores, to infer parental investments. We overcome both limitations in our present work.

The second strand of literature we refer to is that on the effect of early-life conditions on late-life circumstances (see (Case, Fertig, and Paxson, 2005), for example). This literature has achieved a consensus on the negative effect of an early-life health insult on both short- (Currie, Stabile, Manivong, and Roos, 2008) and long-run outcomes (Smith, 2009), however it has not considered the role played by parental behavior.

We join these two literatures using a dynamic model of human capability formation (Heckman, 2007), which links early endowments to late outcomes through both self-productivity processes and effects on parental investment behavior.

3 The Theoretic Model

In this section we extend the model of human capability formation developed in Heckman (2007) to a multiple sibling setting, and we nest it into a standard model of intrahousehold resource allocation (Becker and Tomes (1976) and Behrman, Pollak, and Taubman (1982)). By allowing multidimensionality of child endowments, we allow parents to compensate and reinforce along different dimensions. We show that an early health shock can affect child outcomes through two channels: a direct channel – the production of human capital – and an indirect one – the process of intrahousehold resource allocation.

3.1 The Production Technology

Each family has two children ($\iota = i, j$), and they are twins.[1] There are two periods of childhood ($t = 1, 2$). Each child has a bidimensional skill set: health (H) and other skills. The latter includes

[1] This assumption is dictated by the data we use in our empirical analysis. It is natural to extend the model to a general case with n children in the family. However, fertility and birth spacing may be endogenous to health conditions of existing children (Rosenzweig and Wolpin, 1988). We leave this extension to another occasion.

both cognitive and noncognitive skills, but we refer to it as cognitive skills (C) in the theoretical section for ease of notation.[2] We denote endowments and investments in each period respectively as $\theta^k_{\iota,t}$ and $I^k_{\iota,t}$, where $\iota = i, j$ indexes the child, $t = 0, 1, 2$ the time period (0 is birth), and $k = H, C$.[3] Following Heckman (2007), we write the production technologies and the investment functions for child i as:

$$\theta^H_{i,1} = f^H(\theta^H_{i,0}, \theta^C_{i,0}, I^H_{i,0}) + e^H_{i,1}, \tag{1}$$

$$\theta^C_{i,1} = f^C(\theta^H_{i,0}, \theta^C_{i,0}, I^C_{i,0}), \tag{2}$$

$$\theta^H_{i,2} = f^H(\theta^H_{i,1}, \theta^C_{i,1}, I^H_{i,1}), \tag{3}$$

$$\theta^C_{i,2} = f^C(\theta^H_{i,1}, \theta^C_{i,1}, I^C_{i,1}), \tag{4}$$

$$I^H_{i,1} = f^H(\theta^H_{i,1}, \theta^C_{i,1}, \theta^H_{j,1}, \theta^C_{j,1}), \tag{5}$$

$$I^C_{i,1} = f^C(\theta^H_{i,1}, \theta^C_{i,1}, \theta^H_{j,1}, \theta^C_{j,1}), \tag{6}$$

Our key assumption is that a health shock affecting child i in period 1 ($e^H_{i,1}$) only has a direct effect on her own health in the first period, while it affects second-period outcomes through two channels: the process of health and cognitive capital accumulation (3)-(4), and parental investments (5)-(6).[4] Notice in equations (1)-(4), we assume that children born in the same family share the same production technology, while we allow for the production technology of health to differ from that of cognitive skills. All functions are assumed to be continuously twice differentiable and quasi-concave.

We now analyze the different channels through which an early health shock to child i ($e^H_{i,1}$) operates. First, the total effect on child's i health in the second period can be decomposed as:

$$\frac{d\theta^H_{i,2}}{de^H_{i,1}} = \frac{\partial\theta^H_{i,2}}{\partial\theta^H_{i,1}} \cdot \frac{\partial\theta^H_{i,1}}{\partial e^H_{i,1}} + \frac{\partial\theta^H_{i,2}}{\partial I^H_{i,1}} \cdot \frac{\partial I^H_{i,1}}{\partial\theta^H_{i,1}} \cdot \frac{\partial\theta^H_{i,1}}{\partial e^H_{i,1}}, \tag{7}$$

where the first term is a direct self-productivity effect (Heckman, 2007), and we define the second term a resource reallocation effect (parents reallocate family resources in response to a health shock

[2] In our empirical analysis, we distinguish between cognitive and noncognitive skills.

[3] $I^k_{\iota,0}$ indicate nutrition intake in utero. Given that our empirical analysis focuses on twins, we are safely assuming that $I^k_{\iota,0} = I^k_{j,0}$ or $I^k_{\iota,0}$ is exogenous across twin siblings

[4] Of course a child can be hit by a health shock also in the second period. We assume that health shocks in the second period are serially uncorrelated with health shocks in the first period, conditioning on health in the first period. This assumption can be easily relaxed and it is dictated by the information that we have available in our data.

on child i). Second, the total effect of an early health shock to child i ($e^H_{i,1}$) on her own cognitive capacity in the second period can also be decomposed into two channels:

$$\frac{d\theta^C_{i,2}}{de^H_{i,1}} = \frac{\partial\theta^C_{i,2}}{\partial\theta^H_{i,1}} \cdot \frac{\partial\theta^H_{i,1}}{\partial e^H_{i,1}} + \frac{\partial\theta^C_{i,2}}{\partial I^C_{i,1}} \cdot \frac{\partial I^C_{i,1}}{\partial\theta^H_{i,1}} \cdot \frac{\partial\theta^H_{i,1}}{\partial e^H_{i,1}}, \tag{8}$$

where the first term is a cross-productivity effect (as shown in equation 4), and the second term is again an intrahousehold resource reallocation effect. Finally, an early health shock on child i will also affect child j's ($j \neq i$) health and cognitive skills, in both cases through the intrahousehold resources reallocation process. Specifically, the cross-effects of child i's health shock on child j's health and cognitive skills are:

$$\frac{d\theta^H_{j,2}}{de^H_{i,1}} = \frac{\partial\theta^H_{j,2}}{\partial I^H_{j,1}} \cdot \frac{\partial I^H_{j,1}}{\partial\theta^H_{i,1}} \cdot \frac{\partial\theta^H_{i,1}}{\partial e^H_{i,1}}, \tag{9}$$

$$\frac{d\theta^C_{j,2}}{de^H_{i,1}} = \frac{\partial\theta^C_{j,2}}{\partial I^C_{j,1}} \cdot \frac{\partial I^C_{j,1}}{\partial\theta^H_{i,1}} \cdot \frac{\partial\theta^H_{i,1}}{\partial e^H_{i,1}}. \tag{10}$$

Combining equations (7)-(10), we derive the net effect of an early health shock affecting child i on the twins health and cognitive capital as:

$$\frac{d\theta^H_{i,2}}{de^H_{i,1}} - \frac{d\theta^H_{j,2}}{de^H_{i,1}} = \frac{\partial\theta^H_{i,2}}{\partial\theta^H_{i,1}} \cdot \frac{\partial\theta^H_{i,1}}{\partial e^H_{i,1}} + \left(\frac{\partial\theta^H_{i,2}}{\partial I^H_{i,1}} \cdot \frac{\partial I^H_{i,1}}{\partial\theta^H_{i,1}} - \frac{\partial\theta^H_{j,2}}{\partial I^H_{j,1}} \cdot \frac{\partial I^H_{j,1}}{\partial\theta^H_{i,1}}\right) \cdot \frac{\partial\theta^H_{i,1}}{\partial e^H_{i,1}}, \tag{11}$$

$$\frac{d\theta^C_{i,2}}{de^H_{i,1}} - \frac{d\theta^C_{j,2}}{de^H_{i,1}} = \frac{\partial\theta^C_{i,2}}{\partial\theta^H_{i,1}} \cdot \frac{\partial\theta^H_{i,1}}{\partial e^H_{i,1}} + \left(\frac{\partial\theta^C_{i,2}}{\partial I^C_{i,1}} \cdot \frac{\partial I^C_{i,1}}{\partial\theta^H_{i,1}} - \frac{\partial\theta^C_{j,2}}{\partial I^C_{j,1}} \cdot \frac{\partial I^C_{j,1}}{\partial\theta^H_{i,1}}\right) \cdot \frac{\partial\theta^H_{i,1}}{\partial e^H_{i,1}}. \tag{12}$$

These equations clearly show the two channels through which early health shocks affect the distribution of health and cognitive capital within families. The first term on the right-hand side of both equations shows how an early health shock $e^H_{i,1}$ affects the health and cognitive capital of child i through self- and cross-productivity: this term is always negative. The second term shows how the early health shock operates through intrahousehold resource allocation. Since this process is affected by parental preferences, we now proceed to model parental responses in the next subsection.

3.2 Parental Preferences and Budget Constraint

We assume that parents are altruistic and care about both their own consumption and the quality of their children. Thus, parental preferences can be represented by a utility function of the following form:

$$W = W[c, V(\theta^H_{i,2}, \theta^C_{i,2}), V(\theta^H_{j,2}, \theta^C_{j,2})],$$

where c is parental consumption,[5] and $V(\theta^H_{\iota,2}, \theta^C_{\iota,2})$ is the child quality function ($\iota = i, j$). Notice both children have the same quality function but they may have different health and cognitive skills in the second period. The budget constraint is specified as:

$$p_c \cdot c + I^H_{i,1} + I^H_{j,1} + I^C_{i,1} + I^C_{j,1} = Y,$$

where p_c is the price of parental consumption, and the price of investment is normalized to one. We denote total resources allocated to children as:

$$Y^c = I^H_{i,1} + I^H_{j,1} + I^C_{i,1} + I^C_{j,1} \tag{13}$$

Following Behrman, Pollak, and Taubman (1982), we assume that the utility parents derive from children is separable from parental consumption, so that we can rewrite the utility function (3.2) as:

$$W = W\{c, U[V(\theta^H_{i,2}, \theta^C_{i,2}), V(\theta^H_{j,2}, \theta^C_{j,2})]\}, \tag{14}$$

The separability assumption is very convenient as it allows us to focus on the allocation of resources across children without considering its effects on parental consumption. Thus, we can restate the problem of parental investments in children as that of maximizing the following utility function:

$$U = U[V(\theta^H_{i,2}, \theta^C_{i,2}), V(\theta^H_{j,2}, \theta^C_{j,2})], \tag{15}$$

subject to the budget constraint (13), the production technologies of health and cognitive skills (1)-(4), and the quality function.

[5] We assume that children's consumption (excluding investments) is a basic need, and that parents allocate children's consumption resources identically across them. So we can ignore this term in the parental utility function.

3.3 Early Health Shocks and Parental Resource Reallocations

To derive the comparative static results of the effects of an early health shock on parental resource reallocations, we follow Behrman, Pollak, and Taubman (1982) and specify parental preference as a CES utility function[6]

$$U = \{[V(\theta^H_{i,2}, \theta^C_{i,2})]^\rho + [V(\theta^H_{j,2}, \theta^C_{j,2})]^\rho\}^{\frac{1}{\rho}}, \tag{16}$$

where $\rho < 1$. The nice feature of the CES representation of the parental utility function is that ρ measures the degree of parental inequality aversion across children. When $\rho < 0$, parents exhibit inequality aversion and so adopt a strategy to compensate for the negative effects of an early health shock. On the other hand, when $0 < \rho < 1$ parents do not exhibit inequality aversion, and so adopt a reinforcement strategy. Conceptually, the sign of ρ is determined by the tradeoff between efficiency and equality. If the decision of investment on children is mainly motivated by efficiency, then $0 < \rho < 1$. Otherwise, the motivation of equality out-weights that of efficiency and $\rho < 0$ (Behrman, Pollak, and Taubman, 1982). In less developed countries, efficiency may be the major consideration and ρ is more likely to be positive. In contrast, equality may be the major one in developed countries and ρ is more likely to be negative.[7]

We then assume the following functional form for the child quality function $V(\theta^H_{\iota,2}, \theta^C_{\iota,2})$ ($\iota = i, j$):

$$V(\theta^H_{\iota,2}, \theta^C_{\iota,2}) = (\theta^H_{\iota,2})^{\alpha_H} (\theta^C_{\iota,2})^{\alpha_C}, \tag{17}$$

where $0 < \alpha_H, \alpha_C < 1$, and $\alpha_H(\alpha_C)$ measures the importance of health (cognitive skills) in the quality function. Finally, following Behrman, Pollak, and Taubman (1982) and Cunha and Heckman (2008), we assume substitutability between investment in health ($I^H_{\iota,1}$) and the stock of health ($\theta^H_{\iota,1}$) in the health production function ($\theta^H_{\iota,2}$), and between investment in cognitive skills ($I^C_{\iota,1}$) and the cognitive stock ($\theta^C_{\iota,1}$) in the cognitive skills production function ($\theta^C_{\iota,2}$). We then assume the

[6]We assume that parents have equal concerns for their children. Thus, the weights in the child quality function are equal and normalized to one. Graphically, the symmetry in the parental welfare function means that the parental welfare function (equation (16)) is symmetrical around the 45^o ray from the origin. However, it does not automatically imply that resources are equally distributed across children, as they may have different endowments or may be differentially hit by shocks, as this paper shows. Notice that the analytical results of this section remains qualitatively the same if we assume that parents put different weights on the quality of different children. For more discussion on the parental welfare function, see Behrman, Pollak, and Taubman (1982).

[7]ρ is a continuous variable and it implies that all parents have both efficiency and equality considerations unless $\rho = 1$ or $\rho = -\infty$. $\rho = 1$ means that parents only care efficiency, while $\rho = -\infty$ means that parents only care equality. The sign of ρ indicates which consideration is the dominant one.

following functional forms for the production technologies:[8]

$$\theta^H_{\iota,2} = (\theta^C_{\iota,1})^\gamma [\beta_\theta \theta^H_{\iota,1} + \beta_I I^H_{\iota,1}]^{1-\gamma}, \tag{18}$$

$$\theta^C_{\iota,2} = (\theta^H_{\iota,1})^\gamma [\beta_\theta \theta^C_{\iota,1} + \beta_I I^C_{\iota,1}]^{1-\gamma}, \tag{19}$$

where $0 < \gamma < 1$ and $0 < \beta_\theta, \beta_I < 1$. The parameter γ can be interpreted as the importance of the first-period cognition (health) in producing health (cognition) in the second period, while the parameter β_θ can be interpreted as the *relative* importance of the first-period health (cognition) in producing health (cognition) in the second period, relative to investment in health (cognition) in the first period.

By solving the parental optimization problem (maximizing the utility function (16) subject to the budget constraint (equation (13)), the production technologies (equations (18)-(19)), and the quality function (equation (17))), we derive the optimal investment in health and cognitive skills of child i as:[9]

$$I^{H*}_{i,1} = \frac{\alpha_H}{\beta_I} W \pi_i - \frac{\beta_\theta}{\beta_I} \theta^H_{i,1}, \tag{20}$$

$$I^{C*}_{i,1} = \frac{\alpha_C}{\beta_I} W \pi_i - \frac{\beta_\theta}{\beta_I} \theta^C_{i,1}, \tag{21}$$

where:

$$W = \beta_\theta(\theta^H_{i,1} + \theta^C_{i,1} + \theta^H_{j,1} + \theta^C_{j,1}) + (\beta_I) I, \tag{22}$$

$$\pi_i = \frac{V(\theta^H_{i,2}, \theta^C_{i,2})^\rho}{U^\rho}. \tag{23}$$

Let's first consider equation (22). W measures the *full resources* devoted to the production of health and cognitive skills in the second period, which includes the health and cognitive stock of both children in the first period and the investment budget in the first period, weighted by their relative importance in the production function (see equations (18)-(19)). Notice that $dW/d\theta^H_{i,1} = \beta_\theta > 0$: an increase in child i's health in the first period by one unit increases the *full resources* by β_θ. We call this a *wealth* effect as in Becker and Tomes (1976). The wealth effect is always positive. Let's

[8]We assume a Cobb-Douglas production technology to simplify the calculations. Our basic results are unchanged by assuming a general CES production technology and relaxing the perfect substitutability assumption. They are reported in the web appendix.

[9]The formal derivation is reported in the web appendix.

now consider equation (23): π_i measures the relative importance of child i in the parental utility function.[10] Thus, $W\pi_i$ measures the share of total resources allocated to child i. It is important to notice that the sign of $d\pi_i/d\theta^H_{i,1}$ is determined by the parental inequality aversion parameter ρ:[11] when $\rho > 0$, parents adopt a reinforcement strategy, so they allocate more resource to child i if the child has better health in the first period. Following Becker and Tomes (1976), we interpret $d\pi_i/d\theta^H_{i,1}$ as a "*price* effect", since an increase of child i's health changes the child's relative *price* in the parental utility function. Let's finally consider the equation for optimal investment in health (equation (20)): here α_H measures the relative importance of health in the child quality function (equation (17)); β_I measures the productivity of the investment in health (see equation (18)); and β_θ/β_I measures the trade-off between health in the first period and investments in health in the first period in the production technology (equation (18)). An analogous interpretation applies to the equation for optimal investment in cognitive skills (equation (21)).

We now derive the comparative static results for the effect of health in the first period on investment in health and cognitive skills for child i:

$$\frac{\partial I^{H*}_{i,1}}{\partial \theta^H_{i,1}} = \frac{\alpha_H}{\beta_I}\left(\frac{\partial W}{\partial \theta^H_{i,1}}\pi_i + \frac{\partial \pi_i}{\partial \theta^H_{i,1}}W\right) - \frac{\beta_\theta}{\beta_I}, \tag{24}$$

$$\frac{\partial I^{C*}_{i,1}}{\partial \theta^H_{i,1}} = \frac{\alpha_C}{\beta_I}\left(\frac{\partial W}{\partial \theta^H_{i,1}}\pi_i + \frac{\partial \pi_i}{\partial \theta^H_{i,1}}W\right). \tag{25}$$

We notice that, in addition to the wealth effect and the price effect discussed above, equation (24) also includes an additional term, $(-\beta_\theta/\beta_I)$, that we call a *technological* effect, as it stems directly from the health production technology (equation (18)). Because of substitutability between the health stock in the first period and the investment in health (equation (18)), an increase in the health stock in the first period will reduce the amount invested in health, so the technological effect is negative. As noted above, the wealth effect is always positive, while the sign of the price effect depends on the parental degree of inequality aversion: $\partial\pi_i/\partial\theta^H_{i,1}$ is positive if $\rho > 0$ (parents adopt a reinforcement strategy), while it is negative if $\rho < 0$ (parents adopt a compensation strategy). In either case, the own effect of first-period health on investment in health is ambiguous. On the contrary, the own effect of first-period health on investment in cognitive skills is always positive if

[10] Notice that $U^\rho = V_i(\theta^H_{i,2}, \theta^C_{i,2})^\rho + V_i(\theta^H_{j,2}, \theta^C_{j,2})^\rho$.

[11] Please refer to the mathematical derivation in the web appendix.

parents exhibit no inequality aversion, since both the wealth effect and the price effect are positive (see equation (25)). The cross-effects of child i's health in the first period on investment in health and cognitive skills of child j are:

$$\frac{\partial I_{j,1}^{H*}}{\partial \theta_{i,1}^{H}} = \frac{\alpha_H}{\beta_I}\left(\frac{\partial W}{\partial \theta_{i,1}^{H}}\pi_j + \frac{\partial \pi_j}{\partial \theta_{i,1}^{H}}W\right), \tag{26}$$

$$\frac{\partial I_{j,1}^{C*}}{\partial \theta_{i,1}^{H}} = \frac{\alpha_C}{\beta_I}\left(\frac{\partial W}{\partial \theta_{i,1}^{H}}\pi_j + \frac{\partial \pi_j}{\partial \theta_{i,1}^{H}}W\right). \tag{27}$$

We notice that $\partial\pi_j/\partial\theta_{i,1}^H$ has the opposite sign as $\partial\pi_i/\partial\theta_{i,1}^H$ because that $\pi_i + \pi_j = 1$. For example, under a reinforcement strategy ($\rho > 0$), $\partial\pi_i/\partial\theta_{i,1}^H > 0$, while $\partial\pi_j/\partial\theta_{i,1}^H < 0$. Combining equations (24)-(27), we derive:[12]

$$\frac{\partial I_{i,2}^{H*}}{\partial \theta_{i,1}^{H}} - \frac{\partial I_{j,1}^{H*}}{\partial \theta_{i,1}^{H}} = \frac{\alpha_H}{\beta_I}\left(\frac{\partial \pi_i}{\partial \theta_{i,1}^{H}} - \frac{\partial \pi_j}{\partial \theta_{i,1}^{H}}\right)W - \frac{\beta_\theta}{\beta_I}, \tag{28}$$

$$\frac{\partial I_{i,2}^{C*}}{\partial \theta_{i,1}^{H}} - \frac{\partial I_{j,1}^{C*}}{\partial \theta_{i,1}^{H}} = \frac{\alpha_C}{\beta_I}\left(\frac{\partial \pi_i}{\partial \theta_{i,1}^{H}} - \frac{\partial \pi_j}{\partial \theta_{i,1}^{H}}\right)W. \tag{29}$$

When parents adopt a reinforcement strategy ($\rho > 0$), $\partial I_{i,1}^{C*}/\partial\theta_{i,1}^H - \partial I_{j,1}^{C*}/\partial\theta_{i,1}^H$ is positive, while $\partial I_{i,1}^{H*}/\partial\theta_{i,1}^H - \partial I_{j,1}^{H*}/\partial\theta_{i,1}^H$ is indetermined.

In the final part of this section, we summarize the main predictions of our theoretical model which we will then test empirically. The first prediction is related to the effect of an early health shock on child i on the difference in investment in health and cognitive skills across twins:

$$\left(\frac{\partial I_{i,1}^{H*}}{\partial \theta_{i,1}^{H}} - \frac{\partial I_{j,1}^{H*}}{\partial \theta_{i,1}^{H}}\right)\frac{\partial \theta_{i,1}^{H}}{\partial e_{i,1}^{H}} = \left[\frac{\alpha_H}{\beta_I}\left(\frac{\partial \pi_i}{\partial \theta_{i,1}^{H}} - \frac{\partial \pi_j}{\partial \theta_{i,1}^{H}}\right)W - \frac{\beta_\theta}{\beta_I}\right]\frac{\partial \theta_{i,1}^{H}}{\partial e_{i,1}^{H}}, \tag{30}$$

$$\left(\frac{\partial I_{i,1}^{C*}}{\partial \theta_{i,1}^{H}} - \frac{\partial I_{j,1}^{C*}}{\partial \theta_{i,1}^{H}}\right)\frac{\partial \theta_{i,1}^{H}}{\partial e_{i,1}^{H}} = \left[\frac{\alpha_C}{\beta_I}\left(\frac{\partial \pi_i}{\partial \theta_{i,1}^{H}} - \frac{\partial \pi_j}{\partial \theta_{i,1}^{H}}\right)W\right]\frac{\partial \theta_{i,1}^{H}}{\partial e_{i,1}^{H}}, \tag{31}$$

where $\partial\theta_{i,1}^H/\partial e_{i,1}^H < 0$.[13] When $\rho > 0$, the within-twin-pair fixed-effects estimate of the effect of an early health shock on investment in cognitive skills is predicted to be negative (equation (31)).

[12] Notice we make the additional assumption that children born in the same family have the same stock of health and cognition at birth, i.e. $\pi_j = \pi_i$. Since we use twins data in our empirical analysis and always condition on birth weight, we believe such an assumption to be credible. Therefore, the wealth effects are swept out in the within-twin-pair difference

[13] We assume a negative health shock throughout the paper. It is possible that there exits a positive health shock. In this case, $\partial\theta_{i,1}^H/\partial e_{i,1}^H > 0$

However, the sign of the effect on investment in health is ambiguous (equation (30)), as it depends on the relative magnitude of the price effect (which is positive) and of the technological effect (which is negative). The case when $\rho < 0$ can be analyzed in a similar way.

The second prediction is related to the effect of an early health shock on health and cognition in the second period. By plugging equations (28)-(29) into equations (11)-(12) and assuming that $\frac{\partial \theta_{i,2}^H}{\partial I_{i,1}^H} = \frac{\partial \theta_{j,2}^H}{\partial I_{j,1}^H}$ and $\frac{\partial \theta_{i,2}^C}{\partial I_{i,1}^C} = \frac{\partial \theta_{j,2}^C}{\partial I_{j,1}^C}$, we obtain:

$$\frac{d\theta_{i,2}^H}{de_{i,1}^H} - \frac{d\theta_{j,2}^H}{de_{i,1}^H} = \frac{\partial \theta_{i,2}^H}{\partial \theta_{i,1}^H} \cdot \frac{\partial \theta_{i,1}^H}{\partial e_{i,1}^H} + \frac{\partial \theta_{i,2}^H}{\partial I_{i,1}^H} \cdot \left[\frac{\alpha_H}{\beta_I} \left(\frac{\partial \pi_i}{\partial \theta_{i,1}^H} - \frac{\partial \pi_j}{\partial \theta_{i,1}^H} \right) W - \frac{\beta_\theta}{\beta_I} \right] \cdot \frac{\partial \theta_{i,1}^H}{\partial e_{i,1}^H}, \tag{32}$$

$$\frac{d\theta_{i,2}^C}{de_{i,1}^H} - \frac{d\theta_{j,2}^C}{de_{i,1}^H} = \frac{\partial \theta_{i,2}^C}{\partial \theta_{i,1}^H} \cdot \frac{\partial \theta_{i,1}^H}{\partial e_{i,1}^H} + \frac{\partial \theta_{i,2}^C}{\partial I_{i,1}^C} \cdot \left[\frac{\alpha_C}{\beta_I} \left(\frac{\partial \pi_i}{\partial \theta_{i,1}^H} - \frac{\partial \pi_j}{\partial \theta_{i,1}^H} \right) W \right] \cdot \frac{\partial \theta_{i,1}^H}{\partial e_{i,1}^H}. \tag{33}$$

When $\rho > 0$, the within-twin-pair fixed-effects estimate of the effect of an early health shock on cognitive skills in the second period is predicted to be negative (equation (33)). However, the sign of the effect on health in the second period is ambiguous (equation (32)), since it depends on the relative magnitude of the price effect (which is positive) and of the technological effect (which is negative). The case when $\rho < 0$ can be analyzed in a similar way.

4 The Econometric Analysis

Guided by our theoretical model, we first analyze how parents respond to an early health shock. The stochastic version of the parental investment equations is specified as:

$$I_{\iota,\tau}^\kappa = \alpha^\kappa e_{\iota,\tau}^H + X_{\iota,\tau}\beta^\kappa + \zeta_\tau \varphi^\kappa + \mu_\tau + \epsilon_{\iota,\tau}^\kappa, \tag{34}$$

where $\kappa = H, C$, and ι indexes individual twins and τ households. $I_{\iota,\tau}^\kappa$ is investment in κ during the first period, $e_{\iota,\tau}^H$ is a health shock in the first period; $X_{\iota,\tau}$ is a vector of child-specific characteristics; ζ_τ is a vector of observed household characteristics which affect parental investments; μ_τ is unobservable household heterogeneity; $\epsilon_{\iota,\tau}^\kappa$ is the disturbance term. To sweep out family-level unobserved heterogeneity, we use the following within-twin-pair fixed-effects specification:

$$I_{i,\tau}^\kappa - I_{j,\tau}^\kappa = \alpha^\kappa \left(e_{i,\tau}^H - e_{j,\tau}^H \right) + \left(X_{i,\tau} - X_{j,\tau} \right) \beta^\kappa + \epsilon_{i,\tau}^\kappa - \epsilon_{j,\tau}^\kappa, \tag{35}$$

where i and j index the two twins in the pair. Equation (35) is the empirical counterpart of equations (30)-(31). We notice that the within-twin-pair estimation not only sweeps out the family-level unobserved heterogeneity, but also the wealth effect induced by an early health shock. Thus, when $\kappa = C$, the sign of α^κ is uniquely determined by the degree of parental inequality aversion (ρ): if parents do not avert inequality across their children ($\rho > 0$) and adopt a reinforcement strategy, then α^C is negative. However, the sign of α^H remains undetermined, as it depends on the trade-off between the parental degree of inequality aversion and the substitutability between investment in health and the stock of health in the first period to produce health in the second period. We then analyze how an early health shock affects later outcomes, using the following empirical specification for the outcome equation:

$$\theta^\kappa_{\iota,\tau} = \gamma^\kappa e^H_{\iota,\tau} + X_{\iota,\tau}\delta^\kappa + \zeta_\tau \psi^\kappa + \mu_\tau + \varepsilon^\kappa_{\iota,\tau}, \tag{36}$$

where $\theta^\kappa_{\iota,\tau}$ is outcome κ for twin ι in household τ in the second period, and all the other terms are defined as in equation (34). The corresponding within-twin-pair fixed-effects specification:

$$\theta^\kappa_{i,\tau} - \theta^\kappa_{j,\tau} = \gamma^\kappa (e^H_{i,\tau} - e^H_{j,\tau}) + (X_{i,\tau} - X_{j,\tau})\delta^\kappa + \varepsilon^\kappa_{i,\tau} - \varepsilon^\kappa_{j,\tau}. \tag{37}$$

Equation (37) is the empirical counterpart of equations (32)-(33). Out theoretical model predicts the sign of γ^κ to be uniquely determined by the parental degree of inequality aversion, ρ, when $\kappa = C$:[14]: when $\rho > 0$ (parents adopt a reinforcement strategy), we expect $\gamma^C < 0$. However, the sign of γ^H is undetermined.

Before moving on to the data description, we briefly discuss our identification strategy. On the one hand, although siblings are biologically similar to dizygotic twins, the within-twin-pair fixed-effects estimator requires much weaker identification assumptions than the within-siblings fixed-effects estimator when estimating child outcomes production functions (Todd and Wolpin, 2007). Specifically, the within-siblings fixed-effects estimator requires three additional assumptions. First, the effects of an early health shock must be either independent of age if siblings' outcomes are measured at different ages but at the same point in time, or independent of time if siblings'

[14] As specified in the next section, in our empirical analysis C includes both child academic achievement and noncognitive skills

outcomes are measured at the same age but at different points in time. Second, parents must not make time-varying investments across siblings. Third, parents must not adjust their fertility choices and investment behavior in response to a health shock affecting their existing children – an assumption which seems untenable according to the evidence in Rosenzweig and Wolpin (1988).

On the other hand, our within-twin-pair fixed-effects estimator still relies on the assumption that $\varepsilon_{i,\tau} - \varepsilon_{j,\tau}$ and $\epsilon_{i,\tau} - \epsilon_{j,\tau}$ are uncorrelated with $e^H_{i,\tau} - e^H_{j,\tau}$, conditioning on observables. In other words, our key identification assumption is that, conditional on the family fixed effect and the observed covariates, the early health shock occurs randomly within twin pairs. Of course, there is always the possibility that it could reflect unobserved health differences. Unfortunately, due to data limitations, we cannot estimate a model which also includes individual-level unobserved heterogeneity, but we try to address this concern by controlling for birth weight in all our specifications. Our rationale for doing so is that the birth weight can be considered a proxy for the child's stock of health capital at birth, before the occurrence of the early health shock at ages 0-3 (Behrman and Rosenzweig, 2004).

5 The Data

We use data drawn from the Chinese Child Twins Survey (CCTS), which is the first large scale survey based on a census of child twins of which we are aware.[15] The survey was carried out by the Urban Survey Unit (USU) of the National Bureau of Statistics (NBS) in late 2002 and early 2003 in the Kunming district of China. Kunming is the capital of Yunnan Province, which is located in the far southwestern corner of China and is one of China's relatively undeveloped provinces. It has a total population of about 5 million. The CCTS includes a sample of households with twins aged between 7 and 18 years resident in Kunming. The households were initially identified by the USU using the 2000 population census according to whether the children had the same birth year and month and the same relationship with the household head. The addresses of these households were then obtained from the census office, and the presence of twins was determined with a visit to the household. Starting from 2300 pairs of potential twins identified in the census, 1694 households with twins were successfully interviewed; of these, 1300 households had twins on the first birth

[15] See Rosenzweig and Zhang (2009) for a detailed description of the CCTS.

and 394 households had twins on the second birth.[16] A comparison sample of 1693 households with no twins were also surveyed by means of the same questionnaire.[17] The questionnaire was designed by Junsen Zhang in close consultation with Mark Rosenzweig and Chinese experts at the National Bureau of Statistics. Based on existing twins and child questionnaires in the US and elsewhere, the survey covers an extensive range of information about inputs and outcomes of children, in addition to a wide range of demographic, social, and economic information at the household level. The questionnaire is divided into two parts. The first part is answered jointly by the father, the mother, and the children, and collects information on the household situation, on the parents, on the schooling and health (including the health history) of the children, and on parental investments. After completing the first part, parents and each child are separately interviewed in different rooms. The second part covers information on home tutoring, children's schooling and academic performance, entertainment, and social activities. We now describe the main variables that we use in our empirical analysis.

Early health shocks. Our independent variable of interest (early health shocks) is defined as a dummy indicating whether the child had suffered from a serious disease during the ages 0-3; table 1 in the appendix shows that the prevalence rate in our sample is 9%. The complete list of diseases is reported in Table 4 in the appendix, and it includes diarrhea, calcium deficiency, asthma, fracture, attention deficit disorder, heart disease, hearing difficulties, hooping cough, stammer, eyesight problem, monophobia, obesity, hyperactivity and surgery defect. It shows that diarrhoea is the most frequent disease in our sample, as it is the case for children in developing countries (Strauss and Thomas, 1998); it also shows that there is sufficient variation within twin pairs to enable us to use a within-twin-pair fixed-effects estimator.[18] We now address some potential concerns regarding the measurement of early health shocks, since they are based on health histories reconstructed retrospectively. First, retrospective data may suffer from recall error (Strauss and Thomas, 1998). We believe this to be less of a problem in our case for essentially two reasons: on the one hand,

[16]The one-child policy is strictly implemented in urban areas in Kunming. In rural areas, however, households are encouraged to have one child, but are exempted from the strict one-child policy (they are allowed to have two children at most (of Yunnan Province (2003))).

[17]The fourth household on the right hand side of the same block of the twin household was chosen as non-twin comparison. If the fourth household had no children aged 6-18, then interviewers would continue with the fifth, sixth, etc.

[18]Unfortunately, we cannot distinguish between mental and physical diseases, because the former have low prevalence in our sample. See Currie and Stabile (2006) for an analysis of the effect of child mental health on human capital accumulation.

the health history questions are answered together by the father, the mother and the children (in the first part of the questionnaire); on the other hand, given the young age of the twin sample, the recall period is not very long. Second, respondents may use different thresholds, so that some of the differences in reported illnesses across households may simply reflect differences in the standards (Strauss and Thomas, 1998; Smith, 2009). Like for recall bias, also for reporting heterogeneity there could be systematic differences across households (for example, more educated households could both keep more accurate medical records and have higher standards). However, these differences are unlikely to exist across twin siblings within a same family, so our within-twin-pair fixed-effects estimation strategy will take care of that.[19]

Family Investments. Our main dependent variables are measures of family investments in children. We use two types of measures of parental investments: in money and in time. We can further differentiate the former as medical, education, and clothing expenditure, while the latter is measured as time spent tutoring the child.

Parental Labor Supply and Expenditures. We also analyze the effect of an early health shock on parental labor supply, measured as days worked per month, and on parental expenditures on several goods: cigarettes, alcohol, clothes and cosmetics. Notice that we have separate variables for both the mother and the father.

Child Health. As measures of child health we use anthropometric measures (height and weight) and indicators of health status and the number of visits to the hospital, reported by both parents.

Child Academic and Schooling Performance. The measures of academic performance we use include both objective (exam transcripts) and subjective (self-reported evaluation in comparison to the class norm) measures in three different subjects: literature, mathematics and english. We also have several measures of school performance, both recorded from transcripts (current grade, good student awards and awards in contest) and reported by the parents (whether the parents have been interviewed by the teacher for the poor performance of the child, and whether the child was inattentive and criticized by the teacher in class).

Child Noncognitive Skills. Our data is extremely rich in terms of noncognitive measures,

[19] Another interesting aspect of the twin design is that it overcomes the usual problem of lack of an explicit reference group (or anchoring): it is natural for the parents to think of one twin as the reference point for the other.

which range from child behavior and emotional stability to measures of relationships with the peers. All measures are reported by both parents.

Parent-Child Relationship. Finally, we also have several measures of the parent-child relationship, both from the parents' (educational expectations and quality of the relationship) and the children's perspective (openness of the communication and time spent with the parents).

Summary statistics for all the variables are reported in Table 1 in the web appendix.

6 Results

6.1 The Effects of Early Health Shocks on Parental Resource Reallocations

We first analyze the effects of early health shocks on parental investments. Our main result is that parents adopt a compensation strategy in the case of health, but a reinforcement strategy in the case of education. As shown in Table 1, parents reallocate on average 307 ¥ from the healthy to the sick twin, but they subtract 191 ¥ worth of expenditures in education from the sick twin to the healthy one. An additional result is that we only see the reallocation process working in terms of money invested in children, while there is no change in the time spent with them. This suggests that the effects of early health shocks mainly operate through the budget constraint, not through preferences. Interestingly, we find significant differences across subsamples. On the one hand, the increase in health expenditures in favor of the sick twin in rural areas is not accompanied by a corresponding decrease in educational expenditures; we find evidence, instead, of a reduction in clothing expenditures, nonetheless of modest amount. We rationalize this finding in light of the fact that the budget constraint is already binding in rural areas, so that no further reductions in educational expenditures are possible. In urban areas, instead, the amount of educational resources subtracted from the sick child almost exactly offsets, in monetary terms, the amount redistributed to pay for her medical expenses. On the other hand, we also find significant differences by gender. While, in the case of male twin pairs, a reallocation of medical expenditures in favor of the sick twin is not offset by a corresponding reduction in educational expenditures, we find, instead, that this is the case for female twin pairs.

6.2 The Effects of Early Health Shocks on Parental Labor Supply and Expenditures

Before analyzing the effects on child outcomes, we investigate the effects of an early health shock on parental work and consumption patterns. As these characteristics are invariant within twin pairs, we conduct the analysis at the household level, and and we analyze whether there are differences in parental labor supply and expenditures in case only one twin is hit by the health shock, as compared to the case in which none of them is (we also include the case in which both twins are, as a separate category).[20] Again, we find interesting differences across subsamples. As reported in Table 2, in rural areas, in case one twin is hit by a health shock, the father is significantly less likely to spend money in cosmetics, while the mother has significantly lower expenditures in unhealthy goods like cigarettes and alcohol.[21] In urban areas, instead, we find no significant difference in reported paternal expenditures, while we find that mothers have significantly lower expenditures in alcohol, and supply more work. Similar differences emerge when comparing the male and the female sample (Table 3): in the former case, we only see an increase in maternal working hours, while in the latter we find a significant decrease in expenditures on alcohol and clothing for both parents, and on cosmetics for the father.

6.3 The Effects of Early Health Shocks on Child Outcomes

We now examine the effects of early health shocks on children outcomes. We begin in Table 4 by looking at their effects on later health. Overall, we find some evidence of a long-lasting effect on anthropometric measures, but we see that the twin hit by the early insult is evaluated by the parent as being in worse health, and is reported to have a bigger number of hospital visits. The rural sample is an exception. Here we find that an early health insult has an effect on weight and BMI, but not on the number of hospital visits. We interpret this evidence by speculating that health shocks may have more longlasting effects in a rural setting as a tighten budget constraint might not allow the parents to go to the hospital every time it would be required. Table 5 shows that the twin hit by an early health insult has poorer achievement, both perceived and actual. We also uncover

[20] These two cases could be indicators of, respectively, a positive or negative household-level fixed health endowment.

[21] Notice that, as can be seen in Table 1 in the Appendix, the money spent in these goods amounts to a very small share of the family income.

a significant gender difference: in the case of female twins, the difference in achievement with the healthy sister is only perceived, not real. Table 6 shows that an early health insult negatively affects also the twin's schooling performance. We uncover a significant difference between the rural and the urban sample: while in rural areas we see the effects mainly operating through a problematic behavior in the classroom, in urban areas the long-lasting effects of early-life insults seem to affect mainly the purely educational performance. This is consistent with the evidence reported earlier of a reduction in educational expenditure in the urban areas but not in the rural ones. Lastly, Table 7-Table 8 show that an early health insult consistently and negatively affects the child's personality in several different domains.

6.4 The Effects of Early Health Shocks on the Parent-Child Relationship

Finally, Table 9 shows the results on the effects of early health shocks on the relationship between parents and children. From the parental standpoint, we find that parents consistently lower their expectations for the expected educational level of the child hit by the shock, and they also report a worsening of their relationship. The only exception to this pattern occurs for the rural sample, and can be explained in the context of a more traditional type of parent-child relationship, where parents have expectations and children have duties which are unaffected by changes in circumstances. From the child standpoint, instead, there is no change in the way the relationship with the parents is perceived as compared to the healthy twin, under a wide variety of common activities, ranging from playing with them to having dinner together; this is consistent with our previous result that we find evidence of no change in the time the parent spends tutoring the child.

7 Conclusions

In this paper we have studied how early health shocks affect child's human capital formation. We have first formulated a theoretical model to understand how early health shocks affect child outcomes through parental responses. We have then nested a dynamic model of human capability formation into a standard intrahousehold resource allocation framework. By allowing multidimensionality of child endowments, we have allowed parents to compensate and reinforce along different dimensions. We have then tested our main empirical predictions using a large-scale Chinese child twins survey, which contains detailed information on child- and parent-specific expenditures. We have differentiated between investment in money and investment in time. On the one hand, we have found evidence of compensating investment in child health but of reinforcing investment in education. On the other, we have found no change in the time spent with the child. We have confirmed that an early health insult negatively affects the child under several different domains, ranging from later health, to cognition, to personality. We have also showed that early health shocks negatively affect parental expectations, but do not change the child's perceptions of parental behavior. This suggests that the effects of early health shocks mainly operate through the budget constraint, not through preferences.

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Table 1: Within-Twin-Pair Fixed-Effects Estimates of the Effects of Early Health Shocks on Family Investments

	Health	Education	Clothing	Parents home tutor (a)	Parents home tutor (b)
Whole sample					
Early health shocks	1.362***	-0.206***	-0.057	0.255	0.761
	[0.246]	[0.068]	[0.047]	[0.170]	[1.761]
ΔExpenditure	307.036	-190.589	-13.829	n/a	n/a
# pairs of twins	1450	1450	1450	1430	1440
Rural sample					
Early health shocks	1.512***	-0.051	-0.120**	0.040	0.183
	[0.344]	[0.084]	[0.050]	[0.216]	[2.404]
ΔExpenditure	229.128	-32.243	-20.88	n/a	n/a
# pairs of twins	769	769	769	757	760
Urban sample					
Early health shocks	1.249***	-0.329***	-0.006	0.404	1.182
	[0.355]	[0.106]	[0.080]	[0.262]	[2.592]
ΔExpenditure	385.779	-413.237	-1.921	n/a	n/a
# pairs of twins	681	681	681	673	680
Male sample					
Early health shocks	1.085***	-0.080	-0.109	0.036	-2.320
	[0.380]	[0.080]	[0.080]	[0.269]	[2.700]
ΔExpenditure	252.393	-73.985	-26.454	n/a	n/a
# pairs of twins	540	540	540	534	538
Female sample					
Early health shocks	2.102***	-0.625***	-0.027	0.412	4.416
	[0.427]	[0.149]	[0.078]	[0.267]	[2.837]
ΔExpenditure	542.442	-619.781	-7.047	n/a	n/a
# pairs of twins	556	556	556	547	552

Source: CCTS. Notes: Each entry comes from a separate regression. Robust standard errors are in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%. Birth weight is controlled for in each regression; gender has been controlled for in estimations based on whole, rural, and urban samples. The row "ΔExpenditure" reports the implied change in the level of expenditures. Parents home tutor (a) is measured in number of times per week, while parents home tutor (b) is measured in minutes per day.

Table 2: OLS Estimates of the Early Health Shocks on Parental Labor Supply and Expenditure

	Father					Mother				
	Work	Cigarettes	Alcohol	Clothes	Cosmetics	Work	Cigarettes	Alcohol	Clothes	Cosmetics
Whole sample										
Early health shocks	-0.045	-0.164	-0.233	-0.612*	-0.12	0.050*	0.224	-0.046***	-0.486	-0.133
(only one child)	[0.078]	[0.285]	[0.196]	[0.342]	[0.095]	[0.026]	[0.157]	[0.015]	[0.315]	[0.240]
ΔExpenditure	n/a	-12.133	-3.534	-99.050	-0.405	n/a	0.376	-0.121	-95.555	-8.507
Early health shocks	-0.006	0.091	-0.143	-0.153	-0.176**	-0.045*	-0.047***	-0.049***	-0.307	-0.293
(both children)	[0.025]	[0.217]	[0.165]	[0.275]	[0.072]	[0.024]	[0.014]	[0.016]	[0.253]	[0.203]
ΔExpenditure	n/a	6.732	-2.169	-24.763	-0.594	n/a	-0.079	-0.129	-60.361	-18.741
# households	1158	1413	1413	1413	1413	1055	1451	1451	1451	1451
Rural sample										
Early health shocks	0.005	-0.422	-0.292	-0.734	-0.082***	0.017	-0.049**	-0.048**	-0.542	0.145
(only one child)	[0.051]	[0.362]	[0.296]	[0.492]	[0.024]	[0.041]	[0.020]	[0.023]	[0.478]	[0.345]
ΔExpenditure	n/a	-23.943	-4.291	-77.878	-0.056	n/a	-0.026	-0.212	-60.989	3.946
Early health shocks	-0.028	-0.033	-0.216	-0.403	-0.106***	-0.039	-0.043***	-0.058**	-0.376	-0.322
(both children)	[0.041]	[0.266]	[0.234]	[0.380]	[0.024]	[0.036]	[0.015]	[0.026]	[0.377]	[0.244]
ΔExpenditure	n/a	-1.872	-3.174	-42.759	0.072	n/a	-0.023	-0.256	-42.310	-8.763
# households	646	753	753	753	753	614	769	769	769	769
Urban sample										
Early health shocks	-0.094	0.06	-0.186	-0.512	-0.152	0.076**	0.439	-0.040**	-0.468	-0.348
(only one child)	[0.145]	[0.416]	[0.262]	[0.473]	[0.170]	[0.031]	[0.274]	[0.018]	[0.420]	[0.329]
ΔExpenditure	n/a	5.576	-2.925	-115.092	-0.973	n/a	1.311	-0.027	-135.641	-36.660
Early health shocks	0.015	0.206	-0.081	0.07	-0.235*	-0.045	-0.047**	-0.040**	-0.262	-0.27
(both children)	[0.029]	[0.335]	[0.236]	[0.393]	[0.133]	[0.032]	[0.023]	[0.019]	[0.337]	[0.316]
ΔExpenditure	n/a	19.145	-1.274	15.735	-1.504	n/a	-0.140	-0.027	-75.936	-28.443
# households	512	660	660	660	660	441	682	682	682	682

Source: CCTS. Notes: Each entry comes from a separate regression. Robust standard errors are in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%. The row "ΔExpenditure" reports the implied change in the level of expenditures.

Table 3: OLS Estimates of the Early Health Shocks on Parental Labor Supply and Expenditure (ctd.)

	Father					Mother				
	Work	Cigarettes	Alcohol	Clothes	Cosmetics	Work	Cigarettes	Alcohol	Clothes	Cosmetics
Male sample										
Early health shocks	-0.024	0.117	0.119	0.087	0.012	0.059*	0.159	-0.027	0.126	0.215
(only one child)	[0.042]	[0.409]	[0.318]	[0.514]	[0.201]	[0.035]	[0.199]	[0.018]	[0.483]	[0.367]
ΔExpenditure	n/a	8.743	1.682	12.881	0.033	n/a	0.274	-0.017	24.484	11.580
Early health shocks	-0.029	0.073	-0.063	-0.116	-0.219***	-0.027	-0.050**	-0.036*	-0.022	-0.216
(both children)	[0.039]	[0.316]	[0.238]	[0.390]	[0.078]	[0.030]	[0.025]	[0.021]	[0.368]	[0.292]
ΔExpenditure	n/a	5.455	-0.890	-17.175	-0.609	n/a	-0.086	-0.022	-4.275	-11.634
# households	421	526	526	526	526	391	543	543	543	543
Female sample										
Early health shocks	-0.11	-0.528	-0.759**	-1.240**	-0.250***	-0.001	0.279	-0.086***	-1.403***	-0.552
(only one child)	[0.218]	[0.489]	[0.294]	[0.561]	[0.059]	[0.049]	[0.337]	[0.031]	[0.484]	[0.391]
ΔExpenditure	n/a	-38.538	-13.100	-223.464	-1.015	n/a	0.700	-0.533	-308.017	-44.418
Early health shocks	0.001	-0.095	-0.079	-0.46	-0.265***	-0.097*	-0.054**	-0.081**	-0.737	-0.363
(both children)	[0.052]	[0.413]	[0.314]	[0.524]	[0.058]	[0.055]	[0.024]	[0.032]	[0.448]	[0.360]
ΔExpenditure	n/a	-6.934	-1.363	-82.898	-1.076	n/a	-0.135	-0.502	-161.802	-29.209
# households	455	547	547	547	547	412	562	562	562	562

Source: CCTS. Notes: Each entry comes from a separate regression. Robust standard errors are in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%. The row "ΔExpenditure" reports the implied change in the level of expenditures.

Table 4: Within-Twin-Pair Fixed-Effects Estimates of the Effects of Early Health Shocks on Health

	Height (z-score)	Weight (z-score)	BMI (z-score)	Health Status	# Hospital Visits
Whole sample					
Early health shocks	-0.006	-0.263***	-0.196*	-0.446***	0.698***
	[0.095]	[0.085]	[0.104]	[0.057]	[0.183]
# pairs of twins	1412	1424	1401	1444	1437
Rural sample					
Early health shocks	-0.115	-0.509***	-0.433***	-0.530***	0.252
	[0.156]	[0.127]	[0.151]	[0.089]	[0.261]
# pairs of twins	736	751	742	769	765
Urban sample					
Early health shocks	0.063	-0.069	-0.007	-0.388***	1.049***
	[0.117]	[0.113]	[0.143]	[0.075]	[0.260]
# pairs of twins	676	673	659	675	672
Male sample					
Early health shocks	0.039	-0.072	0.101	-0.440***	0.740***
	[0.111]	[0.120]	[0.139]	[0.083]	[0.257]
# pairs of twins	523	526	519	537	533
Female sample					
Early health shocks	0.107	-0.240*	-0.337**	-0.320***	0.805**
	[0.146]	[0.128]	[0.157]	[0.094]	[0.315]
# pairs of twins	544	549	540	554	552

Source: CCTS. Notes: Each entry comes from a separate regression. Robust standard errors are in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%. Birth weight is controlled for in each regression; gender has been controlled for in estimations based on whole, rural, and urban samples.

Table 5: Within-Twin-Pair Fixed-Effects Estimates of the Effects of Early Health Shocks on Academic Outcomes

	Literature (self-reported)	Mathematics (self-reported)	English (self-reported)	Literature (exam record)	Mathematics (exam record)	English (exam record)
Whole sample						
Early health shocks	-0.345***	-0.536***	-0.420**	-5.172***	-5.433***	-4.664
	[0.110]	[0.126]	[0.199]	[1.655]	[2.006]	[4.172]
# pairs of twins	1419	1413	758	1348	1329	543
Rural sample						
Early health shocks	-0.167	-0.583***	-0.015	-5.497**	-2.584	2.606
	[0.166]	[0.184]	[0.385]	[2.680]	[3.185]	[7.353]
# pairs of twins	753	751	286	705	699	202
Urban sample						
Early health shocks	-0.502***	-0.522***	-0.608***	-4.784**	-7.360***	-6.729
	[0.148]	[0.173]	[0.232]	[2.020]	[2.509]	[5.099]
# pairs of twins	666	662	472	643	630	341
Male sample						
Early health shocks	-0.400**	-0.659***	-0.837***	-5.566**	-6.326**	-20.596***
	[0.166]	[0.197]	[0.268]	[2.286]	[2.888]	[7.639]
# pairs of twins	526	522	277	506	499	192
Female sample						
Early health shocks	-0.467**	-0.461**	0.106	-2.17	-3.985	4.286
	[0.184]	[0.205]	[0.366]	[3.120]	[3.664]	[5.733]
# pairs of twins	546	544	303	512	504	211

Source: CCTS. Notes: Each entry comes from a separate regression. Robust standard errors are in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%. Birth weight is controlled for in each regression; gender has been controlled for in estimations based on whole, rural, and urban samples.

Table 6: Within-Twin-Pair Fixed-Effects Estimates of the Effects of Early Health Shocks on Schooling Performance

	Current grades	# Good Student Awards	# Awards in Contests	Parents interviewed	Criticized by teacher	Minor actions in class	Inattentive in class
Whole sample							
Early health shocks	-0.263***	-0.542***	-0.174***	0.086*	0.241**	0.228**	0.244**
	[0.078]	[0.200]	[0.058]	[0.045]	[0.101]	[0.107]	[0.101]
# pairs of twins	1439	1450	1450	1447	1430	1429	1424
Rural sample							
Early health shocks	-0.175	-0.238	0.005	-0.042	0.315**	0.282*	0.500***
	[0.120]	[0.253]	[0.040]	[0.061]	[0.150]	[0.162]	[0.155]
# pairs of twins	762	769	769	766	759	757	756
Urban sample							
Early health shocks	-0.334***	-0.777**	-0.313***	0.180***	0.171	0.205	0.001
	[0.102]	[0.309]	[0.107]	[0.066]	[0.137]	[0.142]	[0.129]
# pairs of twins	677	681	681	681	671	672	668
Male sample							
Early health shocks	-0.03	-0.969***	-0.090*	0.046	0.201	0.309*	-0.007
	[0.106]	[0.241]	[0.066]	[0.072]	[0.151]	[0.162]	[0.156]
# pairs of twins	536	540	540	540	530	532	532
Female sample							
Early health shocks	-0.572***	-0.267	-0.329***	0.058	0.156	-0.005	0.410**
	[0.140]	[0.350]	[0.100]	[0.064]	[0.161]	[0.164]	[0.169]
# pairs of twins	552	556	556	554	547	545	541

Source: CCTS. Notes: Each entry comes from a separate regression. Robust standard errors are in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%. Birth weight is controlled for in each regression; gender has been controlled for in estimations based on whole, rural, and urban samples.

Table 7: Within-Twin-Pair Fixed-Effects Estimates of the Effects of Early Health Shocks on Noncognitive Skills

	Feel not good	Lose temper	Feel lonely	Disobey	Anxious	Hyperactive	Hostile	Depressed
Whole sample								
Early health shocks	0.114**	0.107**	0.183***	0.124***	0.138***	0.047	0.085**	0.056
	[0.047]	[0.048]	[0.045]	[0.044]	[0.045]	[0.055]	[0.035]	[0.040]
# pairs of twins	1450	1448	1450	1450	1450	1450	1450	1450
Rural sample								
Early health shocks	0.211***	-0.05	0.335***	0.113	0.026	0.135	0.152***	-0.037
	[0.079]	[0.080]	[0.066]	[0.070]	[0.065]	[0.084]	[0.057]	[0.053]
# pairs of twins	769	768	769	769	769	769	769	769
Urban sample								
Early health shocks	0.043	0.235***	0.066	0.140**	0.227***	-0.026	0.034	0.127**
	[0.055]	[0.055]	[0.063]	[0.056]	[0.062]	[0.074]	[0.041]	[0.059]
# pairs of twins	681	680	681	681	681	681	681	681
Male sample								
Early health shocks	0.061	0.219***	0.039	0.175**	0.185***	0.109	0.055	0.122**
	[0.066]	[0.068]	[0.072]	[0.069]	[0.069]	[0.086]	[0.054]	[0.052]
# pairs of twins	540	539	540	540	540	540	540	540
Female sample								
Early health shocks	0.234***	0.053	0.394***	0.101	0.172***	-0.05	0.111***	0.045
	[0.082]	[0.083]	[0.067]	[0.071]	[0.061]	[0.071]	[0.036]	[0.058]
# pairs of twins	556	556	556	556	556	556	556	556

Source: CCTS. Notes: Each entry comes from a separate regression. Robust standard errors are in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%. Birth weight is controlled for in each regression; gender has been controlled for in estimations based on whole, rural, and urban samples.

Table 8: Within-Twin-Pair Fixed-Effects Estimates of the Effects of Early Health Shocks on Noncognitive Skills (ctd.)

	Easily distracted	Teased or bullied	Careless	Easily Frightened	Non persistent	Emotional instability	Good friendship	Good self-expectation
Whole sample								
Early health shocks	0.222***	0.174***	0.157***	0.146***	0.115**	0.111***	-0.137***	-0.146***
	[0.062]	[0.041]	[0.046]	[0.045]	[0.048]	[0.024]	[0.037]	[0.037]
# pairs of twins	1450	1450	1450	1450	1449	1444	1442	1442
Rural sample								
Early health shocks	0.272***	0.154**	0.119*	0.09	0.107*	-0.002	-0.245***	-0.160***
	[0.087]	[0.069]	[0.061]	[0.069]	[0.061]	[0.027]	[0.047]	[0.055]
# pairs of twins	769	769	769	769	768	764	767	767
Urban sample								
Early health shocks	0.182**	0.193***	0.190***	0.191***	0.119	0.196***	-0.052	-0.139***
	[0.088]	[0.047]	[0.068]	[0.059]	[0.073]	[0.039]	[0.057]	[0.051]
# pairs of twins	681	681	681	681	681	680	675	675
Male sample								
Early health shocks	0.086	0.069	0.034	0.155**	0.077	0.051	0.012	-0.170***
	[0.087]	[0.059]	[0.058]	[0.066]	[0.067]	[0.036]	[0.047]	[0.054]
# pairs of twins	540	540	540	540	539	537	537	537
Female sample								
Early health shocks	0.284***	0.223***	0.219***	0.233***	0.114	0.226***	-0.388***	-0.176***
	[0.099]	[0.064]	[0.077]	[0.071]	[0.079]	[0.042]	[0.063]	[0.062]
# pairs of twins	556	556	556	556	556	554	553	553

Source: CCTS. Notes: Each entry comes from a separate regression. Robust standard errors are in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%. Birth weight is controlled for in each regression; gender has been controlled for in estimations based on whole, rural, and urban samples.

Table 9: Within-Twin-Pair Fixed-Effects Estimates of the Effects of Early Health Shocks on the Parent-Child Relationship

	Parents perception		Childs perception					
	Expected college level	Parents-children relationship	Discuss an issue	Tell them school life	Tell them what you think	Eat dinner together	Play games together	Watch TV together
Whole sample								
Early health shocks	-0.147***	-0.068***	-0.154	0.013	-0.035	0.113	0.088	0.107
	[0.035]	[0.026]	[0.117]	[0.120]	[0.124]	[0.105]	[0.116]	[0.108]
# pairs of twins	1431	1442	1438	1448	1440	1450	1439	1444
Rural sample								
Early health shocks	0.005	-0.034	-0.05	0.148	0.009	-0.048	0.249	0.132
	[0.054]	[0.037]	[0.168]	[0.175]	[0.184]	[0.140]	[0.158]	[0.154]
# pairs of twins	761	767	764	768	765	769	762	767
Urban sample								
Early health shocks	-0.265***	-0.097***	-0.244	-0.116	-0.055	0.243	-0.039	0.090
	[0.044]	[0.036]	[0.164]	[0.166]	[0.170]	[0.158]	[0.171]	[0.154]
# pairs of twins	670	675	674	680	675	681	677	677
Male sample								
Early health shocks	-0.254***	0.001	-0.027	0.235	0.239	0.089	0.255	0.137
	[0.051]	[0.031]	[0.180]	[0.191]	[0.189]	[0.177]	[0.194]	[0.169]
# pairs of twins	533	537	536	540	537	540	537	540
Female sample								
Early health shocks	-0.116**	-0.170***	-0.517***	-0.207	-0.119	0.206	0.012	0.045
	[0.053]	[0.039]	[0.197]	[0.197]	[0.210]	[0.186]	[0.189]	[0.181]
# pairs of twins	548	553	549	554	551	556	552	554

Source: CCTS. Notes: Each entry comes from a separate regression. Robust standard errors are in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%. Birth weight is controlled for in each regression; gender has been controlled for in estimations based on whole, rural, and urban samples. Questions underlying dependent variables of Columns (1)-(2) are answered by parents, and those underlying dependent variables of Columns (3)-(8) are answered by children.