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Childhood Circumstances and Adult Outcomes: Act II

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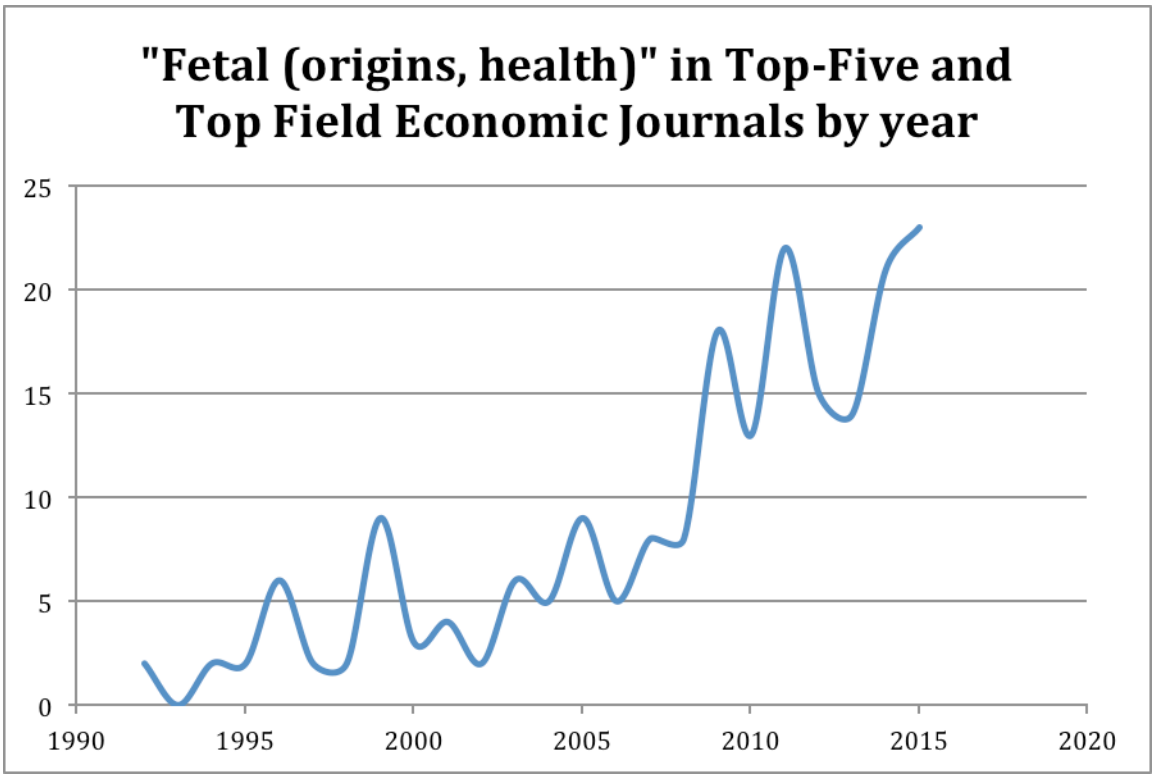
Abstract

That prenatal events can have life-long consequences is now well established. Nevertheless, research on the Fetal Origins Hypothesis is flourishing and has expanded to include the early childhood (postnatal) environment. Why does this literature have a "second act?" We summarize the major themes and contributions driving the empirical literature since our 2011 reviews, and try to interpret the literature in light of an overarching conceptual framework about how human capital is produced early in life. One major finding is that relatively mild shocks in early life can have substantial negative impacts, but that the effects are often heterogeneous reflecting differences in child endowments, budget constraints, and production technologies. Moreover, shocks, investments, and interventions can interact in complex ways that are only beginning to be understood. Many advances in our knowledge are due to increasing accessibility of comprehensive administrative data that allow events in early life to be linked to long-term outcomes. Yet, we still know relatively little about the interval between, and thus about whether it would be feasible to identify and intervene with affected individuals at some point between early life and adulthood. We do know enough, however, to be able to identify some interventions that hold promise for improving child outcomes in early life and throughout the life course.

The fetal origins literature has been particularly active over the last several years rendering reviews by Currie (2009) and Almond and Currie (2011a, b) somewhat dated. Figure 1 shows the number of papers about "fetal origins" in several leading journals by year.[1]



Why does this literature "have legs"? By now, the rudimentary point is familiar. Currie and Hyson (1999) using longitudinal data showed that long-term outcomes seemed to respond to circumstances in utero; Costa (2000) found that chronic health conditions among older men were predicted by early-life infant mortality rates in their natal areas, which can proxy for the disease environment. Papers exploiting natural experiments to show the long-term impact of fetal and

[1] Figure 1 shows the number of annual publications from January 1993 to October 2015 in the Quarterly Journal of Economics, American Economic Review, Journal of Political Economy, Econometrica, Review of Economic Studies, Journal of Labor Economics, Journal of Econometrics, Journal of the European Economic Association, Review of Economics and Statistics, Journal of Human Resources, Journal of Public Economics, American Economic Journal: Applied Economics, Journal of Development Economics, American Economic Journal: Economic Policy, and Journal of Health Economics.

early life shocks such as Almond (2006), Van Den Berg et al. (2006), and Bleakley (2007), are a decade old.

One reason for continued interest is that the large magnitude of the fetal origins effects that have been found, and the short time interval in utero suggest that in principle, Pareto improvements can be made by re-allocating resources from later to earlier in the life cycle. Given the common definition of economics as the study of the allocation of scarce resources (e.g., Blackhouse and Medema, 2009), this literature resonates with a core interest of economists: efficiency. Of course, the separation in time and across people (first the mother then the child) makes it far from obvious how this potentially high-return reallocation of resources can best be achieved.

A second reason for enduring interest in the Fetal Origins Hypothesis (FOH) is that it has proven to describe a surprisingly general phenomenon. Although FOH was first formulated as a specific theory about the effects of prenatal nutritional deprivation on chronic health conditions in adulthood (Barker, 1998), economists have found that a wide range of early life experiences matter and that many other (non-health) outcomes are affected. Outcomes of surpassing interest to economists, including IQ and wages, have been linked to early life influences, as have some newer areas of focus such as personality traits.

This evolving discovery speaks to another area of abiding interest for economics: the debate about nature versus nurture. It has become increasingly clear that we are shaped by many occurrences in early life which interact with our genetic endowments to either help or hinder us in reaching our potential and/or adapting to our environment (Manski, 2011). The FOH literature suggests that it may be possible to respond to entrenched disadvantage by altering the

environment in a way that promotes economic equality (Currie, 2011). Thus, the FOH remains important because it suggests that it may be possible to counter-balance forces leading to greater inequality (such as skill biased technical change) with investments in pregnant women, children, and their environments broadly defined.[2]

In addition to surveying studies that focus on shocks that occur while the child is in utero, this review considers shocks in early childhood. Angrist and Pischke (2010) herald a "credibility revolution" in which clear *a priori* definitions of treatment and control groups combined with time-series variation in environmental conditions help to generate sharp predictions. The FOH hypothesis lends itself to "severe tests" (Dinardo, 2007) given that the in utero period is very well defined, and children subjected to an external shock in utero can often be compared to similar children born a little earlier or later, who escaeped the shock. The beginning and ending dates of the period of "early childhood" are less well defined than the period in utero making it somewhat more difficult to find clean "natural experiments." It is nevertheless possible to employ compelling identification strategies and we feel the majority of papers discussed in this review employ compelling research designs.

In view of the large number of relevant studies, we organize the review around a series of "handbook" style tables. In lyric opera fashion, the tables briefly summarize each study's highlights. We also report the datasets used, sample sizes, the empirical strategy employed, main results obtained, and any heterogeneity by subgroup in the tables. We have also tried to express

[2] In describing "Six examples of the Long-term Benefits of Anti-Poverty Programs", the White House's Council of Economic Advisers summarized recent research in this literature by economists, noting:

> *Economists have traditionally argued that anti-poverty policy faces a "great tradeoff" — famously articulated by Arthur Okun — between equity and efficiency. Yet, recent work suggests that Okun's famous tradeoff may be far smaller in practice than traditionally believed and in many cases precisely the opposite could be the case.*

the main effects both as a percent with respect to the outcome mean (when the outcome mean was provided in the paper) and in terms of a standard deviation (when the outcome's standard deviation was provided). To some extent, reporting estimates in % and in SD facilitates the comparison of the effects across studies when these focus on a similar outcome (e.g., test scores).

Consistent with the broader trend in economics, many of these papers pay particular attention to the use of large-scale administrative datasets. Beyond reducing measurement error and recording additional outcomes, the use of administrative data can help mitigate problems of selective attrition from surveys and the large sample sizes contribute statistical power to detect milder treatments. These tables largely speak for themselves, so rather than walk through them, we focus in the text on a few studies from each table in an attempt to draw some general lessons from the existing literature and to identify promising areas for future research.

We begin by providing a conceptual framework for our review in Section 1. This framework emphasizes the child's human capital accumulation process and parent's optimal investment decisions in the presence of in-utero and early childhood shocks given production functions and budget constraints. The framework can be used to elucidate potential pathways that underlie the empirical findings that we observe in the literature. Section 2 then provides an overview of the literature on the importance of "mild" shocks in the early years. In addition to new evidence about the wide range of factors that matter to child development, an important theme that emerges is that there is often considerable heterogeneity in the effects of specific shocks. Some of the heterogeneity in the effects of shocks may be due to parental responses that either exacerbate or mitigate the effects. Hence, we will also consider the evidence documenting some of these responses and their impacts in Sections 3.

In addition, a small but growing literature exploits situations where there are "two shocks" in order to either separately identify the effects of initial shocks and responses to them, or to investigate potential interactions between various types of shocks. Since this is an interesting and novel development that resonates with the theory of capacity formation (Heckman, 2007), some of these studies are highlighted in Section 4.

As discussed above, economists are beginning to investigate policy responses to the FOH. Recent contributions to this literature are reviewed in Section 5. A striking feature of the most recent literature is that the growing accessibility of administrative data has allowed researchers to conduct policy evaluation by linking current adult outcomes with past "exposures" to policies in a way that was not possible previously.

One practical difficulty with this approach is that it takes many years to see the effects of fetal or early childhood shocks on adult outcomes while timelines for policy decisions are typically much shorter. Thus, one of our conclusions is that it would be extremely useful to know more about the "missing middle" years, and whether long term effects can be predicted using indicators in early and middle childhood. This question is explored in Section 6. We summarize our impressions of the literature and its future directions in Section 7.

Because the literature is growing so rapidly and in so many directions, this review will not do justice to it all. To make the review more tractable we focus mainly on studies that appeared after our previous reviews were published, and we do not do justice to the "disaster" literature which relies on lethal natural catastrophes such as famines, pandemics, wars, and hurricanes, as natural experiments. Although these papers were very important in the emergence of the FOH, most economists now accept that disasters early in life are likely to have negative

long-term effects on survivors, i.e., that shocks which are "extreme enough" are likely to have persistent effects. Moreover, the fetal origins perspective will never be pivotal in a cost-benefit analysis of measures designed to forestall such disasters.[3] Even without the benefit of the recent economic and scientific evidence on the FOH, those suffering disaster often acted in a way to shield pregnant women and young children (such as by giving them larger food rations in a famine). Third, the long term effects of events that involved high mortality can be difficult to discern given the possibility of mortality selection. If the individuals most vulnerable to catastrophe die, then the remaining population could possibly be stronger on average. Selection can be a particular problem when risk of death is higher for groups with lower socioeconomic status, as it often is.

We will also neglect most of the research on conditional cash transfers, in part because it have been reviewed elsewhere (see for example, Fiszbein and Schady, 2009). In addition to these deliberate omissions, we will undoubtedly omit important studies by mistake, given how active the research area has become.

Section 1: Conceptual Framework

Following Heckman (2007), the production technology we consider is a two period Constant Elasticity of Substitution (CES) function:

$$h = A\left[\gamma\left(\bar{I}_1 + \mu_{1g}\right)^{\phi} + (1-\gamma)\left(I_2 + \mu_{2g}\right)^{\phi}\right]^{1/\phi} \quad (1)$$

[3] We do not intend to suggest that insight and nuance cannot be gleaned from the analysis of such events. For example, Anttila-Hughes and Hsiang (2013) study natural disasters and show that the short-run mortality effects are followed by arguably more important future disinvestments which occur with a lag and kill girls.

where *h* denotes health or human capital as assessed after childhood, A represents factor productivity, and $\bar{I}_1$ and I_2 are the investments made in the first and second periods (e.g., parental investments). The first childhood period is denoted with subscript *1* (e.g., in utero) and the second period of childhood (e.g., preschool years) with subscript *2*.[4] A bar superscript indicates that the first period investment is already set, and what is under consideration is the second period investment.

Following Currie and Almond (2011b), we assume that μ_{1g} is an exogenous shock to first period investments (e.g., during pregnancy) and μ_{2g} is an exogenous shock to second period investments (e.g., during pre-school years). The *g* subscript follows from the fact that exogenous shocks in observational studies typically appear at the group level, whereas the other components of investments, $\bar{I}_1$ and I_2 may vary at the level of the individual child. In general, we will consider the effect of investment shocks (μ_{1g} and μ_{2g}) holding fixed the child-specific investments during the first period of childhood. If we also hold fixed second period investments (i.e., $\bar{I}_2$ instead of I_2), then we might consider impacts from shocks on *h* to be "biological" (Royer, 2009). The parameter γ, where $\gamma \in [0,1]$, represents the weight each childhood period receives in the production of adult health (or more generally, adult human capital).[5] The parameter ϕ, where $\phi \in (-\infty, 1]$, denotes the extent to which investments in different periods are substitutes or complements, often a key question determining the efficacy of interventions.

We assume that parents make the investment decisions for their (only) child. Investments are costly, and are valued insofar as they improve *h*. The effects of investments on

[4] For simplicity, we consider only two childhood periods, however, this framework can be extended to any number of periods (Heckman, 2007).

[5] γ is the "capacity multiplier" in Heckman (2007).

h are traded off against parental consumption, i.e., parents maximize their utility, $U = U(C, h)$, which is increasing in both arguments. Parents have a budget constraint (expressed in monetary units) of:

$$Y = p_C C + p_I I_1 + p_I I_2/(1+r),$$

where Y denotes family income, p_c and p_I are the market prices of consumption and investment, and r is the interest rate. We assume a Cobb-Douglas utility function of the form:

$$\mathrm{U} = (1-\alpha)\log \mathrm{C} + \alpha \log \mathrm{h}, \tag{2}$$

and consider how the production technology can shape the observed investment response. In particular, we consider two "extreme" production technologies which have polar opposite predictions for the investment response. The first special case is one of perfect substitutability of investments. If $\phi = 1$, then production technology simplifies to:

$$h = A[\gamma(\bar{I}_1 + \mu_{1g}) + (1-\gamma)(I_2 + \mu_{2g})]$$

and optimizing parents set:

$$\delta U/\delta C^* = \delta U/\delta h \cdot \delta h/\delta I_2^*(1+r)/p_I.$$

So under this scenario:

$$\frac{1-\alpha}{C^*} = \frac{\alpha}{h} A(1-\gamma)(1+r)/p_I$$

$$\frac{1-\alpha}{y - p_I\bar{I}_1 - p_I I_2^*/(1+r)} = \frac{\alpha(1-\gamma)(1+r)/p_I}{\gamma(\bar{I}_1 + \mu_{1g}) + (1-\gamma)(I_2^* + \mu_{2g})}$$

$$I_2^* = \alpha(y - p_I\bar{I}_1)(1+r)/p_I - (1-\alpha)(\gamma/(1-\gamma))(\bar{I}_1 + \mu_{1g}) - (1-\alpha)\mu_{2g}$$

$$\frac{\delta I_2^*}{\delta \mu_{1g}} = -\frac{(1-\alpha)\gamma}{(1-\gamma)} < 0.$$

If the μ_{1g} shock is positive (e.g., prenatal Food Stamps), then optimized postnatal investments fall in response. If μ_{1g} is negative (e.g., prenatal stress), then postnatal investments increase in response. That is, period 2 investments are compensatory. When investment responses are compensatory, reduced form analyses of the impact of μ_{1g} will tend to understate biological effects (Royer, 2009).

Following Heckman (2007), we now consider the opposite extreme of perfectly complementary investments:

$$h = A\ \text{Min}\left[\gamma\left(\bar{I}_1 + \mu_{1g}\right), (1-\gamma)\left(I_2 + \mu_{2g}\right)\right].$$

Now optimizing parents[6] set:

$$\gamma\left(\bar{I}_1 + \mu_{1g}\right) = (1-\gamma)\left(I_2^* + \mu_{2g}\right),$$

so

$$\frac{\delta I_2^*}{\delta \mu_{1g}} = \frac{\gamma}{1-\gamma} > 0.$$

The period 2 investment response is now reinforcing. Attempting to ameliorate a negative prenatal shock is completely ineffective, so it is optimal to match period 1 investments (subject to weighting by γ) but consume the rest.

The takeaway from these two examples is that whether parents reinforce or compensate shocks can depend on the production technology. Above, we have assumed an "intermediate" substitutability in parental preferences between consumption and their child's *h*: Cobb-Douglas.

[6] For whom period 1 investments are "low", i.e., $\delta U/\delta C^* < \delta U/\delta h \cdot \delta h/\delta I_2^*(1+r)/p_I$.

By a similar argument, the substitutability of consumption and child outcomes *h* will also govern the response to early childhood shocks. That said, we might suspect that parameters of parental preferences are particularly difficult to modify.

We might think that in addition to low income, y, poor families face restricted access to production technologies. Given a productivity factor $A' < A$ for disadvantaged families, we would see worse child outcomes for equivalent income and investments. It is also possible that poor families have different values of γ and ϕ, which would generate more nuanced predictions for investments and child outcomes.

There have been few attempts to estimate this underlying production function (1), in order to directly measure the key parameters ϕ and γ, presumably because of the detailed data necessary and the strong assumptions which must be made in order to render the production function simple enough to be estimable (Cunha and Heckman, 2008; Cunha, Heckman, and Schennach, 2010). However, arguably this underlying framework serves to motivate, guide, and interpret the more reduced form and observational work that is discussed below.

The framework also lays bare the multiple mechanisms that can underlie a given empirical result. For instance, if we observe that parents do or do not make compensating later life investments in a child who suffered from an early life shock, is this because of parental preferences, budget constraints,[7] or the production function they are facing? Answering this question is important because without a knowledge of the mechanisms and responses, a policy designed to address this issue will be a shot in the dark.

[7] See page 1330 (bottom) and footnote 7 of Almond & Currie (2011b).

Similarly, given the different pathways through which a child's outcomes can be affected, it is not surprising to see pronounced heterogeneity in the effect of many shocks by parental education, income, and other indicators of socioeconomic status (such as race or gender in some contexts). Subgroups may be more or less exposed to correlated shocks that interact with the "primary" shock considered, either to magnify or to dampen its effect. And even within finely-sliced subpopulations, the same group-level shock can yield varying individual exposures. For example, a house that is airtight may let in less air pollution than a neighboring house that is drafty. Third, families have differential access to knowledge and resources that can be used to offset the effects of negative shocks. For instance, while some individuals may have access to credit markets or savings, others may be credit constrained. They may also have different preferences for such intervention. For example, in communities where gender discrimination is the norm, parents may not endorse interventions targeted to girls. Finally, children of low socioeconomic status may simply be located at a steeper portion of the production function, yielding a larger effect of a shock of any given size (Almond and Currie, 2011b).

Even our focus on the missing research on the "middle years" can be seen as a response to the difficulties involved in understanding the underlying production function for human capital. If it could be shown that outcome measures in middle childhood satisfied the "exclusion restriction" (that early childhood impacts adult outcomes only *through* observed outcomes in the middle years), this would greatly simplify the data requirements necessary to estimate a structural production function.

We should acknowledge that our stylized framework does not lend itself to considering dynamic complementarities -- the idea that "skill begets skill," or alternatively that stocks of

capacities acquired by period t-1 may make investment in period t more productive (Heckman, 2007). Nor does it do justice to "self-productivity" (Heckman, 2007) – which includes the idea that a given dimension of capacity may also affect the accumulation of another, distinct dimension.[8] For example, cognitive capacity might promote health (or vice versa). Were we to "force" dynamic complementarities into (1) and consider $\frac{\delta h}{\delta \mu_{2g}} / \frac{\delta h}{\delta \mu_{1g}}$, for instance, one would find that the interaction of such shocks is always positive (which departs from what some of the recent empirical literature finds as discussed below). Additionally, dynamic complementarities are defined by Heckman (2007) in terms of the return to investments and how they vary with the baseline s*tock,* which is absent from our stylized model. Thus, we will not attempt to model dynamic complementarities here but merely reiterate Heckman's (2007) definition, namely:

$$\delta^2 f_t(p, \theta_t, I_t)/\delta\theta_t \delta I_t$$

where *f* is monotone increasing in its arguments, twice continuously differentiable, and concave in *I*, *p* represents parental capabilities, and θ_t represents (a vector of) child capabilities. Heckman assumes that dynamic complementarities are positive. With instruments for both the baseline stock of human capital and for endogenous subsequent investments, we could shed light on the magnitude of dynamic complementarities without making assumptions about their sign or functional form.

In practice, it is often not empirically possible to distinguish between dynamic complementarities, self-productivity, and the possibility that parents (or society) invest more (or less) in children with higher baseline stocks of human capital in unobserved ways (e.g., Malamund, Pop-Eleches, and Urquiola, 2016). Nevertheless, distinguishing among these

[8] Along with "mechanical" effects on the same dimension.

alternatives remains conceptually important because the source of heterogeneity in the dynamic effects of shocks has implications for the effectiveness of remediation, and specifically, whether investments later in childhood can reduce or eliminate damage originating from the prenatal or early childhood period. For instance, if a child has cognitive difficulties as a result of being premature, a parent may respond by spending more time with the child, reading to them and assisting with homework. We may wish to examine the effects of these interventions, but the interventions themselves are endogenous to the child's state. Moreover, while we would like to be able to consider each potential investment as a stand-alone intervention, in reality many aspects of the environment are in flux at any point in time, and different types of investments may complement or substitute for each other. A few studies that attempt to address dynamic complementarities are discussed in Section 4 below, and illustrate the challenges researchers face. We begin below with the simpler case of single shocks experienced in early childhood.

Section 2: Make Mine Mild

Events and circumstances that are commonly experienced can have lasting effects on children's trajectories. For example, there is growing consensus that relatively mild nutritional deprivation at critical periods can seriously impair fetal and child development. In terms of our conceptual framework, both $\delta h/\delta \mu_{1g}$ and $\delta h/\delta \mu_{2g}$ may be sizable, even when the shock considered is small in magnitude relative to total investments or short in duration. Critically, "mild" prenatal shocks are much more common than extreme ones like famine. Table 1 summarizes much of the recent literature about mild shocks, which are divided into several categories including: nutrition, stress, disease, pollution, weather shocks, and alcohol and tobacco. The last column reports on heterogeneity in the estimated effects on different groups, a

format that is followed in all the Tables that follow. With some exceptions, these papers aim to capture the biological effect of early-childhood shocks, implicitly assuming that second period investments are unresponsive to the shocks and fixed ($I_2 = \bar{I}_2$).

a) Nutritional Shocks

Panel A of Table 1 summarizes some of the recent literature on nutrition-related shocks. Fasting is of broad interest as roughly three-quarters of the world's 1.6 billion Muslims spent some portion of the *in utero* period during Ramadan.[9] Almond and Mazumder (2011), Almond, Mazumder, and Van Ewijk (2015), Hoffman (2014), and Greve, Schultz-Nielsen, and Tekin (2015) all study the effects of Ramadan fasting during pregnancy. Ramadan cycles through the calendar, enabling the effects of Ramadan fasting to be separated from seasonal variation in nutrition. Moreover, most people break their fast at sun down so that the fasting is only for a limited period of time during the day. Nevertheless, this mild and brief nutritional deprivation appears to have effects on sex ratios (reducing the number of boys who appear to be more likely to be miscarried). For example, there are large effects on sex ratios among children of Arabian descent in Michigan. Perhaps surprisingly in view of relatively modest effects on birth weight, prenatal Ramadan exposure is estimated to have pronounced effects on adult outcomes in a wide variety of settings (e.g., Uganda, Iraq, Indonesia, England, and Denmark), including to educational attainment, test scores, adult anthropometrics, mental disability, and wealth measures.

[9] Almond, Mazumder, and Van Ewijk (2015) speculate that meal skipping, dieting, and morning sickness may all exert similar effects in non-Muslim populations. For example, Almond, Edlund, Joffe, and Palme (2016) find that severe morning sickness also reduces the likelihood of male birth in Sweden.

Likewise, positive nutrition-related shocks can also have substantial effects even when relatively mild. For example, Linnemayr and Alderman (2011) examine nutritional supplementation for pregnant women and 0 to 3 year old children in Senegal and find that supplementation during pregnancy has a significant effect on the weight-for-age of toddlers, but that post-birth supplementation had little impact, suggesting the uniqueness of the in utero period (a common refrain in the literature). Two papers by Feyrer, Politi, and Weil (2013) and Adhvaryu et al. (2016) build on Field, Robles, and Torero's (2009) ground breaking study of the effects of iodine deficiency in Kenya. The more recent studies use historical data about the rollout of iodine fortification in the U.S. Because the rollout took place at different times in different places, it is possible to identify the effect of early exposure and to show that it improved both female labor force participation and the probability that male World War I recruits were assigned to the Air Force (a marker for ability). They thus provide additional evidence that relatively mild nutritional deficiency can have large negative long term effects even in otherwise high-resource settings.

Adhvaryu et al. (2016) also analyzes measures of parental investments in children, albeit coarse ones, and find evidence that postnatal investments responded to the shock. In particular, they argue that postnatal vaccinations and breastfeeding behaviors reinforced the prenatal shock, i.e., $\frac{\delta I_2^*}{\delta \mu_{1g}} > 0$, so their reduced form estimates overstate the biological effect. As discussed above (and further in Almond and Currie, 2011b), to the extent that period 1 and period 2 are complements, there are stronger tendencies for parents to reinforce endowment shocks.

Ludwig, Rouse, and Currie (2013) show that maternal weight gain during pregnancy predicts childhood obesity in the context of sibling fixed effects models. This study is based on

birth certificates for several entire cohorts of children born in Arkansas, which were linked to "body mass index (BMI) report cards" issued by the schools. It is one of an increasing number of studies that show how new access to large-scale administrative data sets can shed light on FOH questions.

Fitzsimons and Vera-Hernandez (2014) use a novel instrumental variables strategy for postnatal nutrition, focusing on non-C-section births to U.K. women. They note that mothers of infants born on weekends are less likely to receive breastfeeding instruction, and are correspondingly less likely to go on to breastfeed. Using this variation, they find large effects of breastfeeding on cognitive development. However, the IV approach involves strong exclusion restrictions, in this case that there is nothing else about being born on a weekend (or about having a scheduled C-section) that might lead to poorer outcomes (such as different preferences, inferior nursing care, or less access to specialists).

As a group, these studies support the hypothesis that relatively ordinary variations in nutrition (positive and negative) that are within the experience of many contemporary families even in rich countries like the U.S. and the U.K., have the potential to impact children health both at birth and in the longer term.

b) Prenatal Maternal Stress

Panel B of Table 1 focuses on the impact of maternal stress during pregnancy on fetal outcomes. While the idea that excessive stress has negative health effects is widespread, it is difficult to assess. Cortisol, the most common biometric measure of stress, is not available in most health datasets and also varies widely over the course of a day, which even longitudinal cortisol data do not solve *per se*. In the absence of a direct measure of stress, the most common

approach in the literature is therefore reduced form: Evaluating whether an exogenous event that is likely to have caused maternal stress can be shown to have affected children.

Currie and Rossin-Slater (2013) identify women in Texas who lived in the announced potential path of major hurricanes during pregnancy. It is important to note that most of these women were not in the end affected by the hurricane, so this is not a disaster study in the usual sense in that it is possible to separate the effect of stress from the direct economic or health effects of the event. They highlight an issue that often arises in the fetal effects literature, which is that infants with longer gestations are more likely to have been exposed to any periodic shock because they have a longer exposure window. Since infants with longer gestations are healthier, other things being equal, this mechanical relationship tends to bias the estimated effect of shocks towards zero. They use a sibling fixed effects framework to compare affected to unaffected children and they address maternal mobility, an issue that frequently arises in a sibling fixed effects framework. The problem is that mothers may well respond to a shock by moving. In that case, changes in locational characteristics or exposure between the siblings are endogenous to the shock. This issue is addressed by instrumenting actual exposure with measures of "potential exposure" created by assuming that mothers stay in the same place that they were first observed, and that all gestations last exactly nine months. This counterfactual exposure is in fact highly correlated with actual exposure because most mothers do stay in the same place, and most gestations do last nine months. They conclude that stress increases the probability of an abnormal condition of the newborn, but they found no effects on the incidence of low birth weight or gestation length, two of the more common measures of fetal health.

Persson and Rossin-Slater (2016), and Quintana-Domeque and Rodenas-Serrano (2016) study the effect of more severe emotional shocks including, the death of a family member in Sweden, and terrorist attacks in Spain, respectively. The former uses Swedish registry data to follow affected children up to age 30. An important innovation of their study relative to some earlier work on the same question is that they compare mothers who lost a family member while pregnant, to mothers who lost a family member in the year after birth. Since families of lower socioeconomic status are more likely to lose family members, and since losing a family member could well have an economic impact, this design is cleaner than comparing mothers with a death in the family to mothers without such an event. While the effects on birth weight are small overall, they appear to be concentrated in the lower tail of the distribution, with a 20% increase in the incidence of low birth weight (birth weight less than 2500 grams). In a second contribution, they are able to follow affected infants into adulthood, and they find negative effects on mental health outcomes measured using prescription drug data. For instance, affected individuals are 23% more likely to use ADHD medication, and 9% more likely to use antidepressants as adults. Quintana-Domeque and Rodenas-Serrano also find small but significant effects of terrorist attacks in Spain on overall birth outcomes.

Lee (2014) asks whether the grandchildren of women who suffered a severe stress are less healthy? This is a particularly exciting direction for future work, given that thus far, there is not a great deal of research on intergenerational effects of in utero shocks in humans, although they are known to exist in animal models. In this case the initial shock is was a massacre of civilian demonstrators by the civilian military. He finds small but significant effects on the incidence of low birth weight and prematurity in the grandchildren, with the largest impacts for grandmothers who suffered the shock during the second trimester that the mothers were in utero.

Aizer, Stroud, and Buka (2016) have made an exceptional contribution to this literature because the data they use (which was collected by a consortium of perinatal centers in the 1960s) actually includes measured stress during pregnancy using cortisol. The data set includes a large number of sibling pairs, so that it is possible to conduct mother fixed effects analyses. They find that infants exposed to higher cortisol levels during pregnancy have up to 1 year less school at age 7 than their siblings, indicating that they have been delayed in starting school or held back. Given rich background information on the mothers, this study is also able to ask which infants are most affected by higher maternal stress levels? They find that children born to less educated mothers suffer larger impacts of exposure to a given cortisol level, suggesting that perhaps there were fewer resources available to buffer the impact ex-post.

We have included Aizer's (2011) study of the impact of assault (overwhelmingly due to domestic violence) in this Section of the table even though domestic violence can have direct effects on fetal health in addition to causing maternal stress. Our justification for doing so is that domestic violence is quantitatively important and vastly understudied as a source either of stress or physical injury. The study is based on California hospital discharge data linked to birth records. Variation in the probability of assault is induced by the strengthening of laws against domestic violence, which occurred at different times in different California counties. She finds that domestic violence has a large negative effect on birth weight. Since women of lower socioeconomic status are more likely to be assaulted, violence is therefore an additional cause of disparities in birth outcomes.

c) Infectious Disease

Panel C of Table 1 deals with recent evidence about the effects of disease. Some diseases that have only mild effects in adults are known to have devastating effects on a developing fetus (e.g., Rubella, Zika), while others, like pandemic influenza killed millions and have also been shown to have effects on fetuses in utero. Recent studies focus on the related questions of whether milder diseases can have serious effects; whether the effects of early life exposure to disease are long-lasting; and whether there are spillover effects of disease eradication to children who were not directly targeted. The studies we summarize cover a wide range of settings, from impoverished areas of developing countries, to the historical U.S., to modern Denmark.

The studies by Baird, Hicks, Kremer, and Miguel (2016) and Oizer (2014) build on the famous "worms" paper of Kremer and Miguel (2004) in which the authors investigated the effect of giving children de-worming medication on school attendance and on whether neighboring children were infected with parasites. The new studies ask (respectively) how the effect of deworming affects outcomes of affected children 10 years later, and whether other children benefited from the deworming of their neighbors. Significant and positive effects of deworming are found on virtually all outcomes examined. Unfortunately Oizer does not examine exactly the same outcomes as Baird et al., so it is hard to compare the effects on index children to those on their neighbors, but in keeping with the original paper, deworming initiatives definitely appear to be very cost-effective.

Bhalotra and Venkataramani (2013) and Beach et al. (2016) focus on water borne diseases in Mexico in the 1990s, and in early 20th century America, respectively. The former examine the effect of a clean water reform in Mexico in 1991, which reduced the incidence of water borne diseases, including diarrhea, one of the most common causes of mortality and

morbidity among infants. Beach et al. (2016) use typhoid mortality rates as a proxy for water quality. Bhalotra and Venkataramani find significantly positive but quite small effects of the reduction in water-borne diseases on test scores at ages 9-15. These estimates may understate the effect of clean water given improved survival of the weakest infants, who may end up with low test scores for reasons unrelated to water-borne disease. The Beach et al. estimates appear to be larger: They estimate that moving from the top of the typhoid distribution to eradication would increase educational attainment in surviving children by 1/3 of a year and increase earnings by 4%. This larger effect is unsurprising given that typhoid is at the extreme end of potential severity of water-borne contaminants and many of the contaminants addressed by the water campaigns studied by Bhalotra and Venkataramani would have caused less severe disease. Thus, a possible interpretation is that more severe shocks have a greater impact than less severe shocks but with only two data points it is impossible to say much more about the shape of this relationship.

Venkataramani (2012) builds on work by Bleakley (2010) and others on the long-term effects of malaria. He finds large effects of malaria eradication in the birth year, consistent with those previous studies. Currie and Schwandt (2013) focus on a much milder and currently more common disease: Seasonal influenza. While Almond (2006) showed that the Spanish flu epidemic of 1918 had long lasting effects, it was a killer disease. Currie and Schwandt show that even a relatively mild disease such as seasonal influenza can have negative long term effects if a fetus is exposed at the wrong time during pregnancy. They show that in the contemporary northeastern U.S., infants conceived in May have a much higher probability of preterm delivery (and hence of low birth weight) than infants conceived at other times because they come to term

at the height of the flu season. Moreover, the H1N1 flu season of 2009 was earlier and more virulent than usual and the spike in prematurity was correspondingly earlier and larger that year.

Schwandt (2016) and Ward and Phipps (2014) follow up on these observations by examining the long-term effects of exposure to flu in utero in Denmark and Canada, respectively. Schwandt examines rich individual longitudinal Danish registry data about women who were hospitalized with influenza and follows their children into adulthood. He finds that earnings are 10% lower for affected individuals, and that they are much more likely than others to be dependent on welfare. These long-term outcomes are driven by maternal admissions during the 2nd and 3rd trimester. Ward and Phipps (2014) exploit province-level data on influenza rates to identify the effects of exposure. They do not find any overall effect of an additional week of flu exposure during the pregnancy, but do find a small effect of additional weeks of exposure during the 1st trimester on test scores and on the probability of having a chronic condition. Given that the richness of the Schwandt data it seems that for now, the presumption should be that his conclusions about the timing of the impacts are more likely to be correct. However, the larger message is that millions of children may be harmed in utero by exposure to relatively mild diseases even in rich countries.

Bhalotra and Venkataramani (2015) examine the long-term impact of the introduction of sulfa drugs in 1937, which reduced pneumonia mortality but presumably also had positive effects reducing morbidity.[10] Combining historical data with the U.S. population Census, cohorts who were exposed to sulfa drugs in their infancy attained 0.1 more years of schooling, were 1.5% more likely to graduate from high school, more likely to be employed (0.4%), and earned higher

[10] An earlier paper Jayachandran, Lleras-Muney, and Smith (2010) established that the introduction of these drugs did indeed lead to large declines in mortality from causes such as infections after child birth and pneumonia. Bhalotra and Venkataramani focus on the effects of the introduction on cohorts of children at older ages.

wages (1.5%). Long-term benefits varied for African-American men who were exposed to different levels of segregation in their state of birth, suggesting that despite a strong economic climate (better early life conditions), institutional environment affects the rewards to investments in human capital.

d) Pollution Exposure

The last few years have seen an explosion of research on the effects of pollution in early life, much of which is summarized in Panel D of Table 1. Certain pollutants are well measured in developed countries, exhibit variation over time and across small areas, and have published thresholds which lend themselves to asking whether pollution below the threshold can also be shown to have an adverse effect. Moreover, many sources and types of pollution have been increasingly well documented in recent years, and have discrete beginning and ending dates (such as pollution due to industrial plant openings or closings) that assist identification.

Relative to the literature discussed in our earlier reviews, much of the newest literature focuses on documenting the long-term effects of fetal or early childhood exposures, often relying on newly available large-scale administrative data sources to track children over time. For example, Isen, Rossin-Slater, and Walker (2015) look at the effects of reductions in air pollution due to the Clean Air Acts of 1970 on the employment and earnings of adults who were affected in very early childhood. The Clean Air Acts (CAA) mandated that pollution reduction measures be implemented in counties that were above thresholds for target pollutants. Counties just below these thresholds were not required to clean up. The legislation thus lends itself to analysis using a regression discontinuity framework. In order however to examine outcomes, it is necessary to

merge data from several large administrative data sets, some of which are held in Census data centers.

Specifically, they start with the Census Bureau's Longitudinal Employer Household Dynamics (LEHD) file, which records a worker's unemployment insurance covered earnings each quarter. The authors focus on 24 states that appear continuously in the LEHD and on individuals who were born in these states. The payoff to all this careful data work is that the authors are able for the first time to link air pollution changes around the time of birth to adult earnings and employment. They find an estimated gain of $4,300 in earnings per person for a total of $6.5 billion (2008 dollars) in gains.

Another focus of the literature on pollution and early childhood is to ask whether there is heterogeneity in the effects of pollution. There are many reasons to expect disparate impacts of the same potential exposures. For example, more educated people may be more knowledgeable about ways to protect themselves (i.e., have access to a different production function), or may be more likely to take measures that compensate for the harmful effects of pollution (perhaps because of looser budget constraints). They may even be more likely to move away from known pollution sources while the child is still young (Currie, 2011). Richer people may live in housing that insulates them from the effects of pollution, for example, by having houses that are more airtight, or houses that are physically located slightly further from sources such as freeways or factories.

The literature does generally find more negative effects of pollution on more disadvantaged people, whether disadvantage is defined in terms of minority race, income, or education. The only study in Table 1 that finds the opposite is Black et al. (2014) who study the effect of radioactive fallout from nuclear tests on Norwegians born in the 1950s and early 1960s.

In this one case, they find that the effects of potential exposure are greater for the more educated, perhaps because people were unaware of the danger and more educated people were more likely to spend time out of doors (echoing earlier findings by Lleras-Muney for ozone, 2010).

Billings and Schnepel (2015) offer some evidence that the negative effects of early-life pollution exposure might actually be reversed with appropriate interventions, which can be interpreted as evidence about the substitutability of investments in different life periods. The authors show that children who were lead poisoned in Charlotte, North Carolina, and who also received an intense intervention comprised of education for caregivers, lead remediation services, nutritional and medical assessments, and other nutritional benefits from the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC), experienced reductions in antisocial behavior and substantial improvements in school performance relative to peers who did not receive these services because they had slightly lower blood lead levels. Since we know that the physical effects of lead are irreversible (once deposited in the brain for example, lead tends to stay there), this result offers hope that compensation for early life insults is possible even when the physiological effects of such insults cannot be reversed.

e) Weather and Climate Change

With increasing scientific consensus about the reality of human induced global warming, economists have responded to concerns about the short and long term effects of climate change on young children. These studies generally extrapolate from what is known about the effects of short-term variations in weather, including periods of high temperature, variations in the amount of sunlight, drought, or flooding. These studies are summarized in Panel E of Table 1. Of these papers, only the one by Wernerfelt, Slusky, and Zeckhauser (2016) is arguably really about

weather effects per se. The authors find that exposure to sunlight in utero is associated with lower incidence of asthma in affected U.S. cohorts, a result that they attribute to the effect of vitamin D on lung development in utero.

The remaining papers find effects that may work through economic mechanisms as well as through biological pathways. In terms of the Section 1 framework, these papers are implicitly considering the optimized response of h to ΔY (changes in parental income). Given the budget constraint in Section 1, a negative income shock would reduce investments in children in both period 1 and period 2 so as to equate marginal utilities of parental consumption and investing in children (at a higher level). If the marginal utility of consumption increases substantially with reduced consumption, child investments will need to be reduced even more. This may be particularly true at low baseline levels of consumption.

Several studies focus on weather shocks in rural populations where conditions outside the norm may lead to income losses by affecting crop yields; this may be a major pathway through which weather affects child outcomes. For example, Agüero (2014) examine the effect of high temperatures in a nationally representative sample of Mexicans, and find that higher temperatures during early childhood are associated with lower adult height. The effects are greater in poorer districts which could be either because people in those areas are less able to shield themselves through, for example, air conditioning (i.e., a biological effect working through the production function), or because many poorer parts of Mexico are agricultural and heat may cause crop losses (an economic effect working through the budget constraint). One limitation of the work to date is that it is often impossible to distinguish between these pathways.

The remaining papers in Panel E deal with fluctuations in rainfall, which are probably even more likely to lead to crop loss, and thus to affect outcomes primarily through economic channels. The Shah and Steinberg (2016) study is interesting in that it finds that drought has a positive effect on children's educational attainment in India. They explain this finding by arguing that in India, developments that prevent children from working in the fields may benefit their education. In the context of the model sketched above, one would have to add children's potential earnings to the budget constraint and allow weather to affect the market wage for children's labor (and thereby the opportunity cost of schooling investments) in order to capture this effect.

f) Effects of Alcohol and Tobacco on Fetal Development

Finally, Panel F of Table 1 considers three recent papers discussing the effects of alcohol and tobacco control policies on fetal development. While it is well known that alcohol and tobacco can harm the developing fetus, these studies focus on heterogeneity in the effects of policy, and on longer-term effects. Von Hinke, Kessler, and Scholder et al. (2014) find long-term effects of maternal alcohol consumption during pregnancy on children's test scores up to age 16 in data from the Avon Longitudinal Study. This study uses genetic variation in the mother as an instrument for alcohol consumption. Causal interpretation of an alcohol effect requires the assumption that the genetic variation in question has no effect other than through maternal alcohol consumption, which is questionable since currently scientists have relatively little understanding of the multiple pathways through which an observed genetic variation may impact a person. That is, even if we knew with certainty that a particular gene was associated with alcoholism, it might also be independently associated with cognitive problems in the

offspring. An additional concern about the use of genetic data as instrumental variables is that genetic effect sizes are often very small and therefore raise possible concerns about weak instruments.

Using register data from Sweden, Nilsson (2015) investigates the long-term effects of a policy that permitted strong beer sales in grocery stores, which resulted in a temporary and sharp increase in access to alcohol among young people. He finds that cohorts affected *in utero* early in pregnancy had 24% lower earnings at age 30, as well as lower cognitive, non-cognitive, and educational outcomes. Effects were particularly concentrated on males and among children from low-income families. Boys were also more likely to be premature or spontaneously aborted than girls. In terms of equation (1), Nilsson (2015) floats the possibility that boys and girls have different values for ϕ.

Bharadwaj, Johnsen, and Loken (2014) study the effect of smoking bans in Norway. The authors are able to identify mothers who worked in bars and restaurants while pregnant. They find significant effects on health at birth and also on adult income at age 28, but the effect of the reform is much stronger for mothers who were smoking at the start of the pregnancy, suggesting non-linear effects of tobacco exposure.

Simon (2016) examines the effects of changes in state-level tobacco taxes in the U.S. on maternal smoking and child health and finds that higher taxes were associated with fewer days absent from school, and reductions in the utilization of medical care, as well as with 16% fewer asthma attacks. These effects are much greater for the least educated mothers. Barreca and Page (2015) use a similar design to consider state-level changes in minimum legal drinking age laws

and find improvements in birth outcomes among affected cohorts of women. Their estimates are also suggest improvements in the survival of black infants to term.

An economic model of a parent's choice to use alcohol or tobacco while pregnant is complicated by the fact that while in the short-term the parent trades off utility from their own consumption against the investment in a child's health, their actions also directly affect the return to future investment in child health. That is, future investments are likely to be less productive if the child is damaged by fetal alcohol syndrome, for example.

Section 3: Parental Investments

The evidence in Section 2 shows that relatively mild shocks can, if delivered at the right or wrong time, have lasting positive or negative impacts on the developing fetus and young child. The question arises then as to whether there are parental investments that can mitigate the effects of negative shocks. Conceptually, this question centers on the parameters of the CES production function ϕ and γ.[11] Knowing that period 1 investments have a large effect on *h per se* tells us relatively little about the effectiveness of period 2 investments, including whether damage from a period 1 shock can be remediated by additional period 2 investments (whereas knowing ϕ and γ would take us closer).

A related question is how parents respond to positive or negative shocks to one of their children: Does I_2^* change in response to μ_{1g}? Framed this way, the question does not require assumptions about the production technology for *h* or parental preferences. That said, various underlying concepts from the model will govern any observed investment response. These include parents' preferences (for instance, does the parent wish to equalize outcomes or to

[11] Additionally, it depends on the relative sizes of $\bar{I}_1$ and $\bar{I}_2$. See Section 2.1.1 in Almond and Currie (2011b).

maximize the total productivity of their offspring), and the constraints that they face.[12] For instance if a parent cannot afford the cost of intervening to help a disabled child, but can afford basic investment in a non-disabled sibling, then their choice may well be obvious. If many parents are constrained in their investments, then social investments may have an important impact on parent's choices by changing the productivity and cost of their own investments. Thus, distinguishing between behavior due to preferences and behavior due to constraints can be a key input to intelligent policy responses. Moreover, as Heckman (2008) points out, it may be the case that timing matters. The productivity of current investments may depend in important ways on whether past investments have taken place.

Table 2 summarizes some of the recent literature on parental investments. Hsin (2012) was one of the first papers to consider that parental investments in their young children may reflect not only preferences, but also constraints. Using sibling fixed effects models and employing data from the Panel Study of Income Dynamics (PSID), she showed that college educated mothers compensate low birth weight children (i.e., invest in order to try to equalize outcomes) while less educated mothers tended to concentrate resources (such as reading, playing, and doing hobbies) on higher birth weight children. A limitation of her study is that the number of low birth weight children with low birth weight siblings is quite small in the PSID so the results are suggestive rather than definitive about the behavior of U.S. parents.

Breining et al. (2015) find evidence consistent with parents trying to equalize outcomes between siblings. They use Danish registry data and examine children whose siblings were either

[12] The returns to investment are governed by the elasticity of substitution of investment made at different stages of childhood. These returns have an impact on whether parents compensate versus reinforce, whatever their preferences are. For example, if a parent wants to compensate, but there are no suitable investments available or their return is low, then he or she will might well choose to invest in another child which would have the effect of reinforcing differences.

just above the 1500 gram threshold used to classify children as very low birth weight or just below it. Children just below the threshold were found to receive more care and be healthier subsequently (as in Almond, Doyle, Kowalski, and Williams, 2010). The novel finding is that their siblings also do better in school, which suggests that medical intervention for the very low birth weight child benefitted all the children in the family. One interpretation of this result is that parents would otherwise have sacrificed the well-being of the healthy children in order to focus on the more vulnerable child. Alternatively, however, shocks to one child may work through the budget constraint to affect other children even in a rich country like Denmark where most medical care would be paid for by the state.

Akee et al. (2015) investigate the effects of a casino opening on the Eastern Cherokee reservation which resulted in an exogenous income transfer to tribal households. They find that parents reacted to the transfer by investing more in children who had lower levels of mental health and "worse" personality traits. This result seems to reflect preferences for equal outcomes—although the mechanism is a change in the budget constraint, the parent has a choice about which child to spend the "extra" money on. On the other hand, several studies in developing countries (Yi et al., 2014; Adhvaryu and Nyshadham, 2016) find evidence consistent with parents reinforcing initial differences between children which could reflect either preferences, ϕ, or budgetary realities.

Two studies of gender differences in investments also find opposite results for developing and developed countries. Bharadwaj and Lakdawala (2013) focus on India, China, and Bangladesh and find that mothers pregnant with a boy get more prenatal care and that boys are more likely to receive tetanus shots after birth. One only sees the difference in prenatal care

among mothers who had an ultrasound and so presumably know that they are carrying boys. However, in Canada, the U.S., and the U.K., Baker and Milligan (2016) find that parents of children aged 0 to 3 put more time into girls and that this time investment can explain as much as a third of the gender gap in reading scores in the early grades. It is possible that this pattern reflects mother's preferences for girls if mothers are the primary caregivers.

From this brief description of a number of studies, it should be apparent that there is no simple answer to the question of whether or why parents compensate or reinforce differences between their children.[13] It does seem that parents are more likely to reinforce differences in low resource settings, suggesting that the observed behaviors are at least partially a response to binding budget constraints in many instances.

The discussion above assumes that parents are making informed choices about investments in their children. Dizon-Ross (2015) investigates how parental investments responded to better information about children's academic performance using a field experiment in Malawi that targeted parents with young children. Results show that providing parents with information about how each child is doing causes them to reallocate their educational investments across children so that investments correspond more closely to their children's true achievement level.

[13]Fryer, Levitt, and List (2015) focus on a different but related question, which is whether we can incentivize parents to invest more in their young children? They organized a randomized trial in Chicago in which parents were rewarded for activities such as attending educational sessions about early childhood, completing homework assignments with their children, and for their child's demonstration of mastery on interim assessments. These tasks were chosen to improve cognition and executive function. They found that the intervention benefited white and Hispanic children, but not African-American children. Moreover, effects were bigger for children with better cognitive skills to begin with. This study may illustrate some of the limits of trying to improve children's outcomes by working to improve parenting skills.

Similarly, Cunha, Elo, and Culhane (2015) argue that U.S. mothers have poor information on the return to early childhood investments. They speculate that if the government could implement a policy that moved expectations from the median current belief to the true median return, that parental investments would go up by 4% to 24% and the stocks of cognitive skills at age 24 months would increase by 1% to 5%. If parents lack information about the likely impact of investments in their children, then once again their behavior cannot be said to reflect their underlying preferences; perhaps information could be modeled as an input into child health production such that parents with incorrect information end up optimizing with respect to the wrong production function.

Perhaps an overall take away is that economists have been too quick to interpret parent's choices as revealed preference when even a simple economic model suggests that factors such as available production technologies and budgets, not to mention information, are likely to be tremendously important.

Section 4: Sometimes Lightning Strikes Twice

In this Section (and in Table 3) we consider a handful of studies that attempt to examine dynamic complementarities empirically using cases where there were two shocks. These studies are often reminiscent of the first generation of fetal origin studies in their reliance on quirky and exotic instruments (which is why we characterize them as akin to being struck twice by lightening), and in the fact that it may be difficult to generalize some of their conclusions to other settings. Nevertheless, they represent the frontier in terms of trying to apply insights from the theory outlined in Section 1 to applied work in this area.

Aguilar and Vicarelli (2015) overlay variation from Mexico's conditional cash-transfer Progresa program on top of rainfall shocks induced by El Niño. They consider shocks that affected children both prenatally and up to age 2 and examine anthropometric and cognitive outcomes at ages 2 to 6. They did not find that Progresa mitigated any of the negative effects of weather shocks. In contrast, Adhvaryu et al. (2015) use a very similar design and ask whether Progresa mitigated the effects of rainfall shocks on cognitive test scores and years of education measured at ages 12 to 21. They estimate that Progresa offset 60 to 80% of the negative effects of rainfall shocks on child development. It is unclear whether these conflicting results are caused by subtle differences in the approaches taken, or whether it is really the case that one can see positive long-term effects even in cases where the immediate short-term effects appear to be negligible. Certainly much of the literature on early intervention programs has this flavor, finding initial effects that "fade out" by age 8 or 9 but then reappear in adulthood (Almond and Currie, 2011b).

Gunnsteinsson et al. (2016) examine data from a randomized controlled trial of Vitamin A supplementation in Bangladesh that took place between 2001 and 2007. In 2005, parts of the study area were devastated by a tornado. The authors find that tornado exposure in early pregnancy and early infancy had significant negative effects on birth weight and infant anthropometrics. However, they also find that infants treated with vitamin A at birth were effectively protected from the effects of experiencing a tornado shock at 0 to 3 months of age in that there did not appear to be any effect of the tornado on anthropometrics at 6 months. An unusual feature of this paper is the author's care in trying to entangle the optimal timing of the protective investment relative to the timing of the shock.

One difference between Gunnesteinson et al. and Advharyu et al., is the amount of time that occurs between the negative shock and the human capital investment. While in the case of the tornado in Bangladesh the interval between the shock and the vitamin A supplementation was only a few months, and the outcome was measured a few months after that, in the Progresa paper, the interval between the transfer and the weather shock was at least a decade. The temporal gap between the first and the second event may be relevant to identifying these interactions, as there may be behavioral responses from parents or teachers that could either reinforce or undo the impacts of the first or the second event, or both.

Rossin-Slater and Wust (2015) consider a somewhat different, but related and very important question of how different types of common public early interventions interact. They use Danish registry data to study the interaction of a nurse home visiting program that supplies visits shortly after birth, and a childcare program for three-year-old children. Both programs rolled out beginning in the 1930s and ending in the 1950s. They find that the childcare program had large and persistent effects on educational attainment and income, and reduced adult mortality. In an innovative twist, they also find that the benefits extended inter-generationally to the children of the originally treated children.

A surprising finding however given the dynamic complementarities hypothesis, is that the effects of child care programs were largest for children who had not had exposure to the nurse home visiting program as newborns. At first blush this finding seems the opposite of the "skills beget skills" concept that children who got off to a good start due to the home visitors would be better able to benefit from the child care program. A possible explanation is that the programs actually provide similar but complementary services. For instance, home visiting often focuses

on training parents about health and safety, as well as teaching them what they can expect developmentally from children of various ages. To the extent that a successful program trained parents to give better care at home, that might lesson the benefit of having better care in another setting. We are not aware of other studies of this type, so it is impossible to know how much the complementarities depend on the type of intervention, though it is reasonable to suppose that they would. Regardless, this handful of early two-shock studies establishes that estimating dynamic complementarities in a well-identified way is feasible with enough creativity and luck.

Section 5: How Do Resources Mediate the Effect of Early Life Events?

Broadly considered, there are two types of resources that can be expected to benefit children: Material resources (Y) and time inputs (I_t), which might be an argument in the production of child investments. In addition, parents of higher "quality" may be expected to make better use, on average, of the resources at their disposal (indeed, perhaps this should be considered as part of a definition of parent quality along with evidence of altruistic preferences towards the child). In equation (1), the productivity parameter A might be indexed by parental type, with $A^H > A^L$, where H represents "high" quality and L represents "low" quality. At the same levels of income, type "H" parents could achieve better child outcomes (and higher consumption) than type "L" parents. As we discussed above, one might think of higher quality parents as having access to a different production function than other parents. Accordingly, in this section we focus on policies that affect parental education as well as income and in-kind support and parental leave policy.

a) Effects of Material Resources

Many recent papers examine the effects of cash transfers on child outcomes in a range of settings. We can think of these policies as exogenously increasing Y, which according to (3), would increase both childhood investments and consumption. Aizer et al. (2016) assemble unique historical administrative data about the U.S. mother's Pension Program (a precursor to modern welfare programs). They ask whether being accepted into the program affected outcomes observable on WWII enlistment records or mortality risk (measured using age of death on death certificates). They find that being accepted increased longevity by 1.5 years on average, with larger effects in the poorest families.

Two papers, by Hoynes, Miller, and Simon (2015) and Dahl and Lochner (2012) examine the effect of the U.S. Earned Income Tax Credit Program (EITC). Although it is administered through the tax system, these refundable tax credits function rather like a Conditional Cash Transfer program in that they are mainly available to families who work and file a tax return, that is, they are conditional on working. Both papers exploit variation stemming from a significant increase in the generosity of the program in the mid-90s. The first study finds reductions in the incidence of low birth weight among mothers who benefited from the expansion while pregnant, while the second finds increases in a range of cognitive test scores, which are larger for children from the most disadvantaged families. One possible mechanism contributing to these effects is the positive link between EITC and mother's health (Evans and Garthwaite, 2014).

Black et al. (2014) and Milligan and Stabile (2011) consider cash transfers that are targeted to children (a child care subsidy and a child allowance, respectively). Like Dahl and Lochner, both also find significant improvements in a range of cognitive test scores. Milligan and Stabile find that these effects are mainly driven by boys.

Set against these generally positive findings is the paper by Del Boca, Flinn, and Wiswall (2014) which estimates a structural model based on observational data from a variety of data sets. Their estimates suggest that monetary transfers will likely have only small effects on children because most of the transfer is likely to be spent on other types of consumption, or on parental leisure. However, they are not measuring the effects of an actual transfer policy using design-based variation in that policy.

A second group of papers looks "near cash" programs supplying food aid. It is often argued that if the amount of an in-kind transfer is small relative to the household's budget for that item, then in-kind transfers will have much the same impact as cash. The studies of the U.S. Food Stamp program (now known as SNAP, the Supplemental Nutrition Assistance Program) by Almond, Hoynes, and Schazenbach (2011) and Hoynes, Schazenbach, and Almond (2016) find (respectively) that the roll out of the program increased birth weights, especially among African Americans, and that in the long-term the roll out reduced the incidence of metabolic syndrome (i.e., obesity, high blood pressure, diabetes, etc.) which in turn increased the economic self-sufficiency.

Rossin-Slater (2013) examines the opposite type of policy, which is closures of clinics providing WIC (Supplemental Nutrition for Women, Infants, and Children) in Texas in the late 2000s. WIC closures reduced WIC participation, reduced the probability that a mother gained an adequate amount of weight during pregnancy, and reduced birth weight. Similarly, Meckel (2015) finds that crackdowns on WIC fraud caused small retailers to exit the program and reduced mother's prenatal participation in WIC with negative effects on birth outcomes.

A number of studies look at the broader effects of economic circumstances on child outcomes. Arguably, good economic times may have effects not only through increasing family resources but also through increasing employment (with either positive or negative effects for children depending on the range of child care options available) and social resources. For example, more money may flow to schools and social services in good times. Hence, studies of the effects of business cycles may not tell us about precise mechanisms, though they do once again suggest the vulnerability of young children. The studies by Loken, Mogstad, and Wiswall (2012) and Adhvaryu et al. (2016) examine the oil boom in Norway and a cocoa price boom in Ghana, respectively. These find positive effects of good times with the impacts being felt disproportionately in low-income households.

Lindo (2011) and Carlson (2015) examine the effects of job displacement during pregnancy on health at birth outcomes. Lindo focuses on the father's job loss using data from the Panel Study of Income Dynamics and controlling for mother fixed-effects. Carlson uses data from notices filed under the Worker Adjustment and Retraining Notification Act aggregated at the county-month data to examine the effect of anticipated job losses. Both studies find negative effects on birth weight. Golberstein et al. (2016) go beyond examining effects on health at birth and examine children's mental health. The paper finds that a one standard deviation increase in the state unemployment rate has a negative impact on child's mental health (assessed using the Child Strength and Difficulties Questionnaire) and is associated with a 5.7% increase in the use of special education services for emotional problems. Given the nature of the shock examined (i.e., the Great Recession) and the magnitude of the effects on clinically meaningful outcomes, it would be interesting to know whether these impacts will persist over time.

Bharadwaj, Lundborg, and Rooth (2014) ask how low birth weight affects vulnerability to economic shocks later in life using Swedish administrative data and models with twin fixed effects. Their estimates suggest that a 10% increase in birth weight results in a one percent decline in the probability of using unemployment insurance during a recession as an adult. Conversely, using Dutch data, Scholte et al. (2015) find that individuals subjected to economic downturns early in life are more likely to have chronic diseases and functional limitations in old age.

Two studies by Gould, Lavy, and Paserman (2011) and Lavy, Schlosser, and Shany (2016) study the children of Ethiopian Jews who were air-lifted to Israel either as young children, or while in utero. Those children air-lifted to Israel experienced large differences in material conditions depending on where their families were assigned, and families had little say in this decision. Children who had running water, sanitation, and electricity in early childhood obtained more education, were more likely to be employed, and were less likely to have health problems in later life. Children air-lifted while in utero, faced different conditions during their mother's pregnancy compared to children air-lifted shortly after birth. Those children who experienced Israel's better conditions prior to 8 weeks of gestation did better on standardized tests and obtained more education. Perhaps curiously, these studies both find that the effects were concentrated mainly among girls. They attribute this finding to gender discrimination, particularly in Ethiopia and in the more backward parts of Israel. The idea is that parents would have been more likely to stint girls, so girls are particularly benefitted by relaxation of resource constraints. If this explanation is correct, then the result highlights the fact that the effects of a shock reflect both "biological" effects and the influence of social conditions, and that it is difficult to disentangle the two.

Rossin-Slater (2016) highlights a very different type of policy which also had the capacity to change many aspects of a child's living situation: Changes in U.S. laws governing paternity establishment. Many states adopted policies aimed at making it easier to establish paternity in the hospital. A goal of these changes was to encourage parents to marry. Since married families are generally better off than single-parent households, such a policy might be expected to increase the resources available to children (both in terms of income and possibly father's time). However, Rossin-Slater argues that any positive effect on marriage rates was offset by the fact that the law also made it easier for some mothers to gain child-support without marrying the father. Overall, she finds little effect on measures of paternal involvement or child health, but some negative effect on children's health insurance coverage and utilization of medical care, which may be a result of losing access to paternal employer-sponsored health insurance coverage. This is one of very few studies to explicitly consider the role of fathers in providing resources to households, something that it would be useful to see more of.

Chetty, Hendren, and Katz (2016) focus on the Moving-to-Opportunity (MTO) experiment that randomly offered families living in housing projects vouchers that enabled them to move. Combining MTO experimental data with administrative data from federal tax returns, the authors find significant differences in the later-life outcomes of children who moved when they were less than 13 years old. Moving to a lower-poverty neighborhood improved college attendance rates by 15% and earnings by 14%. Treated children were also 4% more likely to live in better neighborhoods as adults and 15% less likely to become single parents. In contrast, children who moved later in their adolescence either did not benefit or actually faced negative long-term impacts. One potential explanation for these differential effects is that moving to a very different environment as an adolescent could disrupt social networks and have other adverse

effects on child development. The authors discuss potential intergenerational gains to providing access to better neighborhoods to families in public housing, which ultimately could generate positive of these policies returns for taxpayers.

b) Policies to Promote Maternity Leave

If childhood investments are an increasing function of parental time, then maternity leave policies may increase investments at key developmental stages. Such policies appear to be predicated on the belief that the elasticity of child investments in (1) with respect to parental time is large in very early childhood. The key policy question is when specifically maternal (or paternal) time is most important? Recent studies focusing on the effects of maternity leave policy on child outcomes are summarized in Panel B of Table 4. At first glance it is difficult to see any consistent picture in these estimates. However, on closer examination, a story emerges in which facilitating short maternity leaves is highly beneficial, but extended maternity leaves do not have a positive effect. This pattern seems plausible if child investments are an increasing but concave function of maternal time or if the return to childhood investments is diminishing in the investment level.

Rossin-Slater (2011) studies the implementation of the Family and Medical Leave Act in the U.S., a federal law allowing women to take up to 12 weeks of unpaid maternity leave. The law superseded a patchwork of state laws, creating a good deal of variation which she exploits. She finds a positive effect on the birth outcomes of college educated women. These women are more likely than less educated women to have been able to afford to take unpaid leave. Similarly, Carneiro, Loken, and Salvanes (2015) study the effect of a 1977 Norwegian law which replaced a legal right to 12 weeks of unpaid leave with four months of paid leave and an additional right

to take 12 months of unpaid leave. They find that children of affected mothers got more education and had higher wages at age 30. Thus it appears that allowing some maternity leave in the first months of life was associated with better outcomes in these two examples.

In contrast, Baker and Milligan (2015), Danzer and Lavy (2016), and Dahl et al. (2016) study expansions of paid leave from 25 weeks to 50 weeks, 12 months to 24 months, and 18 weeks to 35 weeks, respectively. Baker and Milligan (2015) actually find some evidence of negative effects on children's test scores among boys and among children of more educated mothers. Dahl et al. (2016) find no effects on adult outcomes. Danzer and Lavy (2016) do not find any overall effect, but report that there was some benefit to the reform for children of more highly educated mothers, but negative effects among children of less educated mothers. Thus, although there is some disagreement about the magnitude and direction of effects, there is little evidence in any of these studies that long maternal leaves have overall benefits for children. One possible interpretation is that mothers who go back to work after the first six months manage, on average, to find child care that approximates the care they would offer in their own homes.

c) Policies to Promote Child Care

Panel C of Table 4 reviews recent work on the feasibility of investing in young children through organized child care. These studies are organized into three categories: Long-term follow-ups of small-scale demonstration programs; long-term follow-ups of large, publicly funded programs; and short-term results of more recent demonstration programs.

There is a good deal of previous work showing long-term effects of small-scale child care demonstration programs conducted using randomized controlled trials including Perry Preschool and the Carolina Abcedarian Program. We have reviewed these programs extensively

elsewhere.[14] Suffice it to say here, these studies involved interventions of medium and strong intensity (respectively) with groups of very disadvantaged preschool children. At the time these demonstrations took place the alternative was generally no preschool, rather than some other type of preschool, which is the default today.

Studies by Heckman, Pinto and Savelyev (2013), Campbell et al. (2014), and Conti, Heckman, and Pinto (2015) add to this literature by showing that the interventions had positive effects on a broader set of outcomes than had previously been considered. In particular, they find positive effects on personality traits, health behaviors, and health outcomes. All of these measures have been shown to have important impacts on employment and earnings, though the focus in evaluations of early childhood interventions is often solely on test scores. These studies also take care to correct their estimates for complexities such as attrition and imperfect random assignment, as well as for multiple hypothesis testing (i.e., the problem that if you test 20 hypotheses, it is likely that one of them will fail to be rejected with 95% confidence even if there are in fact no underlying causal relationships). It is increasingly well understood that it can be difficult to interpret results from some randomized experiments given these sorts of problems.

A second set of studies extend the large literature on the effects of public preschool programs in various ways. Havnes and Mogstad (2015) examine the effect of a Norwegian reform that extended publicly funded preschools. The availability of preschool varied across space and time, and the authors exploit this variation to identify its effects. A striking finding is that the reform increased the eventual adult earnings of affected children in the poorest households, but *reduced* the earnings of affected children in the richest households. The paper is

[14] For instance, Almond and Currie (2011b) review some of the studies evaluating these programs in Table 11, p. 1435.

therefore a very nice demonstration of the fact that childcare centers do not exist in a vacuum—hours in child care replace some other form of care for the child. If the care that is replaced is worse than the child care center, then one can expect improvements in child outcomes and vice versa. Of course income matters too. To the extent that child care allows women to work and earn more, their higher earnings may also benefit their children and could possibly offset a mild negative direct effect of child care. One would expect the marginal value of additional earnings to be higher in lower income households, even though more educated women are likely to earn more per hour.

A recent study by Baker, Gruber, and Milligan (2015) showed that the introduction of a universal child care program in Quebec led to negative effects on children's non-cognitive outcomes (with little gain in cognitive test scores), significant declines in long term self-reported health and life-satisfaction, and behavioral problems and criminal activity among boys. These results are quite consistent with those of Havnes and Mogstad because the modal child who was brought into child care as a result of the reform was a middle class child who went into a low-quality, hurriedly-created, child care facility.

Aizer and Cunha (2014), Gelber and Isen (2013), and Kline and Walters (2016) examine the U.S. Head Start program, a publicly funded program that originally served 3 to 5 year old children, but has increasingly served younger children as well. Aizer and Cunha (2014) focus on the roll out of Head Start in the mid-1960s using data from the National Collaborative Perinatal Project and find that children who were able to participate in Head Start had test scores that were 0.1 to 0.2 standard deviations higher at age 7 than those of their older siblings. However, like the parenting intervention studied by Fryer, Levitt, and List (2015), the effect was greatest for the

children with the highest initial endowments. Aizer and Cunha also examine the compensation vs. reinforcement question, and find that in this low-resource setting, parents invested more in highly-endowed children and that parental investments complemented investments from Head Start. Gelber and Isen (2013) focus on parenting practices in Head Start cohorts from the early 2000s who were followed as part of the Head Start Impact Study, a randomized controlled trial intended to examine the short-run impacts of Head Start. They also find that Head Start enrollment tended to increase parental investments.

Kline and Walters (2016) offer a re-examination of data from the Head Start Impact Study. Original analyses found that Head Start had some positive effects on children in the short run, but that these effects quickly "faded out." Kline and Walters point out that about a third of the children treated in the Head Start Impact Study were drawn from other publicly-funded preschool programs and that many of the controls attended other public preschools. One would not necessarily expect to see any difference between Head Start children and children in other similar public preschool programs. Ignoring this fact substantially overstates the cost of providing Head Start to the study children (since a third of them would have been receiving preschool at public expense anyway), and also understates the positive effects of attending a public preschool of some sort; Hence naive estimates substantially understate the cost-effectiveness of the program. Using estimates from previous work showing that short-term boosts in test scores are associated with long-term gains in outcomes (e.g., Garces et al, 2002; Chetty et al, 2011), they estimate that Head Start is likely to be a cost effective program. Interestingly, the eligible children who were not participating in the early 2000s were those with the highest potential benefits, suggesting that expansions that drew these children into care could be even more cost effective.

A common theme in these studies of public preschool programs in developed country settings is that a failure to consider the available alternatives to child care programs leads analysts to understate the positive social returns to expanding these programs.

A third group of recent studies (all randomized controlled trials) examine preschool programs in developing countries. The two papers by Attanasio and collaborators examine the effects of a home based psychosocial intervention program and a center-based preschool program that was implemented in poor Colombian towns. Both interventions find positive effects, though on different domains (cognitive test scores and height-for-age, respectively). Perhaps the main take away is that such publicly funded, large-scale programs can have positive effects even in very low resource settings. Gertler, Heckman, and Pinto et al. (2014) examine the long-term effects of an intervention to provide psychosocial stimulation to impoverished Jamaican children. An ambitious aspect of this project is that they attempted to track migrants, pointing out that in Jamaica, many successful people emigrate and are lost to follow up unless special care is taken to retain them in the study. This study finds large effects of the psychosocial intervention on adult earnings.

Taken as a whole, the studies summarized in Panel C of Table 4 add to the extensive literature on the potential for early intervention programs to improve children's short and long-run outcomes. Both high quality center-based programs and home visiting interventions appear to be effective and have the potential to influence many domains, including education, income, employment, health, and future health behaviors (see Almond and Currie, 2011b for a review of work on this topic before 2011).

d) Policies to Promote Medical Care

Much of the literature on the long-term effects of medical care in childhood exploits the revolutionary expansions of public health insurance (Medicaid) coverage to children in poor and near poor families that occurred in the U.S. during the 1980s and 1990s. But other rich countries have also made efforts to improve medical care for young children, and some of these investments have also been evaluated. Recent studies of the issue are reviewed in Panel D of Table 4.

One noteworthy study by Sievertsen and Wust (2015) uses rich administrative registry data from Denmark and exploits county-by-county variation policies mandating same-day post-birth discharge. Same-day discharge following normal deliveries was apparently implemented as a cost saving measure in a staggered way across Danish counties. They find that same-day discharge leads to a 75% increase in readmissions during the first month of life and also increases contacts with general practitioners. The largest effects are found for disadvantaged mothers (defined in terms of age, education, and income). The authors are able to link administrative data sets together in order to examine long-term effects of this policy change on 9th grade test scores. They find that the policy was associated with a .2 standard deviation decline in test scores in children born to disadvantaged mothers. While modest, this effect is in line with the effect sizes seen in many educational interventions and highlights the inter-relationship of health and cognitive achievement.

Bharadwaj, Loken, and Neilson (2013) examine infants in Chile and Norway and exploit the fact that infants below the 1500g threshold cutoff used to define very low birth weight received more intensive medical services than those just above this threshold. In addition to

finding significant effects on infant mortality in each country, they also find that more intensive medical care increased adult wages by 2.7% in Chile and by 1.8% in Norway.

Studies of the U.S. Medicaid expansions use a variety of methodologies and data sets, but generally rely on the fact that the Medicaid expansions were phased in at different rates across the states (although the expansions eventually became mandatory in every state). Brown, Kowalski, and Lurie (2015) use U.S. Internal Revenue data from tax returns which allows them to examine income and payroll taxes as well as college attendance as outcomes. Cohodes et al. (2016) use publicly available data from the Census, the Current Population Survey, and the Youth Risk Behavior Surveillance System to examine effects on educational attainment. Meyer and Wherry (2016) and Miller and Wherry (2014) examine effects on mortality using Vital Statistics data and on obesity, body mass index, and hospitalizations for endocrine disorders using data from the NHIS, while Wherry et al. (2015) look at hospitalizations and Emergency Room visits using hospital discharge data.

All of these studies find positive long-term effects of having been eligible for health insurance coverage in childhood, suggesting that improved access to medical care in childhood increases the health and productivity of adults. These findings are significant as Medicaid is possibly the largest U.S. policy engaging "fetal origins" linkages, and represents one of the largest social investments that has been made in U.S. children. There is some heterogeneity in the estimated long-term effects. The effects are strongest for African Americans (who were most strongly affected by the expansions, given their lower average incomes and resulting higher eligibility for public insurance). Brown et al. do not see race in the tax data, but find stronger effects on earnings among women than among men. The take away from these studies is that

even in rich countries where much of the morbidity is due to behavioral factors rather than infectious disease, improvements in access to medical care matter for long-term outcomes, especially among the disadvantaged.

e) Maternal Education

In Grossman (1972), more educated individuals are more efficient producers of health. Analogously here, it may be the case that better educated parents have A=$A^H > A^L$, which would yield higher child outcomes *h*, other things equal. As Currie and Moretti (2003) point out, maternal education is endogenously chosen, and has possible effects on many aspects of a woman's life,[15] including fertility choices. McCrary and Royer (2011) and Carneiro, Meghir, and Parey (2012) examine the effect of policies that affected the amount of maternal education. The first paper exploits discontinuities created by rules about age-at-school entry. The idea is that children who are slightly too young to enter school must wait a year and will be in lower grades when they reach the age at which they can legally leave school causing the marginal children to end up with less education than children who were just above the age cutoff for school entry. McCrary and Royer find little overall effect of additional compulsory education on either fertility or infant health, though for African-American women, they do find some reduction in the incidence of low birth weight.

This result contrasts with Currie and Moretti, who examined the effect of additional years of college education induced by having a college open in the mother's county when she was 17 years old. These openings were associated with large improvements in infant health, possibly

[15] There is no time budget in our stylized model. Were labor income a function of hours worked, then another margin for optimization would presumably be through the shadow price of parental time spent on investing in children. Increases in education could increase the return to work and shadow price of time spent investing in children, with ambiguous predictions on net investments given competing income and substitution effects.

through the mechanism of reducing maternal smoking. McCrary and Royer study a different margin (years of high school) and find no effect on smoking, so a possible explanation for these conflicting results is that the studies are looking at different margins presumably affecting different parts of the distribution of potential mothers. Carneiro et al. (2012) also focus on college education and instrument for education using variables such as tuition and distance to college. They find positive effects on child test scores, with slightly larger effects for African Americans.

In order to place these results in context, it is important to note that the fraction of U.S. women with less than a high school degree has fallen by more than 50% in the last 25 years, and there is increasing evidence that high school dropouts and those with only a high school degree fare similarly in the labor market (Card, 2009). Hence, college may be the key margin for maternal education to affect child health in the United States.

Section 6: The Missing Middle and Latent Effects

In order to examine the long-term impact of policies experienced as young children, researchers must wait patiently to observe a "fully formed" measure of h. For example, Hoynes et al. (2016), Dahl et al. (2016), and Isen, Rossin-Slater, and Walker (2016) study the impact of policies that were rolled out 30 to 40 years ago. In addition to the usual difficulties identifying policy effects, these studies must address the problems involved in tracking affected people or cohorts over decades. In the case of Hoynes et al. (2016) the problem was addressed by gaining restricted-access information on county of residence over time in the Panel Study of Income Dynamics, while the other two studies rely on administrative records that geocode county of birth.

Clearly, while long-term follow up is the most reliable way to assess whether a policy is effective in the long-term, it limits our ability to assess *current* or even recent policies within a reasonable amount of time. While economists may be particularly interested in adult productivity and earnings, skipping the middle years between early childhood and adulthood means that we have little idea about what typical developmental trajectories look like and how they are shaped by policies experienced over the life course. If we knew more about the relationship between early childhood, middle-childhood, and adulthood, it would aid us in making medium-term inferences about those early childhood policies that are likely to successfully impact adults. Our lack of knowledge also means that we are largely shooting in the dark when trying to compare the efficacy of programs targeted at very young children to those targeting older children. While there is a wide-spread perception that it is more cost-effective to focus on the very young, there is surprisingly little direct comparison of policies targeting different age groups.

An additional reason to be interested in the middle years, is that the limited amount that we do know presents some real puzzles. For instance, a common finding in the literature evaluating early childhood intervention programs is that there is an immediate gain in test scores, followed by "fade out" of test score gains in the early elementary school years (Almond and Currie, 2011b; Currie and Thomas, 1995). However, these same children tracked many years later often show positive effects of the intervention in terms of completed schooling attainment and other measures (Garces et al, 2002). Are the initial test score effects a "red herring" in that the intervention is really affecting something else that matters for future development (such as non-cognitive skills)? Or do the initial effects on cognition simply become latent for some period of time and re-emerge?

In many cases, data on the "missing middle" is simply unavailable. For instance, Isen, Rossin-Slater, and Walker know where people were born, and link information about their birth counties to their adult earnings records. Their data has no information on movement patterns between birth and adulthood, which is perhaps something that could be examined using tax records, as in Chetty et al. (2016). However, a few recent papers have begun to examine the effects of events in early childhood on outcomes during the school years.

A few of these papers have already been discussed. For example, in student register data for Pakistani and Bangladeshi families in England, Almond et al. (2015) examined whether Ramadan's overlap with pregnancy affects subsequent academic outcomes at age 7. They find that test scores are 0.05 to 0.08 standard deviations lower for students exposed to Ramadan in early pregnancy.

A few additional studies focusing on middle childhood are summarized in Table 5. Figlio et al. (2014) use the universe of births in Florida matched to data from standardized tests. They find that in models with twin fixed effects, increases in birth weight are associated with higher performance. The estimates are slightly smaller than those found in Black, Devereux, and Salvanes (2007) who conducted a similar investigation in Norway. Bharadwaj, Eberhard, and Neilson (2013) report very similar findings for Chile. A further interesting result is that the effects of low birth weight are largely stable between the ages of 9 and 14 in Florida, and between 1st and 12th grade in Chile.

Another approach to the problem of measuring trajectories is to try to develop better measures of fetal damage, i.e., quantifying μ_{1g} and μ_{2g}. We know for example, that low birth weight is an extremely crude measure of fetal damage, which while predictive, is certainly not

dispositive. There are babies who were low birth weight who seem to be just fine ex-post, and many babies who are not low birth weight but who nonetheless have developmental problems. Robinson (2012) attempts to distinguish between "brain sparing" forms of low birth weight, and low birth weight that is associated with evidence of brain damage. He does this largely by focusing on head circumference, which may feel uncomfortably close to the preoccupations of early eugenicists. His estimates suggest that there are no cognitive effects of low birth weight in the infants with brain sparing. However, his low birth weight infants were more likely than normal weight siblings to have congenital malformations, and vision, hearing, or speech abnormalities regardless of head circumference. Biomedicine has proposed some intriguing alternative metrics to birth weight, e.g., telomere length, methylation patterns, etc., but none that have gained widespread acceptance as yet.

The multidimensional nature of both investments (I) and outcomes (h) (Heckman, 2007) is one reason for the measurement problem. It is unclear whether any unidimensional metric will ever fully capture the effects of early childhood policies and investments insofar as they will impact later life outcomes. At present, waiting until cohorts reach adulthood to observe effects remains useful, though it is severely limiting. For example, how do we know today whether policy A or B will have bigger long-term effects? Presumably this is where a structural, well-calibrated model of investments in early childhood and human capital formation could help to fill the gaps in our knowledge. In addition, a potential avenue of research could be the development

of "sufficient statistics" to identify key reduced-form elasticities that summarize the human capital effects of early life shocks or investments.[16, 17]

Section 7: Discussion and Conclusions

We now know that variegated shocks, some of them relatively mild and brief, can have lasting measurable impacts on child outcomes. Many authors start from the basic, scientific perspective of asking whether shock *X* has a casual effect on outcome *Y*. While that is an important question, it is reasonable to ask whether, given all of this research, we can say anything yet about the relative magnitudes of the effects and in particular, about which investments and interventions would be most cost effective in terms of improving young children's future outcomes? Answering this question is hampered by the wide range of both shocks and outcomes that have been considered. However, at this point a large number of studies have examined three types of outcomes: Birth weight (and low birth weight), test scores, and wages -- three outcomes that offer glimpses of an individual's well-being at birth, in childhood, and in adulthood.

Table 6 summarizes what some of these studies have found. These estimates do not lend themselves to comparative analysis of cost-effectiveness. For one thing, we do not have estimates of what it would cost to prevent or ameliorate some types of shocks such as stress due to a death in the family or domestic violence. Still, given what we know about interventions that

[16] Bleakley (2010), for instance, showed that years of schooling is not a sufficient statistic for measuring the impact of early-life health on lifetime income as it is possible that when health improves, lifetime income goes up, but years of schooling declines.

[17] The use of sufficient statistics has been relatively common in other fields of economics such as in public finance, for welfare analysis. For instance, Chetty (2009) showed that in order to calculate the welfare impact of a tax policy, one only needs to estimate the elasticity of equilibrium quantity with respect to the tax rate and avoid estimating all the "primitive" parameters in a structural model.

are feasible and a rough idea about the likely costs of intervention, the table can serve as a starting point for a discussion about what interventions appear to be most promising.

Studies that focus on birth weight as an outcome are shown in Panel A. Unfortunately, we don't know whether small changes in birth weight for babies well above the cutoff for low birth weight will have meaningful effects on future adult outcomes. Studies that focus on effects on mean birth weight can answer the rudimentary question of whether a given shock affects the fetus, but are not necessarily well suited to considering the cost effectiveness of intervention because we don't know how much a small change in the entire distribution of birth weight is likely to be worth.

On the other hand, we do know that low birth weight is associated in a meaningful way with future outcomes such as adult health, schooling attainment, and wages (see for example, Bharadwaj, Lundborg, and Rooth, 2014; Bharadwaj, Eberhard, and Neilson, 2013; Figlio, Guryan, Karbownik, and Roth, 2014). Table 6 suggests that there is low hanging fruit in terms of potential for meaningful interventions to reduce the incidence of low birth weight. For example, Schwandt (2016) finds that reducing severe influenza cases among pregnant women would have a meaningful effect on the incidence of low birth weight (and on children's future wages). This goal could be accomplished quite cheaply by promoting immunization for influenza among women of child bearing age.

Hoynes, Miller, and Simon (2015), Almond, Hoynes, and Schazenbach (2011), and Rossin-Slater (2013) find that small increases in annual income (or equivalent in-kind transfers) have relatively large impacts on the incidence of low birth weight, which suggests that some sort of pregnancy bonus or mother's allowance might have positive effects at a modest cost

(compositional effects aside). Another policy which could accomplish the same thing though perhaps at higher cost is paid maternity leave, which would be particularly valuable if it covered some of the prenatal period (Rossin-Slater, 2011).

Conversely, uncertainty about income seems to be extremely harmful (Carlson, 2015). It isn't clear at this point how much this problem could be mitigated by expanding unemployment insurance, or at what cost. For example, we don't know how many pregnant women or their partners now qualify for unemployment insurance (UI) or how much they typically receive in benefits. Lindo (2011) finds extremely negative effects of paternal unemployment, though again, it is not clear what policy response could best prevent or address this. This result does point to the importance of fathers, a topic that has generally been neglected in the literature.

Currie and Walker (2011) and Currie et al. (2013) show that exposure to pollution during pregnancy has particularly negative effects on the developing fetus. The cost of pollution control varies greatly depending on exactly how it is done. One option that has not been explored a great deal to date is the potential role of zoning to keep residences, schools, and child care centers away from sources of pollution such as busy highways. Over time, zoning changes might accomplish a lot in terms of health protection at a relatively modest cost. Improvements in filtration by daycare and school HVAC systems are probably cheaper still.

The second panel of Table 6 briefly summarizes shocks that have been shown to affect future test scores. Perhaps unsurprisingly, the same things that have an impact on low birth weight often have significant impacts on test scores. Black et al. (2014), Milligan and Stabile (2011), Dahl and Lochner (2012) all show that small increases in annual income in childhood has measurable effects on children's test scores. Sanders (2012), Bharadwaj et al. (2016), and Black,

Butikofer, Devereux, and Salvanes (2014) further explore the effects of pollution, while Aizer, Stroud, and Buka (2016) highlight negative effects of maternal stress during pregnancy on test scores.

Almond, Mazumder, and Van Ewikjk (2015) and Greve, Shultz-Nielsen, and Tekin (2015) focus particularly on mild nutritional deprivation during pregnancy and find large negative effects on test scores. It would be particularly interesting to tie this literature on mild nutritional deprivation together with the literature on nutritional supplementation (e.g., analyses of the U.S. WIC program) to draw inferences about the potential effects of small variations in nutrition during pregnancy.

Turning to shocks in early childhood that have been shown to impact the wages of young adults, panel C of Table 6 points once again to some of the same suspects. Policies to improve immunization for influenza (Schwandt, 2016), reduce alcohol consumption in pregnant women (Nilsson, 2015), and reduce exposure to pollution (Isen et al., 2015) hold considerable promise. Maternity leave in very early childhood (Carneiro et al., 2015), child care subsidies (Havnes and Mogstad, 2011), and health insurance coverage for young children (Brown et al., 2015) all appear to have payoffs down the road. The Gertler et al. (2014) study of psychosocial stimulation applies to very disadvantaged children in a developing country. Yet there may be parallels to nurse home visiting programs that target disadvantaged parents in the U.S. and many developed countries.

Clearly, we cannot pin down specific cost-benefit ratios without a lot more information. But arguably we have still learned quite a bit about the types of interventions that could be expected to make children healthier, smarter, and more productive as adults.

That said, there remains a great deal of room for future research. More progress could be achieved if some of the measurement problems could be addressed. Some of our most widely used measures, such as low birth weight, are at best only proxies for a whole range of subtle damages that a developing fetus may have suffered. Without sensitive and specific "real time" measures of how someone has been harmed, and how interventions are affecting them, all we can do is wait and see what the eventual outcome will be. In addition to specific measures of harms, knowing more about how intermediate outcomes are affected could help us to identify individuals in need of assistance more quickly, and to target interventions more effectively.

Similarly, being able to identify sensitive or critical periods when particular shocks have their greatest impact, would be extremely helpful. To date, we have learned that the *in utero* period is itself an especially critical and sensitive period of an individual's life. But breaking this period down further and learning more about critical periods in early childhood would also be extremely useful. If the early stages of pregnancy matter most, does starting WIC a few weeks earlier have a high return? Does fostering earlier recognition of pregnancies help?

Another area that could benefit from more precise measurement concerns the development of non-cognitive skills. A few of the studies discussed above focus on non-cognitive skills, and there is growing evidence that such "soft" skills matter a great deal in terms of producing "hard" outcomes such as educational attainment and employment. Yet these skills are typically represented by a hodge-podge of different measures that happen to be available to researchers and there is no consensus as yet on which measures are best or how to get a comprehensive overview of an individual's non-cognitive skills.

We have emphasized that there is often considerable heterogeneity in the effects of a given shock. Most often, more disadvantaged people suffer greater harms, though not always. It is perfectly reasonable that there should be heterogeneous effects given differences in endowments, budget constraints, and available production technologies. Yet in many cases effective interventions may depend on knowing the source of the heterogeneity, something we can largely only speculate about now. Moreover, as we have discussed, families may act either to magnify or mitigate the effects of initial shocks. Hence, a greater understanding of the way that shocks and disadvantage interact, and of the role of parents in responding to them, is highly desirable.

To date, most of the literature focuses on the role of mothers, largely because we have had much better information about mothers than about fathers in many data sets. As large administrative data sets have become increasingly available, it has become possible to explore the role of fathers, but this exploration is only just beginning.

Similarly, improvements in the availability of data are making it possible to explore intergenerational effects. Given evidence from animal models, it is highly likely that changes in the fetus or young child could be passed on to the next generation. This type of mechanism could offer an additional reason for the intergenerational persistence of poverty, and for the existence of poverty traps in some disadvantaged areas.

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