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Gabriella Conti
Mark Hanson
Hazel Inskip
Sarah Crozier
Cyrus Cooper
Keith Godfrey

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The University of Chicago
1126 E. 59th Street Box 107
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Beyond Birth Weight: The Origins of Human Capital

Gabriella Conti, Mark Hanson, Hazel Inskip, Sarah Crozier, Cyrus Cooper, and Keith Godfrey*

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Abstract

Birth weight is the most widely used indicator of neonatal health. It has been consistently shown to relate to a variety of outcomes throughout the life cycle. Lower birth weight babies have worse health and cognition from childhood, lower educational attainment, wages, and longevity. But what's in birth weight? What are the aspects of the prenatal environment that birth weight actually reflect? In this paper we address this fundamental, yet currently unanswered, question, using unique data with fetal ultrasound measurements from two UK sources. We show that birth weight provides a distinctly limited picture of the uterine environment, capturing both positive and negative aspects of fetal health. Other newborn measures are more informative about different dimensions of the prenatal environment and more predictive of child growth and cognitive development, beyond birth weight. Additionally, patterns of fetal growth are predictive of child physical and mental health conditions, beyond health at birth. Our results are robust to correcting for measurement error, and to accounting for child- and mother-specific unobserved heterogeneity. Our analysis rationalizes a common finding in the early origins literature, that prenatal events can influence postnatal development without affecting birth outcomes. It further clarifies the role of birth weight and height as markers of early health, and suggests caution in adopting birth weight as the main target of prenatal interventions.

Keywords: Birth Weight, Fetal Development, Prenatal Investments, Developmental Origins of Health.

*Gabriella Conti is Associate Professor in Economics at University College London, Department of Economics and Department of Social Science, London, UK. Email: gabriella.conti@ucl.ac.uk. Keith Godfrey is Nutrition Theme Lead at the NIHR Southampton Biomedical Research Centre and a member of the MRC Lifecourse Epidemiology Unit, University of Southampton and University Hospital Southampton NHS Foundation Trust, Southampton, UK. Mark Hanson is British Heart Foundation Professor, Institute of Developmental Sciences at the University of Southampton. Hazel Inskip, Sarah Crozier and Cyrus Cooper are at the MRC Lifecourse Epidemiology Unit, University of Southampton, Southampton, UK. Mark Hanson, Hazel Inskip and Cyrus Cooper are also members of the NIHR Southampton Biomedical Research Centre, University of Southampton and University Hospital Southampton NHS Foundation Trust, Southampton, UK. Contributions: Gabriella Conti, Mark Hanson, and Keith Godfrey conceptualised the paper. Gabriella Conti designed and carried out the empirical analysis and wrote the paper. Keith Godfrey provided important feedback at different stages of analysis and writing. Sarah Crozier carried out the analysis of the Birthright data. All the authors commented on the final version. This work was supported by grants from the Medical Research Council (MC-UP-A620-1017, MC-ST-U12055), British Heart Foundation (RG/07/009), European Union's Seventh Framework Programme (FP7/2007-2013, project EarlyNutrition under grant agreement n.289346), UK Food Standards Agency, Arthritis Research UK, National Osteoporosis Society, International Osteoporosis Foundation, Cohen Trust, NIHR Southampton Biomedical Research Centre, University of Southampton and University Hospital Southampton NHS Foundation Trust, British Lung Foundation and NIHR Musculoskeletal Biomedical Research Unit, University of Oxford. KMG is supported by the UK Medical Research Council (MC-UU-12011/4), the National Institute for Health Research (NIHR Senior Investigator (NF-SI-0515-10042), NIHR Southampton 1000DaysPlus Global Nutrition Research Group) and NIHR Southampton Biomedical Research Centre), the European Union (Erasmus+ Programme Early Nutrition eAcademy Southeast Asia-573651-EPP-1-2016-1-DE-EPPKA2-CBHE-JP, H2020 grant no. 633595 DynaHEALTH), the US National Institute On Aging of the National Institutes of Health (Award No. U24AG047867) and the UK ESRC and BBSRC (Award No. ES/M00919X/1). We thank Orazio Attanasio, Jere Behrman, Janet Currie, Angus Deaton, Matthew Gillman, Victor Lavy, Cheti Nicoletti, Stavros Poupakis and seminar participants at the 2013 NBER Summer Institute Children Program Meeting, 2014 NBER Cohort Studies Group Meeting, 2014 NBER Summer Institute Health Economics Program Meeting, 2014 "Beyond Birthweight" Workshop at the University of Sussex, 2015 Essen Health Conference, 4^{th} Toulouse Economics and Biology Workshop, 2016 Essex Workshop "Health and Gender", 2016 Barcelona GSE Summer Forum "Children's Health, Well-Being and Human Capital Formation", EDePo&IDB workshop "The Early Years: Child Well-being and the Role of Public Policy", "Power of Programming" 2016 Conference, Royal Economic Society 2017 "EJ Special Session: Early Investments and Life Cycle Outcomes", and at University College London for valuable comments.

1 Introduction

The importance of the prenatal period in affecting a variety of outcomes throughout the lifecycle is now documented in a vast interdisciplinary literature, to which economics has provided several important contributions in recent years (see Almond et al. [2011a, 2011b, 2017] for reviews). Within this literature, birth weight has been routinely used as measure of neonatal health, both as an input in the production of human development, and as an output to assess the impact of prenatal investments. However, apart from what it measures directly, there is little clarity on what birth weight actually represents. In this paper we address this important, yet currently unanswered, question. As Almond et al. [2017] put it: "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 measures [...] all we can do is wait and see what the eventual outcome will be".

In this paper we use unique UK data with measures of fetal development from ultrasound scans to open the "black box" of birth weight. Our key objective is to examine the information content and the predictive power of key measures of fetal development, which are routinely collected as part of prenatal care in several countries. Our analysis proceeds in two stages. We first investigate the association between measures of fetal head, abdominal and femur size (the "fetal health capital"[1]) with a variety of neonatal measurements, including birth weight (the "neonatal health capital"). While measures of fetal size using ultrasounds are novel in economics,[2] there is an emerging literature in medicine and epidemiology which shows that they are powerful predictors of early childhood health outcomes (see Alkandari et al. [2015] and Larose et al. [2017] for the first reviews of this literature), and that they are associated with different prenatal investments and environments. According to the medical literature, fetal head size is highly correlated with brain growth, abdominal circumference with adiposity accretion and femur size with linear skeletal growth (Godfrey et al. [2012]). We then examine the predictive power of fetal and neonatal health capital for child physical and mental health, growth and cognitive development.

While previous work has emphasized the presence of inequalities at birth, we start by showing that disparities in human development emerge even *before birth*. Figure 1, based on the Southampton Women Survey (SWS) data (our main source; Inskip et al. [2006]), shows the mean standardised differences for each trimester of gestation in the three measures of fetal size that we study in this paper and in the corresponding measures of birth size,[3] by prenatal investments (maternal smoking in pregnancy and excessive gestational weight gain) and environments (neighbourhood deprivation). This simple descriptive analysis reveals several interesting patterns. The fetuses of mothers living in the more deprived neighbourhoods of Southampton are significantly smaller since early gestation by any measure studied, and preserve this disadvantage until birth (panel a). The fetuses of mothers smoking continuously in pregnancy have a smaller size since the beginning of gestation, and more than double their initial disadvantage, which amounts to 0.518 and 0.578 of a standard deviation lower weight and shorter length at birth, respectively (panel b). In contrast, the fetuses of mothers gaining excessive weight are significantly bigger since early gestation by any measure studied, and grow significantly more in the second part of gestation, to have a 0.353 of a standard deviation larger abdominal circumference in the third trimester, and a corresponding 0.349 of a standard deviation higher birth weight (panel c). This descriptive evidence suggests that fetuses conceived in different environments display since very early different patterns of development.

[1] Throughout the paper we refer to health capital in the spirit of Grossman [1972] and Becker [2007].

[2] We are aware of only another study by Anand and Chen [2018], who study gender discrimination in the womb.

[3] Birth weight for fetal abdominal circumference, birth length for fetal femur length and birth head circumference for fetal head circumference, see the analysis in section 5.

In the first part of our analysis, we study the relationship between fetal and neonatal health using the SWS data. We provide several novel results. We start by showing that birth weight is a proxy for specific body components of the fetus, reflected particularly in her abdominal circumference; however, while fetuses with relatively larger girths at the end of gestation have higher birth weight, they are also more likely to be born preterm and to have lower Apgar scores. We then show that other newborn measures, such as birth length and head circumference, and the Apgar score, are more informative than birth weight about different aspects of the prenatal environment. These results are robust to controlling for a large set of predetermined covariates, to accounting for measurement error in the fetal measures using factor-analytic methods, and for individual unobserved heterogeneity using a child fixed effects model. We also replicate them using another UK dataset with fetal ultrasound scans data - the Birthright study. We then study different indicators of poor neonatal health - low and high birth weight, small- and large-for-gestational age (SGA and LGA), and preterm birth, and show that they are predicted by different patterns of fetal growth in middle and late gestation. Lastly, we examine the fat content of the three anthropometric birth measures that we study (the weight, the length and the head circumference of the newborn). We find that all three measures are positively associated with lean mass in the new born, but only birth weight is also positively associated with fat mass. Hence, birth weight captures both negative as well as positive aspects of fetal health.

In the second part of our analysis, we assess the predictive power of fetal and neonatal health. Again, we provide several novel results. First, while we confirm that birth weight is associated with both height and body mass index (BMI), we show that not accounting for birth length overestimates the strength of its association with height and underestimates the strength of its association with BMI. We also show that fetal anthropometrics in the third trimester of pregnancy are predictive of child growth (height and BMI) at six years of age, above and measures of size and length at birth, and even postnatally (in the first year of age). These results are robust to accounting for individual unobserved heterogeneity using a child fixed effects model. Second, using two U.S. data sources - the Children of the National Longitudinal Survey of Youth (CNLSY) and the Pathways to Adulthood (PtA) - and accounting for family-level unobserved heterogeneity via a mother fixed effects approach, we show that birth length rivals birth weight in predicting growth and cognition in childhood. Third, we show that patterns of fetal growth after the second trimester of gestation are predictive of the most common and costly child physical and mental health conditions - overweight, asthma and hyperactivity - above and beyond poor health at birth (and even postnatal growth in the first year of life).

Our work provides several contributions to the literature on the early origins of health and the production of early human development. First, we show what is being measured by birth weight as the most commonly used indicator of early health. Our results suggest that health *in utero* and at birth is complex and multidimensional, and cannot be easily summarized by one proxy measure. Multiple indicators should be collected and used to achieve a more complete assessment of the causes and consequences of early life health. Second, we bridge two parallel streams of research by showing that birth weight and height reflect different aspects of the uterine environment. Third, we rationalize a common finding in the developmental origins literature, by showing that prenatal shocks can have postnatal consequences through suboptimal fetal growth patterns, without being fully reflected in worse neonatal health.

The paper proceeds as follows. In section 2 we briefly review the economic literature on early life health; in section 3 we present our conceptual framework and in section 4 we describe the data that we use. The results are presented in section 5. In particular, the results on the relationship between fetal and neonatal health are presented and discussed in section 5.1, and the analysis of the predictive power of the different fetal and neonatal health measures is reported in section 5.2.

Section 6 concludes.

2 Early Life Health in the Economic Literature

In this section we review key papers in the economic literature which have examined the consequences of early life health. We mainly focus on the papers which have studied birth weight using a twins fixed effects approach, and also, we briefly review some papers that have examined height.

Birth weight has been routinely used in the economic literature as measure of birth endowment, both as a determinant of later outcomes, when examining the long-term consequences of early life health (Behrman and Rosenzweig [2004], Black et al. [2007], Figlio et al. [2014], Royer [2009]) and as an outcome itself, when analyzing the impact of maternal behaviours in pregnancy (Rosenzweig and Schultz [1983], Grossman and Joyce [1990], Rosenzweig and Wolpin [1991,1995]), and prenatal policies (e.g. Currie and Gruber [1996], Hoynes et al. [2015]). Although there is a consensus in the literature that birth weight has significant effects on a variety of outcomes, these effects are not fully consistent across studies, and appear larger in the long-run than in the short-run;[4] this suggests that, beyond the differences in sample composition and econometric specification across studies, birth weight might act as a proxy for other unmeasured fetal and neonatal endowments, and so affect different outcomes through different mechanisms.

Behrman and Rosenzweig [2004] use a sample of female twins from the Minnesota Twins study, who were followed-up at an average age of 46 years by means of a mailed questionnaire (achieving a return rate of over 60%). Differently from most of the literature, they use overall birth weight divided by gestational length as their measure of early health. They find that an increase of 0.4 oz./week (corresponding to an increase in birth weight of 1 lb.) results in almost a third of a year more of schooling, a 0.6 in. increase in adult height and a 7% increase in earnings - and no effect on BMI, or on the birth weight of the children of the twins. Interestingly, for schooling and wages, their fixed effects estimates are bigger than the Ordinary Least Squares (OLS) estimates, which suggests a *negative* correlation between birth weight and unobserved endowments.

Almond et al. [2005] are the first to use large administrative data from the United States Vital Statistics to estimate the impact of low birth weight on hospital costs, infant mortality, assisted ventilator use and Apgar scores. Unlike Behrman and Rosenzweig [2004], their twin fixed effects estimates are much smaller than the ordinary least squares ones: a one standard deviation increase in birth weight (667 grams) reduces 1-year and neonatal mortality by 0.078 and 0.061 of a standard deviation, respectively; and increases 5-minutes Apgar score by 0.056 of a standard deviation. When the authors exclude twin pairs in which one or both twins have a congenital abnormality, the fixed effects estimates are further reduced in magnitude and for half of the outcomes are no longer significant.[5] Additionally, the size and the statistical significance of the impacts tend to decrease along the birth weight distribution. Almond et al. [2005] also exploit a different source of variation in birth weight than the random exposure to different environmental inputs in the womb occurring within twin pairs, i.e.

[4] One interesting area of research (see Almond and Mazumder [2013] for a review) investigates the extent to which differences in initial endowments might be exacerbated or mitigated by parents who make investments and resource allocation decisions within the household in a reinforcing or compensatory manner. See also Torche and Conley [2016] for a recent assessment of the literature on the use of birth weight as measure of early endowments.

[5] Conley et al. [2006] further elaborate on this point, by showing that within-twin genetic variation may be largely responsible for the higher mortality risk faced by a smaller twin only in the case of full-term pregnancies, while within-twin variation in the prenatal environment seems more important in accounting for differences in infant mortality in the case of pregnancies that lasted less than 37 weeks. See also Conley et al. [2003] for an extensive study of the determinants and consequences of low birth weight.

the one driven by maternal smoking in pregnancy. Using a propensity score matching approach, they find that newborns of smoking mothers have lower birth weight, but no discernible differences in infant mortality or Apgar scores.[6] Thus, Almond et al. [2005] make the important point that low birth weight might (or not) have negative consequences, depending on what caused it in the first place (for example, poor nutrition or smoking). Hence, some policies may be effective in raising birth weight, but not in improving immediate outcomes, depending on the nature of the intervention itself.

Black et al. [2007] examine both short- and long-run effects of birth weight, using large administrative data from Norway. They find that, while the twin fixed effects estimates are smaller than the OLS estimates for the short-run outcomes, the opposite is true for the long-run outcomes, thus reconciling the results of Behrman and Rosenzweig [2004] and of Almond et al. [2005]. Their results show that a 10% increase in birth weight translates into about 0.57 cm of additional height at age 18, a 0.06 increase in the IQ score (measured on a scale from one to nine), 1 p.p. (percentage point) increase in high school completion, 1% increase in full-time earnings and 1.5% increase in the birth weight of the first child. While there are significant non-linearities in the relationship between birth weight and mortality (with significantly larger effects for smaller babies), the relationship between birth weight and the other outcomes is remarkably constant across the distribution, as already seen in Almond et al. [2005]. Interestingly, they find that the returns to birth weight have increased across cohorts, possibly because advances in medical technologies have allowed more twins to survive. Lastly, although the authors show that the cross-sectional relationships between birth weight and the outcomes studied are very similar for twins and singletons, they rightly point out that the source of variation in birth weight, and the mechanisms through which later outcomes are affected, might still differ across the two groups, with consequences for the external validity of twin-based studies.

Oreopoulos et al. [2008] analyze three neonatal measures (birth weight, gestational age and Apgar score) using administrative data from Canada, and examine outcomes both within siblings and within twin pairs. They confirm for Canada the results by Almond et al. [2005] for the United States, i.e. that higher birth weight reduces one-year mortality only for very low birth weight babies. The results on the longer-term outcomes differ somewhat between the siblings and the twins sample, although in general they are not sensitive to the newborn measure used within each sample.[7]

Royer [2009] uses administrative data on a sample of female twins from California and finds, instead, that the twin fixed effects estimates are consistently smaller than the ordinary least squares results for both short- and long-run outcomes: in her sample, a one kilogram increase in birth weight is associated with an increase in education by 0.16 of a year, and with an increase in own child's birth weight by 70 grams. She also uses data from the Early Childhood Longitudinal Study Birth Cohort, and finds that a one kilogram increase in birth weight translates into a 0.09 standard deviation increase in the mental score, and into a 0.15 standard deviation increase in the motor score. Importantly, she finds significant evidence of nonlinearities, whereby the effects of increasing birth weight are stronger on health (infant mortality and adult hypertension) below the 2,500 grams threshold, but larger on education above it - potentially suggesting that birth weight might proxy for different prenatal endowments and affect later outcomes through different mechanisms at various points in its distribution.[8]

Figlio et al. [2014] use administrative data from Florida and find that a 10% increase in birth weight is associated with a

[6] The authors also show that the Apgar score outperforms birth weight in predicting within twin-pair differences in both one-day and one-year mortality.

[7] In their siblings - but not twins - fixed effects estimates, both birth weight and the Apgar score are significant predictors of mortality between 1 and 17 years and of reaching grade 12 by age 17, while the opposite is the case for social assistance take-up. No significant impacts are instead detected on the Language Arts Score and on the number of total physician visits between the ages 12 and 17, regardless of the model and measure used.

[8] She also confirms the similarity in the cross-sectional relationship between birth weight and several outcomes across the singleton and twins samples already seen in Black et al. [2007].

0.044 standard deviation increase in test scores at grades 3-8, with effects present as early as age 5 and stable until the middle school years. Importantly, this additional increase is associated with moving children from below to above the average of the test scores, rather than away from the tails of the distribution. As in previous studies, the estimated coefficients on log birth weight are very similar in the twin fixed effects specification and when using the population of singletons (upon restricting birth weight to the gestational age range observed for twins). Additionally, the relationship between birth weight and test scores is qualitatively similar across the birth weight and the discordance distributions, and does not vary substantially with measures of school quality. It does vary, nevertheless, by parental background: the authors find that the birth weight effects are somewhat bigger for children in high socioeconomic status families, suggesting that neonatal health and parental resources are to some degree complementary.[9] Crucially however, the test scores differences associated with variation in birth weight are extremely small compared to those associated with mother's education: these latter are ten times larger, and also constant throughout the school years.

Lastly, a recent paper by Bharadwaj et al. [2018] examines the long-run effects of birth weight using data on Swedish twins born between 1926-1958. The authors find that birth weight has a significant and economically meaningful impact on permanent income, sickness benefits take-up, hospitalizations, and mortality (the latter only for males). They also show that birth weight is less important for early life health outcomes across more recent cohorts, but the labour market effects remain quite stable over time.

This short review reveals that, while the recent economic literature has significantly advanced our knowledge on the effects of birth weight on a variety of outcomes, it has also left several unanswered questions. One key question left unanswered is the following: is birth weight *per se* important, or is it merely a proxy for other prenatal endowments which differ among the twins, and which are reflected, for example, in differences in birth length or head circumference? Almond et al. [2005] rightly point out that birth weight might not be in itself a relevant policy variable, and that "while some interventions may indeed succeed in both raising birth weight and improving health outcomes, others may only be effective in raising birth weights, with little or no effects on health". Thus, "other methods of infant health assessment may need to be developed". Another key question left unanswered concerns the external validity of the twin design: given that twins are usually smaller than singletons, how informative are the twin-based estimates about marginal increases in birth weight at higher points of the distribution? Behrman and Rosenzweig [2004] rightly point out that the effect of fetal growth on earnings can be overstated when estimated on twins, by showing that the within-MZ estimate on log earnings is statistically significant for the bottom third of the U.S. singleton distribution of fetal growth rates, but not for the top third.[10] While several papers show that the cross-sectional profiles are identical for the populations of singletons and twins, Almond et al. [2005] rightly notice that this can be the case even if the relationship between birth weight and the outcome of interest is subject to different omitted variables in the two groups. In this paper we aim to advance this literature by addressing the first question.

Another influential strand of the economic literature which has studied the causes and consequences of early life health has used height as measure of early endowments. The inverse relationship between adult height and morbidity and mortality rates was observed first by Waaler [1984],[11] and subsequently by many others (see e.g. Fogel et al. [1993]). Economic

[9] Royer [2009] also reports suggestive evidence that parents offer more resources to the heavier twin.

[10] When carrying out this exercise, the authors reweigh their sample using the US singleton distribution of fetal growth rates.

[11] In a study of the adult population of Norway during the period 1963-1975, Waaler found that, for both sexes and for

historians have long considered height to be one of the best indicators of standards of living (Steckel [1995]) and individual productivity (Fogel [1987]); and Gowin [1915] was the first to link it with labour market status. Height has then become a topic of interest to economists in recent years because of its importance as predictor of wages (Persico et al. [2004]; Case and Paxson [2008a]), well-being (Deaton and Arora [2009]), health (Case et al. [2005]), and cognitive function (Case and Paxson [2008b]). Within this literature, the paper closest to ours is Case and Paxson [2010], which traces the differences in height among children back to birth and to the prenatal period. The authors show that part of the height differences between siblings stems from differences in their weights and lengths at birth, which are themselves attributable to differences in mothers' behaviours during pregnancy. We build and expand on their insights in our analysis.

Lastly, while both literatures briefly surveyed above have significantly advanced our understanding of the causes and consequences of early life health, they have proceeded in a somewhat parallel fashion. In this paper we also attempt to unite them, by comparing the fetal correlates and the predictive power of birth weight and birth length, respectively as neonatal precursors of weight and height.

3 Empirical Framework

In this section we lay out our empirical framework. We build on the seminal work by Case et al. [2005] and extend their framework to consider three stages of early human development: childhood, birth, and the prenatal period.[12] We specify health in childhood (H^C) as a linear function of health at birth (H^B) and health in the prenatal period (H^P):[13]

$$H_{ij}^C = \beta_0 + \beta_B H_{ij}^B + \beta_P H_{ij}^P + \mathbf{X}'_{ij}\gamma\mathbf{X} + \mu_{ij} + \eta_j + \varepsilon_{ij}^C \tag{1}$$

where subscript i refers to the child, subscript j refers to the mother, $\mathbf{X}$ is a vector of predetermined (pre-pregnancy) characteristics, μ_{ij} and η_j are child- and mother-specific time-invariant unobservables, and ε_{ij}^C is an idiosyncratic error term assumed independent of all the other terms in the equation.

We further specify health at birth as a linear function of health *in utero*:

$$H_{ij}^B = \gamma_0 + \gamma_P H_{ij}^P + \mathbf{X}'_{ij}\delta_{\mathbf{X}} + \mu_{ij} + \eta_j + \varepsilon_{ij}^B \tag{2}$$

where all the terms are defined as above.

Equation (1) formalizes one of the central principles of the Developmental Origins of Health and Disease (DOHaD) concept, i.e. that the fetal environment can affect post-natal health and development both indirectly through its effect on birth outcomes, and also directly, for example via epigenetic pathways (see e.g. Gluckman and Hanson [2008] for the case of obesity). Due to data limitations, the literature in economics to date (reviewed in Section 2) has estimated a restricted

all ages, mortality risk declines as body height rises, possibly with an exception for the very tall.

[12] In this paper we do not fully specify and estimate a production function for child health, which is the topic of ongoing work. Hence, we do not examine the effects of maternal investments in pregnancy, but we include maternal behaviours before conception, along with a wealth of other predetermined characteristics, as controls in our extended specification.

[13] The linearity is assumed purely for simplicity and can be relaxed. Health in each period can be multidimensional, e.g. H^C could include height and longstanding conditions of the child, and also cognitive development; H^B could include indicators of birth size, fetal distress and Apgar scores; and H^P could include indicators of fetal size and growth in different trimesters. The actual indicators we use in our analysis will be described in the next section.

version of equation (1) in which $\beta_P = 0$.[14] In this paper, instead, armed with unique data on fetal measurements from ultrasound scans, we bring to the data equation (1), to examine whether fetal development predicts child outcomes above and beyond health at birth (section 5.2). Before doing so, we estimate different versions of equation (2) to understand the relationship between fetal and neonatal health capital (section 5.1).

Under the DOHaD hypothesis,[15] we expect that, controlling for health at birth (H^B), prenatal health (H^P) has significant effects on childhood health (H^C) in equation (1). Clearly, any association between prenatal, birth and postnatal health estimated by ordinary least squares (OLS) might not reflect causal impacts but common unobserved third factors, given the potential correlation of prenatal and birth health with the unobserved endowments μ_{ij} and η_j. We will address this issue using three different strategies: (1) controlling for an extensive set of predetermined variables to act as a proxy for unmeasured endowments;[16] and estimating (2) fetus and child fixed effects models and (3) mother fixed effects models.[17]

First, given the richness of our fetal data, we are able to control for a wealth of predetermined characteristics, including indicators of socioeconomic background, lifestyles and anthropometric measurements of both parents and maternal and paternal grandparents. We show that our estimates are robust to conditioning on this large set of controls. Second, we exploit the availability of repeated anthropometric measures at birth and pre- and post-natally to estimate fetus/child fixed effects models in the SWS. Third, we use the two US data sources with birth and postnatal information on siblings (CNLSY and PtA) to estimate mother fixed effects models. Obviously, taking sibling differences eliminates the mother fixed effect η_J from 1 but does not eliminate the child fixed effect μ_{ij}. It is plausible that mothers change behaviours across pregnancies as a response to the realization of prior siblings' outcomes; to address this, we will control for maternal investments in pregnancy and show that our results are robust to their inclusion. In sum, even if each of our strategies has limitations, all the evidence we produce shows a very coherent picture of the importance of prenatal development and the value of fetal and neonatal measures, in addition to birth weight, in models of child development.

4 Data

4.1 Southampton Women's Survey

Our main data source is the Southampton Women's Survey (SWS, Inskip et al. [2006]), a survey of 12,583 non-pregnant women in Southampton (U.K.) aged 20-34 years, who were recruited and interviewed between 1998 and 2002 about diet, body composition, physical activity, socioeconomic circumstances and lifestyles. It is the only population-based cohort study in

[14] A complementary literature has instead examined the impacts of shocks and policies in utero (e.g. famines or provision of prenatal care) on birth and postnatal outcomes, see Almond et al. [2017] for a review. However, the lack of data on fetal development has limited our understanding of the mechanisms through which these prenatal inputs operate.

[15] In the words of Barouki et al. [2012] "Functional changes result in changed susceptibility to non-communicable diseases that will likely show up later in life, with a latency that may vary from months to years or even decades. The disease or functional outcome will depend on the stressor, its concentration and timing. Again, the latency before the appearance of health impacts necessitates the development of biomarkers of exposure and the future risk of ill health that can be measured early in life."

[16] We also use the approach recently formalized by Oster [2017] which uses coefficients and R^2 movements after the inclusion of controls to evaluate the robustness of the results to omitted variable bias in linear models.

[17] As it will be clear from sections 5.1 and 5.2, not all strategies can be applied to all parts of our analysis – the main constraint being the unavailability of information on siblings in the fetal ultrasound data. It is important to note that alternative, robust ways of dealing with the choice of confounders to adjust for in the analysis involve the use of Directed Acyclic Graphs (DAGs), which an area of recent development in epidemiology (see e.g. Greenland et al. [1999]).

Europe in which the mothers were recruited before conception of the child, and it has been widely used to study determinants and consequences of fetal development. Women who subsequently became pregnant were followed-up. Ultrasound scans were performed at 11, 19 and 34 weeks of gestation, and interviews were conducted at 11 and 34 weeks. Extensive information on both the mother and the child was collected at birth, 6 months, 1 year, 2 years, 3 years, 4 years and 6 years.

In the SWS, 3,158 women became pregnant and gave birth between 1999 and 2007. Experienced research ultrasonographers used standardised anatomical landmarks and high-quality Acuson 128 XP, Aspen and Sequoia ultrasound machines calibrated to 1540 m/s, to perform fetal measurements almost at the end of the first trimester of pregnancy (11 weeks), in the middle of the second trimester (19 weeks), and in the middle of the third trimester (34 weeks of gestation). Figure A1 in the Appendix presents screenshots of different bodily parts of the fetus from ultrasounds which show how the three anthropometric indicators we use are measured. Of all the women with recorded fetal measurements, for our analysis we use data on the 1,982 who belong to the "fetal growth sample". This sample, according to the SWS protocol, only includes women with reliable menstrual data, i.e. with estimated date of conception derived either from declared date of conception (if not on hormonal treatment), or from detailed last menstrual period (LMP) data, ascertained soon after the woman's first positive pregnancy test, and subsequently verified by scan data (this is the majority of cases with n=1,966).[18] The remaining 1,174 women not in the fetal growth sample were excluded because their menstrual data was deemed unreliable, either because the estimated date of conception had to be derived from the scan data (n=1,079), because they were on hormonal treatment, or because the scan data were not in range.[19]

As mentioned, our main measures of interest are the head circumference, the abdominal circumference and the femur length of the fetus. Each fetal anthropometric indicator we use is the unweighted average of three different measurements. Summary statistics are reported in Table 1. Panel A shows that the ultrasound scans have been performed at three different points of gestation: towards the end of the first trimester (at 82.5 days on average), and in the middle of the second and the third trimesters (at 137 and 241 days on average, respectively). The table shows that the head of the fetus has a larger circumference than the abdomen, and that both double in circumference at each of the three stages of gestation; the femur instead grows by a multiple of four between the first and the second trimester, and doubles between the second and the third.

Table A2 reports the summary statistics for the derived prenatal measures (panel A, H^P in equations 1 and 2), for the birth measures (panel B, H^B in equations 1 and 2),[20] and for the postnatal outcomes (panel C, H^C in equation 1) outcomes[21] that we will use in the analysis. The measures of fetal size and growth have been internally standardized for gestational

[18]Trivially, if the date of conception is established from the size of the fetus at the first visit (with reference to either internal or external growth charts) – for example because the woman does not recall the date of her last menstrual period, or because she has an irregular period – one cannot use that fetus as a reference for size at a certain gestational age.

[19]In Table A1 in the Appendix we compare the background (pre-pregnancy) characteristics of the fetal and non-fetal growth samples. Unsurprisingly, the mothers in the fetal growth sample are positively selected under different socioeconomic characteristics and health behaviours: they are older and more educated, belong to a better social class, live in less deprived neighborhoods, eat fewer kilocalories per day, are more likely to be married and to work, and less likely to receive welfare benefits and to smoke. However, fewer differences are present between the two samples in terms of health and anthropometric outcomes: the mothers in the fetal growth sample are on average taller (and so their mothers) and less likely to report to be in bad health; but no differences are observed for BMI, waist or head circumference, subcutaneous fat as measured by skinfolds and perceived stress. While this does not invalidate the internal validity of our strategy, it somewhat limits its external validity.

[20]All neonatal measurements are collected within 48 hours since delivery.

[21]All the birth and postnatal anthropometric measures have been converted into z-scores, using the Child Growth Foundation (CGF) charts (Cole et al. [1998]), which are the standard for UK measurements.

age according to the method developed by Royston [1995], which has been used extensively in the medical literature.[22] We see that the average birth weight is 3.45 kg and that 4% of the newborns are low birth weight (<2,500 grams) – a lower proportion than recorded for the South East of England for 2010, i.e. 6.7%.[23] The proportion of small-for-gestational age (SGA) babies (below the 10^{th} percentile of the birth weight-by-gestational age distribution) is twice that of low birth weight babies, i.e. 8%. At the other end, 13% and 9% of the newborns have high birth weight ($\geq$ 4,000 grams) and are large-for-gestational age (LGA, above the 90^{th} percentile), respectively, in line with the overall trend in England.[24]

Table A3 reports summary statistics for several preconception characteristics, collected at sample recruitment.[25] Women in the SWS are predominantly of white ethnicity and on average 31 years old at delivery,[26] and for 52% of them this is the first birth; a quarter of them have a university degree, 42% belong to social class I or II, and 12% of the families receive welfare benefits. Additionally, their average BMI is at the overweight threshold (25 kg/m^2), 18% of them report being in 'fair' or 'poor' health, and almost half have experienced some stress in the last 4 weeks. The majority of them (81%) worked before pregnancy, about a quarter of them smoke (25%), 55% drink more than 4 units of alcohol per week, more than 60% exercise weekly, and their average daily intake is 2,090 calories. In order to examine the representativeness of the sample, we have compared the characteristics of the SWS participants to those of the women in the 1970 British Cohort Study (BCS) at the age 30 interview. Reassuringly, we have found the two samples remarkably similar: 40% of the BCS women belong to Social Class I and II, 45% are single, 49% are married, 5% separated, divorced or widowed, and their average BMI is 24 kg/m^2; the corresponding figures for the SWS women are 42%, 45%, 50%, 5% and 25, respectively. Hence, the SWS is broadly representative of the British population.

4.2 Birthright

The Birthright Study to examine maternal nutrition and fetal growth recruited a sample of pregnant women age 16 years or older with singleton pregnancies and known menstrual data, who attended the antenatal booking clinic at the Princess Anne Hospital in Southampton before 17 weeks of gestation in the years 1993 to 1995 (see for example Cole et al. [2009]). We use the Birthright data to replicate the SWS results on the association between fetal anthropometrics and birth outcomes.

[22] See also Royston and Altman [1995]. For example, it is referred to in the WHO multicentre study for the development of growth standard, see Merialdi et al. [2014]. See also Pike et al. [2010] for a detailed description of the methods for the derivation of the fetal growth variables. We have also checked that the z-scores derived using the Royston [1995] method are highly correlated with those derived using Cole's [1990] LMS method.

[23] Source: Office for National Statistics. The South East of England is the region where Southampton is located, and 2010 is the first year in which this statistic is available.

[24] Ghosh et al. [2018], using vital statistics of all live, singleton births, document that in 2012 the percentage of low and high birth weight babies is 5.77 and 8.84 respectively, lower and higher than the corresponding figures in 1986 (6.39 and 6.72).

[25] A limited number of these characteristics, which we use in the models where we control for an extensive set of covariates, has missing data for some observations. In these cases, we replace missing values for social class of the mother, the mother's father and the mother's partner with zeros; and we replace missing values for maternal birth weight and head circumference, for paternal height, weight and birth weight, for mother's mother weight and mother's father height and weight with the sample means of the non-missing observations. In all the analyses, when we use these variables we also include binary indicators which take value one when the original observation has a missing value (we detail this in the notes to the respective tables). The prevalence of missing data varies between 3% for mother Social Class to a maximum of 24% for mother's partner Social Class, with most variables having missing data in 12%-15% of the observations. An alternative method to deal with missing data is multiple imputation, see e.g. Sterne et al. [2009].

[26] The mother's date of birth ranges between 1963 and 1981.

4.3 Children of the National Longitudinal Survey of Youth

Since 1986, the women who were originally included in the National Longitudinal Survey of Youth (NLSY79) have been interviewed bi-annually about their children. The CNLSY (Children of the NLSY) has been used extensively to study the determinants and consequences of child development, including the above-mentioned paper by Case and Paxson [2010] on the causes and consequences of early life health.

We select our analytical sample as follows. First, we select only the white children born between 1975 and 2000, to enhance comparability with the English sample. Second, to minimise measurement error,[27] we only keep those children for whom the birth length is reported as not being an estimate; we further remove a few outliers in birth weight and birth length using Tukey's method.[28] We then standardise birth weight and birth length for gestational age using the growth chart developed by Olsen et al. [2010] for the United States;[29] we further remove those z-scores resulting in values less than -4 or more than 4 standard deviations. Lastly, we only consider children with measurements between the ages 7-12 years.[30]

Summary statistics for our analytical sample of 3,224 children with non-missing z-scores for both birth weight and birth length for the years 1996-2014 are reported in Table A4. The mean birth weight in the CNLSY sample is comparable to that of the SWS sample, while the average birth length is 1.4 cm higher; from the z-scores we see that the sample is on average heavier and longer at birth than the reference population. As child outcomes, we focus on height and BMI (both standardised using the 2000 CDC growth standards) and the following four tests: the Peabody Picture Vocabulary Test (PPVT),[31] the Wechsler Intelligence Scale for Children (WISC) Memory for Digit Span total standard score,[32] the Peabody Individual Achievement Test (PIAT) Mathematics and Reading Recognition assessments.[33]

4.4 Pathways to Adulthood

The fourth and last dataset that we use is the Pathways to Adulthood (PtA, Hardy and Shapiro [1998], ICPSR 2420), which includes data on three generations of families living in the inner-city area of Baltimore.[34] In particular, we use data on the Second-Generation (G2) children born in the years 1960-1965 at John Hopkins Hospital. Our analytical sample includes information on birth outcomes and maternal characteristics at delivery, and anthropometric measurements and cognitive assessments at ages 7-8. We follow the same procedure as in the CNLSY to construct z-scores for the birth outcomes and for removing outliers.

Summary statistics for the analytical sample of 1,422 children with non-missing z-scores for both birth weight and birth length are reported in Table A5. This sample is quite different from the SWS and the CNLSY: the average birth

[27]Differently from the SWS, the Birthright and the PtA, in the CNLSY all the anthropometric measures are self-reported.

[28]We remove observations which are smaller than the lower quartile, or larger than the upper quartile, by more than three times the interquartile range, respectively.

[29]The Olsen charts are only available for gestational ages between 23 and 41 weeks.

[30]This choice is dictated by the fact that this is a common window during which all our tests of interest have been administered.

[31]The PPVT measures an individual's receptive (hearing) vocabulary for standard American English, and provides, at the same time, a quick estimate of verbal ability or scholastic aptitude.

[32]This is a component of the WISC and measures short-term memory in children.

[33]The PIAT Math subscale measures a child's attainment in mathematics as taught in mainstream education. The PIAT Recognition subscale measures word recognition and pronunciation ability. For all the tests, we use the age-specific standard scores provide (with a mean of 100 and standard deviation of 15. We don't use the PIAT comprehension since it has been seldomly used in the literature, as it was administered only if PIAT reading exceeded a certain minimum score.

[34]The sample comprising the PtA is a subsample of the John Hopkins Collaborative Perinatal Study (JHCPS) which was selected for an adult follow-up. Of the JHCPS participants, 2,694 were eligible to participate in PtA.

weight is 2.99 kg, 400 grams lower, and the average birth length is 48.93, 2.34 cm shorter than the average newborn in the CNLSY sample; from the z-scores we also see that the sample is lighter and shorter than the reference population. As child outcomes, we focus again on height and BMI, and on five cognitive tests administered by a child psychologist at ages 7-8 which measures the same domains as those in the CNLSY: the WISC Verbal Comprehension and Verbal Digit Scales, the Wide Range Achievement Test (WRAT) Math and Reading Scales, and the PPVT.[35]

5 Results

5.1 Understanding Health at Birth

What Birth Weight Measures In this section we begin to open the "black box" of fetal development by examining the relationship between birth weight and fetal health capital. We start by presenting some graphical evidence in Figure 2, where we plot the mean birth weight for different values of the measures of fetal size,[36] grouped into suitably sized bins. Across all the dimensions considered, it is immediately visible that the strength of the association between the measures of fetal size and birth weight (the slope of the fitted OLS regression line) increases throughout gestation.

We then proceed by estimating different versions of equation 2. We present in Table 2 conditional associations between the three measures of fetal size and birth weight expressed in kilograms (columns 1a-1c), gestational age at birth (columns 2a-2c), and birth weight expressed as z-scores (columns 3a-3c), separately by trimester of gestation. Here we condition on a minimal set of covariates: gender, ethnicity, being a first born and year and month of birth.[37] Conditioning on an extensive set of biological and socioeconomic characteristics and lifestyles measured at study intake does not significantly change the estimated coefficients (Table A6 in the Appendix).[38] Each cell presents the estimated coefficient from an OLS regression of a birth measure on a fetal measure. We make several observations. First, we confirm that the strength of the positive association between the measures of fetal size and birth weight increases throughout gestation: fetuses with a one standard deviation larger abdominal circumference at 11 weeks are 39 grams heavier at birth (column 1a, upper panel); the magnitude of this association almost triples to 118 grams in the second trimester (column 1b, upper panel) and then to 277 grams in the third trimester (column 1c, upper panel).

Second, we observe that birth weight is indeed correlated with various fetal measures, however it shows a stronger association with abdominal circumference than with head circumference (middle panel) or femur length (bottom panel). This is reflected not only in the magnitude of the estimated coefficients – fetuses with one standard deviation larger abdominal circumference at 34 weeks are on average 277 grams (column 1c, upper panel) or 0.647 of a standard deviation (column 3c, upper panel) heavier at birth – but also in the amount of explained variation, which ranges from 31% for birth weight in

[35]The Comprehension and Digit Span assessments are two of the four verbal subtests of the WISC. The WRAT Math and Reading Scales evaluated the child academic performance as measured by arithmetic computation, and reading, word recognition and pronunciation.

[36]Specifically, fetal head circumference in panels (a)-(c), fetal abdominal circumference in panels (d)-(f), and fetal femur length in panels (g)-(i).

[37]Conditioning on being a primiparous is important because maternal supply capacity differs between first and subsequent pregnancies. This is due to the action of the fetal trophoblast cells, which invade the arteries of the endometrium and convert the uterine spiral arteries into uteroplacental arteries; as result, the arteries become completely dilated and distended, able to accommodate the increased blood supply for the placenta (Blackburn, 2007).

[38]Gaillard et al. [2014], who study the tracking of fetal growth characteristics during different trimesters, also find that the tracking coefficients are not influenced by maternal socio-demographic and lifestyle characteristics.

kilograms (column 1c, upper panel) to 46% for birth weight standardised by gestation (column 3c, upper panel).[39] While reported here for the first time in economics, the strong association between abdominal circumference and birth weight is well known in the medical literature. Indeed, the prediction of birth weight from abdominal circumference was first proposed by Campbell and Wilkins [1975], and subsequently refined among others by Smith et al. [1997], who showed that the predictive power is not significantly improved when femur length is also included in the equation. This can be explained by the fact that the rate of fetal growth in weight increases exponentially, so that most of the weight is gained during the third trimester (7 to 9 months) of pregnancy, while the fetus grows in length mainly in the second trimester (4 to 6 months, Schoenwolf et al. [2012]). However, the weight provides information accruing from all the tissues together, so that greater weight does not necessarily imply healthier growth: it may be achieved at the cost of liquid retention or fat accretion. Although birth weight provides *some* information about the endpoint of fetal growth, it neither describes the trajectory followed in utero, nor does it reflect the body composition of the fetus. The fact that the association between abdominal circumference and birth weight is stronger at the end of gestation is consistent with evidence from the epidemiological literature on the Dutch Hunger Winter (see e.g. Stein and Susser [1975]), which finds a reduction in birth weight among women exposed to the famine in the last trimester (see also Stein et al. [2004]); and also with more recent evidence from economics showing that the largest improvements in birth weight occur with interventions in the third trimester (see e.g. Almond et al. [2011]).

Thirdly, we uncover a *negative* association between the measures of fetal size and gestational age at birth, which - opposite to that seen for birth weight - is *decreasing* throughout gestation (columns 2a-2c). In other words, women with bigger fetuses in the early stages of gestation have on average shorter pregnancies (as previously reported in Johnsen et al. [2008]).[40] Thus, the counterbalancing effects of fetal size on weight at birth and on length of gestation explain why we detect associations of greater magnitude and statistical significance between the fetal measures and birth weight when we standardize it by the age of completed gestation (especially in the first trimester, compare cols. 3a and 1a). Lastly, it is interesting to notice that the associations between fetal and neonatal health capital are essentially unchanged when we condition on our extensive set of controls (Table A6).

Other Measures of Neonatal Health While being the most widely used, birth weight is not the only measure of neonatal health. Developmental plasticity in response to the uterine environment manifests itself in other physiological processes than fetal weight growth, which are likely not captured by birth weight alone. Other indicators of neonatal health convey information about other aspects of the prenatal environment.

First, other neonatal anthropometric measures, such as birth length and head circumference, are of value. These measures are routinely collected in the birth records of the Scandinavian countries, and are also available in some survey-based datasets.[41] Birth length in particular is a measure of increasing interest in the public health literature as a marker of nutrition and fetal growth. While birth weight is a short-term indicator and mainly reflects the nutritional environment around the time of measurement (i.e. in the last weeks of gestation), birth length is a longer-term cumulative indicator. For example, Neufeld et al. [2004] have shown that maternal weight gain from the first to the second trimester, not from the second to the third, is associated with fetal linear growth (fetal femur length at 17 and 30 weeks) and with infant length at

[39] Here we refer to the semi-partial R^2 reported in the table.

[40] We have checked that this is not driven by differences in the method of delivery, by restricting the sample to children with normal onset of labour,

[41] For example, in the Avon Longitudinal Study of Parents and Children (ALSPAC) for the UK.

birth.[42] Chong et al. [2014] have found that maternal protein intake at 26-28 weeks of gestation is associated with birth length, but not with birth weight. These findings echo those of much earlier work, such as Burke et al. [1943], one of the first studies on maternal nutrition in pregnancy and birth size. Kusin et al. [1992] have also shown that the effect of energy supplementation in pregnancy in a community characterized by chronic energy deficiency is of greater magnitude on height than on weight. Morris et al. [1998] have shown that birth length has a strong association with development at 12 months in the Brazilian cohort Pelotas. More recently, Adu-Afarwuah et al. [2016] have shown that small-quantity, lipid-based nutrient supplements provided to women during pregnancy and 6 months postpartum and to their infants from 6 months of age increase the mean attained length of 18-month-old children in semi-urban Ghana. Lastly, a recent trial on prenatal nutrition (Hambidge et al. [2014]) has selected birth length as its primary outcome.

The other neonatal anthropometric measure we study is head circumference. This is recognized in several studies as a marker of brain development, especially in early childhood (see e.g. Bartholomeusz et al. [2002]). Heritability estimates from twin studies (Smit et al. [2010]) suggest that common environmental effects on head circumference other than pregnancy duration (e.g. maternal behaviours in pregnancy) play an important role in the earliest stages of life, but quickly give way to subsequent growth that is highly genetically determined.

In addition to these anthropometric measurements, another neonatal indicator routinely collected in the birth records of many countries, such as Scandinavia, U.S. and Canada - is the Apgar score. This is a method to quickly summarize the health of newborns, which was developed by the anaesthetist Virginia Apgar in 1952.[43] The newborn is evaluated on five simple criteria (Appearance, Pulse, Grimace, Activity, Respiration) which reflect physiological parameters, each on a scale from zero to two; the five values obtained are summed up, in a score which can range from 0 to 10. The test is generally performed at one and five minutes after birth, and may be repeated later if the score is low. Its continuing value for assessing newborns has been shown repeatedly over the years (see e.g. Casey et al. [2001] and Iliodromiti et al. [2014]).

We start by presenting some graphical evidence in Figure A2, where we see that, while birth weight is strongly associated with the abdominal circumference of the fetus (panel a), birth length exhibits the strongest association with fetal femur length (panel e), and birth head circumference with fetal head circumference (panel i). The results on the association between fetal health capital and other measurements of neonatal health are displayed in Table 3. Here, differently from Table 2, we also condition on all the three fetal anthropometrics at the same time, rather than separately including each of them, for the second and the third trimester measures.[44] In columns (1a) and (1b) we look again at birth weight standardised by gestation. In comparison to columns (3b) and (3c) in Table 2, the estimated coefficients on abdominal circumference are smaller in absolute magnitude, but more than twice the size of those on the other two fetal dimensions. Along the same lines, columns (2a) and (2b) show that birth length is more strongly associated with fetal femur length, and columns (3a) and (3b) that birth head circumference is more strongly associated with fetal head circumference. A fetus with a one

[42] Complementary evidence is provided in Wander et al. [2015], who find that late pregnancy gestational weight gain is associated with greater increase in birth weight than early pregnancy gestational weight gain.

[43] She validated the scale by assessing the mortality rates of 2,096 newborn infants with low, moderate, and high Apgar scores (Apgar [1953], Apgar et al. [1958] and Apgar [1966]).

[44] For the first trimester, as also seen for birth weight, the very high correlation among the fetal measures makes it difficult to detect meaningful associations. We have checked for multicollinearity in two ways. First, we have checked that in all cases the Variance Inflation Factor is smaller than 10 (the value used as rule of thumb). Second, we have performed a simulation study. We have simulated data with the same sample size and correlation structure among the variables as in the SWS data, and verified that the coefficients of the relationship between birth weight and the three fetal measures in the third and second trimester estimated on the simulated data are remarkably similar to those estimated using the real data. Full results are available upon request.

standard deviation longer femur in the middle and towards the end of gestation is, respectively, a 0.204 and 0.344 standard deviation longer newborn. A fetus with a one standard deviation larger head circumference in the second and in the third trimester has, respectively, a 0.426 and 0.626 larger head circumference at birth. A different pattern emerges, instead, with respect to the Apgar score: fetuses with a larger head circumference at the end of gestation have a higher score, while fetuses with a larger abdomen have a *lower* one.[45] As already seen for Table 2, conditioning on an extensive set of biological and socioeconomic characteristics and lifestyles measured at study intake does not significantly change the estimated coefficients (Table A7). We also provide a formal test of the extent to which omitted variables could bias the relationship between the fetal measurements and birth weight using the method recently formalised by Oster [2017], following Altonji et al. [2005], which uses movements in the coefficient of interest and in the R^2 after adding observable controls to learn about the likely impact of the unobservables. The results are shown in columns (1c) and (1d) of Table A7. The estimates of the bias-corrected coefficients for the abdominal circumference β_c[46] are very similar to the controlled ones in columns (1a) and (1b), and those of the related coefficients of proportionality (δ) are all above one, implying that unobservables would have to be more important than observables for the coefficient to be zero.[47] Interestingly, though, the bias-corrected coefficients of birth weight on femur length and head circumference in the third trimester (column 1d) have a negative sign and a smaller magnitude, and the related coefficients of proportionality (δ) in this case are below 1. This additional evidence provides further support to our finding that birth weight proxies for the abdominal circumference of the fetus. Lastly, we confirm the different timing of development for the various dimensions by showing that, conditional on the third trimester measures, the development of the fetus in the second trimester is only predictive of birth outcomes for the measures of length and head circumference, *not* of weight (Table A8). This provides evidence that two dimensions of newborn health other than weight provide information about earlier parts of gestation.

We have tested in two ways the robustness of these results. First, rather than using the average of three fetal measurements for the same indicator at each time point, we have accounted for measurement error using factor-analytic methods. The results, presented in Table A9 (cols. 4-6), are remarkably similar to those reported in Table 3. Additionally, as shown in columns 2-3 of Table A9, the three fetal measurements have very similar coefficients, reassuring us on the quality of our data. Second, we have performed a replication exercise on the Birthright data. The results are displayed in Tables A12-A13 and confirm the SWS results: birth weight proxies for the abdominal circumference of the fetus (cols. 1b and 2b of Table A12, and col. 1 of Table A13), which is negatively correlated with the Apgar score (col. 4 of Table A13); and birth head circumference and length are more strongly associated with their respective fetal counterparts (cols. 2 and 3 of Table A13).

Third, we check the robustness of our results to unobserved heterogeneity. Our findings so far suggest that the three fetal measures are capturing both an underlying common component ("fetal health") and specific components related to the different body parts. This naturally lends itself to using a fetus fixed effects estimator, where we exploit the measure-specific deviations from the common component. In other words, our findings suggest the following relationship between dimension-specific fetal and neonatal measures H_{imt} and latent health H^*_{it}:

$$H_{imt} = H^*_{it} + \upsilon_{imt} + \varepsilon_{imt} \tag{3}$$

[45]A larger abdomen may be associated with obstructed labour and shoulder dystocia, hence reducing the Apgar score.

[46]These are computed assuming an equal degree of selection on observables and unobservables, i.e. δ=1.

[47]All the computations are made using as R_{max} (the R^2 from including the unobservables) the R^2 from the full models in columns (1a) and (1b), multiplied by 1.3, as suggested in Oster [2017].

where $m = 1, 2, 3$, $t = tr1, tr2, tr3, birth$; υ_{imt} is the deviation at developmental time t of the dimension-specific measure from the general latent health, independent and identically distributed across dimensions and children, but not independently distributed across ages for the same dimension; ε_{imt} is a random measurement error. To assess the validity of these assumptions, we first run an exploratory factor analysis of the three measures at each developmental stage.[48] The results, reported in Panel A of Table A10 (cols. 1-4), show that the first factor explains on average 64% of the variance of the fetal and neonatal measures, and therefore supports a single-factor model.[49] We then estimate a structural equation model with one single factor, separately for each developmental period. Estimation results are reported in Table A10. Panel B reports the factor loadings for the three measures, where the loading for the measure of size (abdominal circumference in pregnancy, and weight at birth) is constrained to be 1. The results show that the factor loadings for the head and the length are very close to 1 in early and mid-pregnancy, but of a smaller magnitude in late pregnancy and birth – again, providing evidence that the three measures are capturing increasingly differentiated dimensions. This increase in specificity is also reflected in the uniquenesses, which, as expected, are higher in the third trimester and at birth than in the first two trimesters. Complementary evidence is shown in Table A11, which reports the raw correlation matrix and shows that the correlations across developmental stages between indicators of the same dimension (e.g. the correlation between head circumference in the third trimester and at birth) are stronger than those between indicators of different dimensions at the same developmental stages (e.g. the correlation between head circumference and femur length in the third trimester) for late gestation and birth, but not for early and mid-gestation. Lastly, in Panel D of Table A10 we report the estimated covariances between the dimension-specific components of the fetal and neonatal indicators, for a structural equation model with correlated errors, and we show that they are indeed 0.

In sum, all this evidence supports our interpretation of the fetal and neonatal indicators as a proxy for one general latent fetal-neonatal health, and also specific sub-dimensions. Supported by these findings, we estimate a fetus/newborn fixed effects model, to understand whether the conditional associations reported in Table 3 can be given a causal interpretation.[50] The results, reported in Table 4, indeed suggest that the association between fetal and neonatal health can be interpreted as causal, and not merely reflecting unobserved common factors.[51] On average, 1 SD improvement in fetal health in the third trimester leads to a 0.3 SD improvement in neonatal health (cols. 2-3). Conditional on fetal health in the third trimester, a 1 SD improvement in fetal health in the second trimester leads to a 0.07 SD improvement in neonatal health (cols. 3-4).

Our analysis so far has provided robust evidence that the fetal environment, since mid-gestation, affects health at birth. However, so far we have focused on measures at single timepoints. The medical literature suggests that the growth trajectories of the fetus in the womb are also very important in determining birth outcomes. Hence, we now study how fetal growth trajectories in abdominal circumference in middle and late gestation predict the more common and costly birth outcomes: low birth weight (birth weight below 2,500 grams), small-for-gestational age (SGA, $<10^{th}$ centile of birth weight

[48] Bollen et al. [2013] have modelled birth weight, birth length and gestational age as proxies for a latent variable, Favorable Fetal Growth Conditions (FFGC).

[49] Interestingly, the percentage of explained variation is as high as 79% in the early stages of pregnancy, and declines to 43% in the last trimester, suggesting an increased differentiation and specificity of the fetal measures.

[50] This approach is similar to the one recently adopted in the education literature for the estimation of cognitive ability production functions, see for example Nicoletti and Rabe [2013].

[51] We also find that, even conditional on the fixed effect, the fetal measures in the third trimester (col. 2) have slightly different effects on health at birth. However, conditional on the third trimester measures, we cannot reject the equality of the coefficients of the second trimester measures. This is unsurprising, given that we had already seen in Table 3 that the measures have different persistence across developmental stages.

for gestational age), high birth weight (birth weight above 4,000 grams), large-for-gestational age (LGA, $>90^{th}$ centile of birth weight for gestational age) and prematurity (birth before 37 weeks of completed gestation).[52] While the significance of low birth weight and of small-for-gestational age for subsequent mortality and morbidity has long been recognized (McCormick [1985]), the increased prevalence of high birth weight and large-for-gestational age (Surkan et al. [2004]) and their associated costs (Cnattingius et al. [2012]) constitutes an emerging public health threat. This exercise shows the importance of looking at patterns of fetal growth - rather than simply at fetal size - to explain birth outcomes. First of all, column (1) of Table 5 reveals that two different abdominal growth patterns can lead to low birth weight: fetuses who are both *continuously* small[53] and also fetuses who become much smaller[54] between the second and in the third trimester of gestation have an increased probability of having a weight at birth less than 2.5 kilograms (of 4.7 p.p. and 3 p.p., respectively), as compared to fetuses with continuous normal size.[55] Column (2) shows that both fetuses who are continuously small, and those who become much smaller, between the second and the third trimester, are 14.2 p.p. and 7 p.p. more likely to be born SGA, respectively. Conversely, the fetuses who become much bigger, and especially those who are continuously big in mid- and late gestation, are 8-9 p.p. and 15-18 p.p. more likely to be born high birth weight and LGA, respectively. Last, column 5 shows that any deviation from a balanced growth trajectory increases by 2-4 p.p. the probability of being born preterm.[56] This finding is particularly important since preterm birth complications are the leading cause of death for children under the age of five years (Liu et al. [2015]), and the role of various risk factors in the aetiology of prematurity remains unclear (Muglia and Katz [2010]). As seen previously, the estimated associations are virtually unchanged after controlling for an extended set of socioeconomic and biological determinants and lifestyles measured before conception (Table A15).

Lastly, we investigate the relationship between birth weight, length and head circumference, and the body composition of the newborn. We present the results in Table 6, where we report the coefficients from OLS regressions where the dependent variables are three measures of body composition from DXA (dual-energy X-ray absorptiometry) - fat and lean mass, and the proportion of body fat - and one measure of thigh subcutaneous tissue thickness from the skinfolds. DXA is an indirect method to assess body composition safely and non-invasively using the principle of X-ray beam attenuation by the different body tissues, and to differentiate between fat and lean mass (de Vargas Zanini et al. [2015]). The measurement of subcutaneous tissue thickness by skinfold calipers is also a safe and non-invasive method, which has been used for more than fifty years (Edwards et al. [1955]). Here we focus on the thigh skinfold since previous research has shown that it is the most repeatable and representative of the skinfolds (Farmer [1985]); however, we obtain identical results (not shown here) when using the other skinfolds (biceps, triceps and subscapular). We make several observations. First, all the three neonatal anthropometrics are positively associated with the four measures of body composition when entered separately (columns 1-3 and 5-7), with birth weight displaying the strongest association and accounting for more of the explained variation in all cases. Second, when the three birth size measures are entered simultaneously (columns 4 and 8),[57] birth weight is still positively associated with all the four measures of neonatal body composition, while birth length and head

[52] There is not a lot of overlap among the different categories in the data, with only 10% of the preterm being also SGA.

[53] We classify fetuses as small or large if their abdominal circumference falls below the 25^{th} or above the 75^{th} percentile, respectively.

[54] More precisely, fetuses who are in the lower quartile of the distribution of the difference between the third and the second trimester abdominal circumference.

[55] Table A14 column 1 shows that actually fetuses displaying a declining trajectory in any of the three dimensions considered are more likely to become low birth weight newborns.

[56] In Table A14 we see that a declining trajectory in head circumference is also a significant predictor of preterm birth.

[57] Again, we have checked that collinearity is not an issue, using the Variance Inflation Factor.

circumference are negatively associated with measures of fatness, either derived from DXA (fat mass and % of body fat) or from skinfolds (thigh), and positively associated with lean mass. Once more, the estimated associations are virtually unchanged after controlling for an extended set of socioeconomic and biological determinants and lifestyles measured before conception (Table A16).

In sum, in this section we have shown that fetal health since mid-gestation is robustly associated with health at birth, that different fetal and neonatal measures capture both a general and a specific health component, and that birth weight is only one imperfect indicator, capturing both positive and negative aspects of health.

5.2 Beyond Birth Weight

In this section we examine the predictive power of fetal and neonatal health capital for child health and development.

We start by examining conditional associations between fetal and neonatal health capital and height and BMI at age 6. All the neonatal anthropometric measures we use are z-scores.[58] The OLS results for height are reported in the upper panel of Table 7. Columns (1a)-(1b) and (2a)-(2b) display the results of models where we only include birth weight and length as measures of early health, respectively; columns (3a)-(3b) display the results of models where we include the three measures of neonatal health;[59] Columns (4a)-(4b) include the three measures of fetal size in the third trimester of gestation as indicators of early health; columns (5a)-(5b) display the results of models where we condition on all the fetal and neonatal measures. By comparing column (1a) and column (2a), we see that birth length is a stronger predictor of height than birth weight, both in terms of the magnitude of the association – a one standard deviation increase in birth length is associated with a 0.529 standard deviation increase in height, while the coefficient on birth weight is 0.310 – and in terms of the amount of explained variation (0.211 versus 0.085). Moreover, the semi-partial R^2 for birth weight falls to zero when the three birth measures are added to the regression (column 3a), while the one for birth length is 0.135. Crucially, upon conditioning on length at birth, the association between birth weight and height becomes negative. Lastly, birth length remains predictive of child height even upon conditioning on postnatal growth in the first year of life (col. 7 of Table A17). Our results confirm the findings of Black et al. [2007], who had noted (footnote 13) that, when including both birth weight and birth length in a height regression, birth length was a more important predictor than birth weight; the same result had been previously reported in Sorensen et al. [1999] on Swedish data, and in Eide et al. [2005] on Norwegian data. Our findings are also consistent with recent evidence from molecular genetics, which has shown that SNPs associated with adult height also influence birth length (van der Valk et al. [2015]), and that by age 10 years they explain approximately 5% of the variance in height (Paternoster et al. [2011]), which is half of that explained in adults (i.e. approx. 10%, see Allen et al. [2010]). In column (4a) we show that the fetal femur length rivals birth weight, both in terms of the magnitude of its association with height (0.355 of a standard deviation) and of the explained variation (0.097). Lastly, we show that, even upon conditioning on birth length, the femur length of the fetus at the end of gestation is predictive of child height at 6 years, with a magnitude equal to 0.178 of a standard deviation for each standard deviation increase in femur length (column 5a). All these estimated associations are robust to the inclusion of an extended set of parental socioeconomic and biological characteristics (see columns 1b, 2b, 3b, 4b and 5b). Additionally, in columns (4c) and (5c) we formally test the extent to which omitted variables could bias

[58] Just as reported in Black et al. [2007, footnote 13], we find that alternative continuous measures of birth weight (both in levels and in logs) produce very similar results. All results using alternative measures of birth weight are available from the authors upon request.

[59] Full results are reported in Table A17 in the Appendix.

the estimated coefficients, again using the Oster [2017] method. We see that the bias-corrected coefficients (β_c, computed assuming equal selection) are two thirds of the fully controlled ones, and the related coefficients of proportionality (δ) are above 2, implying that unobservables would have to be much more important than observables for the femur length coefficient to go to zero. Lastly, femur length remains predictive of child height even upon conditioning on postnatal growth in the first year of life (col. 7 of Table A17). We also obtain very similar results if we use as the dependent variable a measure of bone health: bone mineral content (BMC), which is associated with the risk of fractures and osteoporosis (Hansen et al. [1991]); in other words, early life length is associated not only with longer, but also healthier bones.[60] This first piece of evidence suggests that the intrauterine environment has consequences for child growth which are not entirely captured by different measures of health at birth. Our findings also have implications for the specification of height production functions: while the literature commonly assumes a Markovian process (see e.g. Strauss and Thomas [2008] and De Cao [2015]),[61] whereby height in the previous period is a sufficient statistic for past growth, they suggest the need for a more flexible specification with additional lags, at least for the perinatal period. Additionally, our results show that birth weight and height proxy for different dimensions of the fetal health capital, and so should *not* be used interchangeably as measures of early health.[62]

We next examine the conditional associations between fetal and neonatal health capital and childhood BMI (bottom panel of Table 7).[63] Birth weight displays a sizeable and significant association with BMI (column 1a), which is robust upon conditioning on neonatal (column 3a) and fetal health (column 5a): a one standard deviation higher birth weight is associated with a 0.297 standard deviation higher BMI at 6 years of age. A similar result had been previously reported in Black et al. [2007], for a cohort of Norwegian men born between 1977 and 1986 measured when they were tested for military service: the authors found that a 10% increase in birth weight led to a higher BMI by 0.11 kg/m^2 and to a 0.9 p.p. higher probability of being overweight. The positive association of birth length with BMI in the baseline model (column 2a), instead, becomes negative upon conditioning on the other measures of neonatal (column 3a) and fetal health (column 5a), with a one standard deviation increase in birth length associated with a 0.245 standard deviation lower BMI. Differently from what reported above for height, birth weight explains more of the variation in BMI than birth length. Lastly, even upon conditioning on the three birth measures, the abdominal circumference of the fetus at the end of gestation is predictive of child BMI, with a standard deviation increase being associated with a 0.141 standard deviation higher BMI (col. 5a).[64] As seen before, the results are robust to conditioning on an extensive set of biological and socioeconomic characteristics (cols. 1b, 2b, 3b, 4b and 5b). We have also used once more the Oster [2017] method to gain some insights on the role of unobservables: the bias-corrected coefficients (β_c in cols. 4c and 5c) are similar to the ones in the models with full controls (cols. 4b and 5b), and the related coefficients of proportionality (δ) are around 4, reassuring us on the importance of prenatal size for child BMI, even upon conditioning on health at birth.

We obtain very similar results if we use measures of central adiposity, which are considered to be more clinically useful than BMI when assessing metabolic disease risk (McCarthy [2006]): the waist-hip and the waist-height ratio. We find that

[60] Results are available from the authors upon request.

[61] See however Puentes et al. [2016], who specify, estimate and test the fit of several flexible specifications for the growth paths of height in Guatemala and in the Philippines.

[62] A related point is also made in a recent paper by Duc and Behrman [2017], who find that height growth in the first year of life adds predictive power for educational outcomes beyond that of birth weight and weight gain, and unlike them predicts receptive vocabulary.

[63] The full set of results with all the estimated coefficients is reported in Table A17 in the Appendix.

[64] When we condition on postnatal growth, the coefficient on fetal abdominal circumference is still of a meaningful magnitude, but our estimate becomes imprecise.

birth length is negatively associated with both measures, while birth weight predicts a higher waist-height ratio; and that fetal abdominal circumference is also a significant predictor of central adiposity.[65] On the other hand, upon conditioning on health at birth, no fetal measure is predictive of child weight (Panel C of Table A17): this is once more showing the specificity of their predictive capacity, since a greater weight does not necessarily imply a greater body mass.

Lastly, we exploit the availability of measures of IQ in a subsample at age 4 to study the prenatal correlates of intelligence.[66] Given the small sample size, we focus only on one measure – head circumference – which has been shown to be significantly correlated with brain volume (Lindley et al. [1999]). In particular, we investigate whether the first or the second part of gestation is a more sensitive period. The results, reported in Table A18, show that language and verbal ability in childhood is more strongly associated with head circumference growth in the first part of gestation than with growth in the second part of gestation or postnatally, or with head circumference at birth. This is also consistent with recent evidence from the economics literature, (Black et al. [2013]), which shows that environmental shocks (radiation exposure) in early gestation have negative impacts on cognitive and educational outcomes.

The results obtained so far show robust associations between fetal anthropometric measures and child height and BMI at age 6, even upon conditioning on measures of birth size and length. However, although we have shown their robustness by conditioning on an extensive set of biological and socioeconomic factors, they can still be biased by unobserved heterogeneity, either at the child level, or at the mother level; in other words, H_{ij}^{P} can be correlated with μ_{ij} or with η_j in equation 1. We then perform additional analyses to address both concerns.

First, we extend to the postnatal period the same child fixed effect approach adopted in Table 4 for the prenatal period.[67] The results, displayed in Table 8, support a causal interpretation of the conditional associations reported in Table 7: fetal health in the third trimester of gestation has a strong and significant impact on child health at 6, over and above newborn health (col. 3) and child health at 1 year (col. 4), and conditional on a child fixed effect. They also show that the persistence of health capital is both different depending on the specific measure considered, and varies over developmental periods.

Second, given the unavailability of siblings data in the SWS, we resort to the CNLSY and the PtA data to account for mother-level unobserved heterogeneity. Given that none of these data contain fetal measures from ultrasound scans, we focus on understanding the effects of birth weight and length on child anthropometric and cognitive outcomes. Hence, we estimate different versions of equation 1 without the inclusion of H^P. The CNLSY results are reported in Table 9.[68] Panel A shows that birth length has a positive and significant association with height, which rivals that of birth weight. The magnitude of this association – one standard deviation increase in each birth measure leading to a 0.125-0.101 higher SD in height – is similar to the one obtained by Case and Paxson [2010] on the same data. While birth length has a significant effect on height, within families it is not associated with BMI. Panel B shows that, between children of the same mother, the heavier – not the longer – sibling at birth has a significantly higher BMI in childhood, with a 1 SD higher birth weight leading to an increase in BMI by 0.215 of a standard deviation. In panels C-F we present the test scores results. In three

[65] Results are available from the authors upon request.

[66] See Gale et al. [2010] for the details on the collection of IQ measures in this subsample.

[67] In Table A10 we see that the structural equation model for the postnatal measures deliver very similar results as for the late gestation and birth measures, supporting the interpretation that they capture both a general latent health factor, and dimension-specific components.

[68] In all the estimated specifications we control for gestational age, and include binary indicators for the child being male, for birth order, for the mother being 20 years old or younger, and for being older than 35 years, for age at measurement (in years), and for year-of-birth-specific bi-monthly dummies – to allow seasonality effects to vary by year, as suggested in McGrath et al. [2007].

out of four cases, i.e. for the PPVT, PIAT Math and Digit Span tests, it is the longer – not the heavier – sibling at birth who has the higher test score (cols. 3); this result is robust to controlling for maternal investments in pregnancy (cols. 4).[69]

We perform an additional robustness test by estimating the same model on the Pathways to Adulthood data, which also include birth anthropometrics, and childhood measures of growth and cognitive development. The results, reported in Table 10, confirm and reinforce the CNLSY results: the longer – not the heavier – sibling at birth is the taller child and has the higher test scores; and in four our of five cases, the difference between the birth weight and the birth length coefficients is statistically significant (for the WRAT Math and Reading scales, and for the WISC Verbal Digit and Comprehension scales).[70] In sum, the CNLSY and PtA results point not only to the importance of mother-specific unobserved heterogeneity, but also of accounting for different dimensions of newborn health.[71]

The evidence presented so far has shown the importance of the prenatal period for child physical and cognitive development, however it has mostly focused on size and linear growth. We now turn to study the predictive power of fetal and birth measures for three indicators of common (and costly) childhood health conditions at 6 years of age: overweight, asthma, and hyperactivity.[72] Both our analysis of the prenatal determinants of poor health at birth (Table 5) and the existing medical and epidemiological literature point to the importance of patterns of growth (Larose et al. [2017]). Given the numerosity of the growth measures which can be computed with our indicators, we proceed in two steps: in a first step, we use lasso methods (Belloni et al. [2014], Ahrens et al. [2018]) to select among different fetal and neonatal measures;[73] in a second step, we use the measures selected in the first step as predictors of the three child health conditions listed above.

The main results for child overweight at age 6 are presented in Table 11.[74] We make several observations. First, the fetal measures have a greater predictive power than the birth measures, both in the basic model (AUC=0.686 in col. 1a versus AUC=0.666 in col. 2a) and in the one with the extended set of controls (AUC=0.794 in col. 1b versus AUC=0.773 in col. 2b). Several dimensions of fetal development predict child overweight. Fetuses with both a larger abdomen in mid-gestation, and faster growth between the second trimester and birth, have a higher probability of ending up as overweight

[69] The corresponding OLS results are reported in columns 1, 3 and 5 of Table A19: the within-family estimates of the effects of birth length on the cognitive test scores are of a greater magnitude than the corresponding OLS estimates.

[70] The WISC Comprehension scale results are in Table A20. The only exception is the PPVT, for which the birth length coefficient has bigger magnitude, but is imprecisely estimated. Birth length seems to display a stronger association with the cognitive test scores in the older cohorts; this temporal pattern is also detectable in the CNLSY data (results available upon request).

[71] Following Behrman and Rosenzweig [2004], the difference between the OLS and the fixed effects results suggest a positive(negative) correlation between birth weight (length) and unobserved endowments. We leave further exploration of this issue to future work.

[72] A child is classified overweight if the BMI-for-age is above the 85^{th} percentile according to the CGF standards; suffering from asthma if the mother reports that the child has had doctor-diagnosed asthma or wheezing in the last 12 months; hyperactivity problems if the child has a score higher than 5 in the hyperactivity subscale of the mother-reported Strengths and Difficulties Questionnaire (SDQ).

[73] We use the Akaike Information Criterion to select among the different models. We consider 21 predictors constructed from the fetal measurements: abdominal and head circumference and femur length in the second trimester, conditional growth between the second and the third trimester, and between the third trimester and birth (the latter only for the first two dimensions, given that femur length has not been measured at birth), slow, fast and accelerated growth between the second trimester and birth, excess (asymmetric) growth in abdomen (head) as compared to head (abdomen), and symmetric growth in the head with respect to the abdomen and the femur, respectively. We define slow growth as below the 25^{th} percentile, and fast growth as above the 75^{th} percentile of the respective distributions. We define accelerated and excess growth as the difference in two growth measures being above the 75^{th} percentile. We consider 13 predictors constructed from the neonatal measurements: birth weight, length, head circumference, low and high birth weight, low Apgar (less than 8) at 1 and 5 minutes, small head circumference (<35.36 cm, Barker et al. [1993]), short birth length (<47 cm, Tuvemo et al. [1999]), SGA and asymmetric SGA (birth weight-for-gestational age $<10^{th}$ percentile and head circumference-for-gestational age $\geq 10^{th}$ percentile), LGA and preterm.

[74] Full results showing the coefficients on all the predictors selected by the lasso are shown in Table A21.

children, by between 2.2 and 4.5 p.p. in the full model (col. 2a). Second, the inclusion of measures of fetal development significantly improves the predictive ability of the model for overweight, as compared to the model which only includes birth measures: the AUC increases from 0.666 to 0.696 (p=0.020) for the basic model, and from 0.773 to 0.795 (p=0.011) for the model with extended controls. Third, the inclusion of measures of fetal development leads to improvement in the prediction of child overweight even in the model which includes postnatal growth: the AUC increases from 0.821 to 0.836 (p=0.019). In particular, we find that patterns of sustained slow ($< 25^{th}$ percentile) or fast ($> 75^{th}$ percentile) growth between mid-gestation and birth are strongly predictive of child overweight, and in addition to weight at birth.

The main results for respiratory health are displayed in Table 12. Here the lasso algorithm selects a relatively greater number of neonatal than fetal predictors.[75] Still, the inclusion of the fetal measures adds predictive power to the model which includes the birth measures only: the AUC increases from 0.631 to 0.662 (p=0.018) in the basic model, and from 0.691 to 0.714 (p=0.015) in the extended model; and also to the model with the postnatal measures: the AUC increases from 0.694 to 0.719 (p=0.010). Among the fetal measures, a sustained fast growth in abdominal circumference since mid-gestation until birth is associated with a 14.4 p.p. lower probability of suffering of asthma at age 6 (col. 3b);[76] An acceleration in head circumference growth in the same developmental periods is associated with a 7.5. p.p. lower probability of suffering of asthma at age 6 (col. 3b); and a fetus whose head grows at a similar rate as the abdomen (i.e., symmetrically) between middle and late gestation has a 6.3 p.p. lower probability of developing asthma at age 6 (col. 3b). Among the birth measures, being born at a low birth weight, low Apgar at 1 minute or with a small head increases the likelihood of developing asthma at 6 years (by 21.2 p.p., 8.3 p.p. and 7.8 p.p., respectively); conversely, high birth weight infants are less likely to develop a respiratory condition (by 7.6 p.p, col. 3b).

Last, the main results for child mental health conditions are reported in Table 13. Again, the inclusion of the measures of fetal development significantly adds predictive power both to the model with birth outcomes only (the p-values for the difference in AUCs are 0.008 and 0.022 for the models with the basic and the extended set of controls, respectively, see cols. 3a and 3b), and to the model which also includes postnatal outcomes (p-value=0.012, see col. 4b). Among the fetal measures, fetuses with a continuously slow growth of the abdomen and the femur between mid-gestation and birth have a higher probability of developing a hyperactivity problem by age 6 (by 9-10 p.p., depending on the specification); conversely, fetuses with continuously fast or with accelerated head circumference in the same developmental periods, and with symmetric head-femur growth, have a lower probability of suffering of hyperactivity problems by age 6 (respectively, by 10.8, 6.2 and 4.3 p.p., see col. 3b). Among the birth measures, being born short and as an asymmetric SGA baby increases the probability of becoming hyperactive by age 6; however, the estimates lack statistical precision.

In sum, our results show that measures of fetal growth patterns significantly add predictive power for child physical and mental health conditions, above and beyond indicators of health at birth and postnatal growth. They are consistent with a substantial body of literature which shows adverse long-term effects of suboptimal in utero conditions, even in the absence of any observed impact at birth. Our results highlight the need to reconsider the central role which has been assigned to birth weight in the economics literature, and to pay greater attention to other measures, which contain information on other aspects of the fetal environment. On a more practical level, the fetal measurements which are collected in routine ultrasound scans could be profitably made available to researchers.

[75] See Table A22 for the full results.

[76] Note the same fetal growth measure is associated with a lower probability of being overweight, see Table 11.

6 Conclusions

Health at birth is a crucial link in the transmission of advantage and disadvantage both along the life course and across generations. Economists have routinely used birth weight to measure neonatal health, however, the extent to which it both acts as a proxy for specific body compartments of the fetus, and predicts later outcomes as compared to other measures of early health, has never been previously investigated.

In this paper we have used two unique datasets from the United Kingdom with measures of fetal health capital from ultrasound scans, and two datasets from the United States with measures of neonatal health capital on siblings, to open the "black box" of birth weight. We have provided several important insights. In the first part of our analysis, we have shown that birth weight is a proxy for the size of specific compartments of the fetus, primarily reflected in abdominal circumference; however, while fetuses with relatively larger abdomens at the end of gestation have higher birth weight, they are *more* likely to be preterm and have *lower* Apgar scores. Other newborn measures, such as birth length and head circumference, and the Apgar score, are more informative than birth weight about different dimensions of the prenatal environment. We have then studied different indicators of poor neonatal health - low and high birth weight, small- and large-for-gestational age (SGA and LGA), and preterm birth, and show that they are predicted by different patterns of fetal growth in middle and late gestation. Lastly, we have examined the fat content of the three anthropometric birth measures that we study. We have found that abdominal circumference, head circumference and femur length are all are positively associated with lean mass in the newborn, but only birth weight is also positively associated with fat mass. Hence, birth weight captures both negative as well as positive aspects of fetal health. Other neonatal measurements are more informative than birth weight about different dimensions of fetal health capital.

In the second part of our analysis, we have shown that alternative measures of fetal and neonatal health capital are differentially predictive of child development, *beyond birth weight*. Not accounting for them overestimates the importance of birth weight, as compared to other measures of early health. We also found that fetal anthropometrics in the third trimester of pregnancy are predictive of child growth (height and BMI) at six years of age, above and beyond measures of size and length at birth, and even postnatally (in the first year of age). Then, using two complementary datasets with information on siblings from the United States, we have also shown that birth length rivals birth weight in predicting cognitive and anthropometric outcomes throughout childhood. Lastly, we have shown that patterns of fetal growth since the second trimester of gestation are predictive of the most common and costly child physical and mental health conditions - overweight, asthma and hyperactivity - above and beyond poor health at birth (and even postnatal growth in the first year of life).

Our results suggest that health *in utero* and at birth is a complex and multidimensional entity, which cannot be easily summarized by one proxy. Although birth weight provides *some* information about the endpoint of fetal growth, it neither describes the trajectory followed in utero, nor it reflects the body composition of the fetus. The lack of a strict correspondence between birth weight and neonatal health is further supported by historical evidence which shows that, in the industrialized world, average birth weight has been remarkably stable between the mid-nineteenth century and today, despite substantial changes in social conditions and in front of significant increases in average height and massive reductions in infant mortality. At the same time, it is likely that substantial differences exist between populations. Therefore, using measures of fetal size to derive universal standards of optimal fetal growth such as has been recently proposed in the Intergrowth-21st project (Villar et al. [2014]) might lead to health interventions setting inadvertently harmful policy targets.

Our results also suggest that multiple perinatal indicators should be routinely collected and used to gain a more complete assessment of the causes and consequences of early life health. Birth weight should be re-considered as the sole potential target for prenatal interventions and proxy of early life health. Since birth weight acts as a proxy for other, usually unobserved, endowments, policies aimed at increasing it might not lead to improvements in later outcomes, especially if implemented at the end of gestation. Along the same lines of reasoning, failing to find an impact of an intervention on birth weight might not necessarily imply the inability for a certain policy to improve later health. An instructive example is provided in this regard by the recent evaluation of the Family Nurse Partnership programme in England (Robling et al. [2016]),[77] which has shown no impact on birth weight (one of the four primary outcomes), but significant improvement in cognitive and language development until age 2 (the end of the intervention).[78] Whilst birth weight is commonly, and easily, measured, its underlying biology is complicated and it should therefore be used with caution. At the same time, the use and interpretation of other neonatal measures require an understanding of the specific inputs generating them. Hence, an important topic of ongoing work is to study the production functions for birth length and head circumference, in addition to those for birth weight, which have already been examined in several papers (e.g. Rosenzweig and Schultz [1983]) - none of these papers used fetal ultrasound data.

While the developmental origins of health and disease (DOHaD) literature has made great strides in recent years, especially in establishing robust associations of early environmental exposures and later health risks, the key challenge is to understand how early experiences have long-term consequences, in order to establish effective pathways to remediation of the effects of early adversity. Two promising avenues are currently being pursued. The first, to which the current work belongs, focuses on more accurate measurements of early life health (including records of the mother's health) and specific proxies for various exposures, including epigenetic markers. The second aims at disentangling biological mechanisms from behavioural responses, by estimating production functions rather than reduced-form impacts. Recent examples include Yi et al. [2015], who show that parents can compensate and reinforce along different dimensions of the child's human capital; and Kesternich et al. [2015], who show that behavioural pathways do not operate only in the early years, but also in adulthood. It is likely that combining these two avenues will lead to significant advances in our understanding of the causes and consequences of early life circumstances, with resulting benefits for public health.

[77] This is the UK implementation of the Nurse Family Partnership, the nurse home visiting programme for first-time teenage mothers which was created more than thirty years ago by David Olds in the United States.

[78] Unfortunately the experimental design does not allow to disentangle the role of the prenatal component of the intervention in promoting child development.

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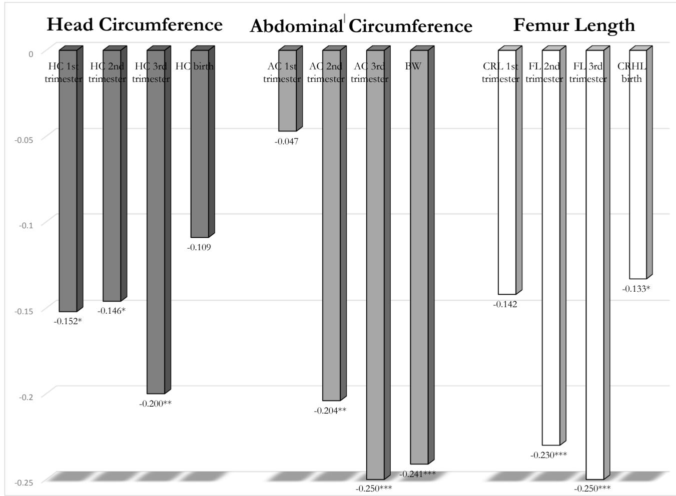
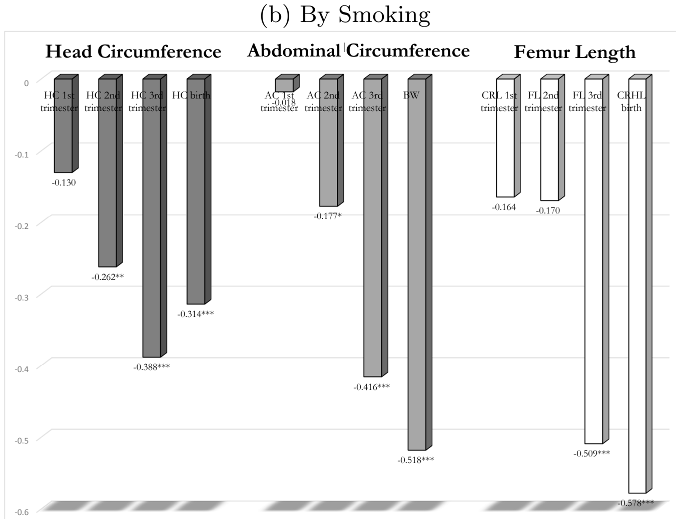
7 Tables and Figures

Figure 1: Gradients in Fetal and Neonatal Health Capital

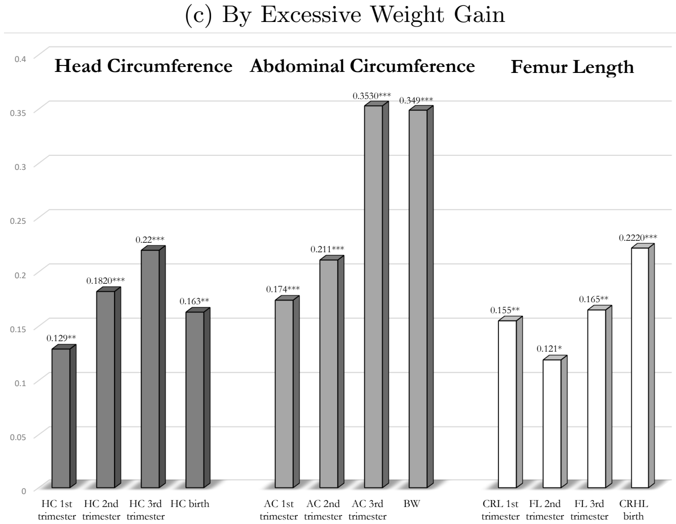
(a) By Deprivation



(b) By Smoking

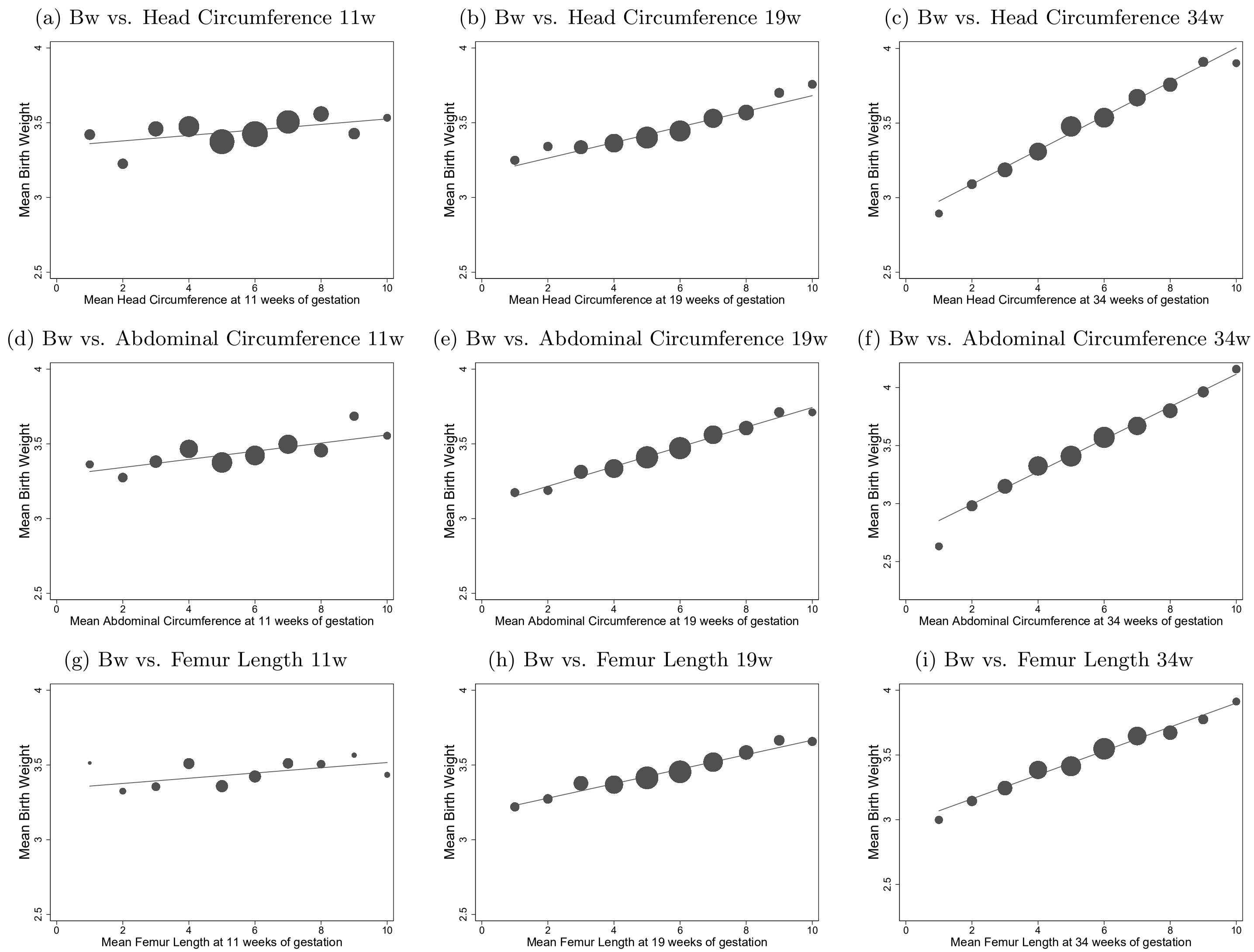


(c) By Excessive Weight Gain



Notes: The graphs above are based on the SWS data. Each bar in each graph plots the coefficient (the number displayed at the end of the bar) of a linear regression of a specific fetal or birth measure on a different exposure (without including additional controls): (a) Mother resident in a neighbourhood in the bottom quartile of the Townsend Deprivation Index (baseline: top quartile); (b) Mother smoking both in the early and late part of pregnancy; (c) Mother with excessive weight gain in pregnancy (Institute of Medicine 2009 definition). We use balanced samples of 965 (panel a), 850 (panel b) and 827 women (panel c), respectively. CRL: Crown-Rump Length; HC: Head Circumference; AC: Abdominal Circumference; FL: Femur Length; CRHL: Crown-Heel Length; BW: Birth Weight. Each fetal anthropometric indicator is the unweighted average of three different measurements. Here we use crown-rump length rather than femur length for the first trimester since the smaller number of observations for the latter would lead to a severe reduction in size for the balanced sample. *** p<0.01, ** p<0.05, * p<0.1.

Figure 2: Birth Weight and Fetal Health Capital in the Three Trimesters of Pregnancy



Notes: The graphs above are based on the fetal growth sample, SWS data. Each circle represents the mean birth weight (in kilograms) for each of the ten bins in which the fetal measures (expressed as z-scores) have been grouped, as follows: 1=-4 to -2; 2=-2 to -1.5; 3=-1.5 to -1; 4=-1 to -0.5; 5=-0.5 to 0; 6=0 to 0.5; 7=0.5 to 1; 8=1 to 1.5; 9=1.5 to 2; 10=2 to 4. The size of the dots is proportional to the number of observations in each bin. The lines represent fitted values from an ordinary least squares regression of birth weight on the respective (binned) fetal measure. Abbreviations: bw=birth weight; w=weeks.

Table 1: Summary Statistics: Fetal Development

	(1) Mean	(2) SD	(3) Min.	(4) Max.	(5) N
Panel A: Gestational Age					
Gestational Age at 11w ultrasound scan (days)	82.48	4.09	68	100	1,676
Gestational Age at 19w ultrasound scan (days)	136.92	3.65	120	156	1,945
Gestational Age at 34w ultrasound scan (days)	241.20	3.52	223	260	1,920
Panel B: Head Circumference					
Head Circumference 11w (mm)	70.00	9.18	43.00	102.30	1,255
Head Circumference 19w (mm)	168.42	8.63	143.10	199.00	1,941
Head Circumference 34w (mm)	317.70	10.78	282.60	360.50	1,846
Panel C: Abdominal Circumference					
Abdominal Circumference 11w (mm)	55.90	7.66	32.00	85.30	1,175
Abdominal Circumference 19w (mm)	146.27	9.08	117.40	177.30	1,932
Abdominal Circumference 34w (mm)	307.70	15.30	256.30	383.90	1,920
Panel D: Femur Length					
Femur Length 11w (mm)	7.11	1.90	3.15	14.30	468
Femur Length 19w (mm)	30.63	2.09	23.80	37.80	1,943
Femur Length 34w (mm)	64.85	2.69	55.20	73.70	1,918

Notes: Own calculations from the SWS data. Each fetal anthropometric indicator is the unweighted average of three different measurements. SD = Standard Deviation. Min. = Minimum. Max. = Maximum. N=sample size. w=week.

Table 2: Conditional Associations between Measures of Fetal and Neonatal Health Capital: Birth Weight and Gestational Age

	Birth Weight (kg)			**Gestational Age (weeks)**			**Birth Weight (z-score)**		
	TR1	**TR2**	**TR3**	**TR1**	**TR2**	**TR3**	**TR1**	**TR2**	**TR3**
Fetal Measure	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)	(3a)	(3b)	(3c)
Abdominal Circumference (z)	0.039***	0.118***	0.277***	-0.402***	-0.362***	-0.118***	0.261***	0.422***	0.647***
	(0.015)	(0.013)	(0.010)	(0.047)	(0.045)	(0.037)	(0.027)	(0.021)	(0.016)
N	*1,160*	*1,906*	*1,902*	*1,169*	*1,922*	*1,914*	*1,160*	*1,906*	*1,902*
R^2	[0.079]	[0.105]	[0.376]	[0.077]	[0.054]	[0.021]	[0.143]	[0.228]	[0.512]
Adjusted R^2	[0.061]	[0.094]	[0.368]	[0.058]	[0.042]	[0.009]	[0.126]	[0.218]	[0.506]
Semi-partial R^2	0.005†	0.041†	0.309†	0.048†	0.034†	0.006†	0.072†	0.176†	0.457†
Head Circumference (z)	0.026*	0.096***	0.231***	-0.465***	-0.381***	-0.068*	0.263***	0.379***	0.520***
	(0.015)	(0.013)	(0.011)	(0.045)	(0.042)	(0.037)	(0.027)	(0.021)	(0.020)
N	*1,238*	*1,915*	*1,829*	*1,249*	*1,931*	*1,840*	*1,238*	*1,915*	*1,829*
R^2	[0.080]	[0.093]	[0.267]	[0.085]	[0.059]	[0.017]	[0.137]	[0.200]	[0.329]
Adjusted R^2	[0.063]	[0.082]	[0.258]	[0.068]	[0.048]	[0.005]	[0.121]	[0.191]	[0.320]
Semi-partial R^2	0.002	0.028†	0.199†	0.057†	0.039†	0.002†	0.068†	0.147†	0.273†
Femur Length (z)	0.017	0.091***	0.190***	-0.310***	-0.320***	-0.081**	0.179***	0.342***	0.441***
	(0.026)	(0.013)	(0.011)	(0.089)	(0.041)	(0.036)	(0.041)	(0.021)	(0.020)
N	*466*	*1,917*	*1,900*	*468*	*1,933*	*1,912*	*466*	*1,917*	*1,900*
R^2	[0.101]	[0.090]	[0.209]	[0.086]	[0.049]	[0.017]	[0.144]	[0.178]	[0.263]
Adjusted R^2	[0.057]	[0.079]	[0.199]	[0.041]	[0.038]	[0.005]	[0.101]	[0.168]	[0.254]
Semi-partial R^2	0.001	0.027†	0.142†	0.032†	0.029†	0.003†	0.032†	0.126†	0.209†

Notes: This table shows the estimated coefficients from ordinary least squares regressions of three measures of health at birth (as reported in the top row) on three measures of fetal size (as reported in the first column), by trimester of gestation. The results in each cell come from separate regressions of each birth measure on each fetal measure separately. All models include binary indicators for white ethnicity, male, being a first born and year and month of birth. Birth weight is measured in kilograms; gestational age in weeks; birth weight z-score has been computed using the Child Growth Foundation standards. The fetal size z-scores have been computed according to the Royston [1995] method. TR1=11 weeks; TR2=19 weeks; TR3=34 weeks. *** p<0.01, ** p<0.05, * p<0.1, † p<0.1. Robust standard errors in parentheses.

Table 3: Conditional Associations between Measures of Fetal and Neonatal Health Capital: Birth Weight, Length and Head Circumference, and Apgar Score

	Birth Weight (z-score)		**Birth Length (z-score)**		**Birth Head Circ. (z-score)**		**APGAR 1M**	
	TR2	**TR3**	**TR2**	**TR3**	**TR2**	**TR3**	**TR2**	**TR3**
Fetal Measure	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)	(4a)	(4b)
Abdominal Circumference (z)	0.273***	0.480***	0.140***	0.242***	0.108***	0.190***	0.008	-0.120***
	(0.034)	(0.019)	(0.032)	(0.020)	(0.034)	(0.018)	(0.061)	(0.046)
Head Circumference (z)	0.128***	0.172***	0.095***	0.147***	0.426***	0.626***	0.080	0.119**
	(0.035)	(0.019)	(0.031)	(0.019)	(0.034)	(0.019)	(0.064)	(0.046)
Femur Length (z)	0.071**	0.169***	0.204***	0.344***	-0.060**	0.013	-0.055	0.012
	(0.031)	(0.018)	(0.029)	(0.018)	(0.030)	(0.015)	(0.060)	(0.043)
N	*1,901*	*1,828*	*1,774*	*1,728*	*1,793*	*1,744*	*1,845*	*1,784*
R^2	[0.241]	[0.565]	[0.231]	[0.479]	[0.256]	[0.621]	[0.018]	[0.022]
Adjusted R^2	[0.231]	[0.559]	[0.220]	[0.472]	[0.246]	[0.615]	[0.005]	[0.008]
Semi-partial R^2 AC	$0.028^{\dagger}$	$0.157^{\dagger}$	$0.009^{\dagger}$	$0.047^{\dagger}$	$0.004^{\dagger}$	$0.025^{\dagger}$	0.000	$0.004^{\dagger}$
Semi-partial R^2 HC	$0.006^{\dagger}$	$0.020^{\dagger}$	$0.004^{\dagger}$	$0.017^{\dagger}$	$0.067^{\dagger}$	$0.261^{\dagger}$	0.001	$0.003^{\dagger}$
Semi-partial R^2 FL	$0.002^{\dagger}$	$0.024^{\dagger}$	$0.023^{\dagger}$	$0.120^{\dagger}$	$0.002^{\dagger}$	0.000	0.000	0.000

Notes: This table shows the estimated coefficients from ordinary least squares regressions of four measures of health at birth (as reported in the top row) on three measures of fetal size (as reported in the first column), by trimester of gestation. The results in each column come from separate regressions of each birth measure on the three fetal measures. All models include binary indicators for white ethnicity, male, being a first born and year and month of birth. The birth measures z-scores have been computed using the Child Growth Foundation standards. The fetal size z-scores have been computed according to the Royston [1995] method. TR2=19 weeks; TR3=34 weeks. AC=Abdominal Circumference; HC=Head Circumference; FL=Femur Length. *** p<0.01, ** p<0.05, * p<0.1, † p<0.1. Robust standard errors in parentheses.

Table 4: Effects of Prenatal Health on Birth Health

	Health at Birth			
	(1)	(2)	(3)	(4)
Size TR2	0.194***		0.053***	
	(0.017)		(0.018)	
Head TR2	0.233***		0.073***	
	(0.020)		(0.020)	
Length TR2	0.188***		0.076***	
	(0.019)		(0.019)	
Health TR2				0.068***
				(0.015)
Size TR3		0.293***	0.286***	0.278***
		(0.013)	(0.014)	(0.014)
Head TR3		0.375***	0.356***	0.358***
		(0.016)	(0.018)	(0.017)
Length TR3		0.253***	0.232***	0.236***
		(0.015)	(0.017)	(0.016)
Child FE	✓	✓	✓	✓
Test for equality of lagged terms (p-value)				
TR2	0.047		0.375	
TR3		0.000	0.000	0.000
N	*5,622*	*5,622*	*5,622*	*5,505*
# of children	1,962	1,962	1,962	1,924

Notes: This table shows the estimated coefficients from ordinary least squares regressions of health at birth (weight, length and head circumference) on fetal health in the second and third trimester of gestation, controlling for child fixed effects. The size measure we use is abdominal circumference for the second and third trimester, and weight at birth; the length measure we use is femur length for the second and third trimester, and body length at birth. In the first three columns we allow the measures of fetal health to have different effects on the measure of birth health; the fourth column restricts the measures of fetal health at 19 to have the same effects. The models also include dummies for type of measure. The birth measures z-scores have been computed using the Child Growth Foundation standards. The fetal size z-scores have been computed according to the Royston [1995] method. Standard errors in parentheses are clustered at the level of the child. TR2=19 weeks; TR3=34 weeks. *** p<0.01, ** p<0.05, * p<0.1.

Table 5: In Utero Growth Patterns in Second and Third Trimester and Birth Outcomes

	LBW (1)	**SGA** (2)	**HBW** (3)	**LGA** (4)	**Preterm** (5)
AC Stable Low Trajectory	0.047***	0.142***	-0.167***	-	0.021*
	(0.009)	(0.014)	(0.040)	(-)	(0.012)
AC Declining Trajectory	0.030***	0.070***	-0.066***	-0.026	0.021*
	(0.009)	(0.014)	(0.024)	(0.021)	(0.011)
AC Increasing Trajectory	0.009	0.010	0.089***	0.076***	0.022*
	(0.011)	(0.017)	(0.017)	(0.016)	(0.012)
AC Stable High Trajectory	-0.017	-0.117***	0.154***	0.180***	0.041***
	(0.017)	(0.043)	(0.018)	(0.016)	(0.012)
N	*1,781*	*1,781*	*1,781*	*1,553*	*1,792*
AUC_X	0.676	0.632	0.630	0.645	0.573
	(0.042)	(0.024)	(0.018)	(0.022)	(0.037)
$AUC_X + fetal$	0.906	0.817	0.799	0.817	0.704
	(0.017)	(0.017)	(0.014)	(0.017)	(0.033)
p	*0.000*	*0.000*	*0.000*	*0.000*	*0.002*

Notes: This table shows average marginal effects from probit models of five measures of health at birth (as reported in the top row) on patterns of fetal growth between the second and the third trimester. All models include binary indicators for white ethnicity, gender, being a first born and year and season of birth. LBW=Low Birth Weight: binary indicator for birth weight <2,500g. SGA=Small-for-Gestational Age: binary indicator for birth weight $<10^{th}$ percentile; HBW=High Birth Weight: binary indicator for birth weight >4,000g; LGA=Large-for-Gestational Age: binary indicator for birth weight $>90^{th}$ percentile; Preterm: binary indicator for gestational age at birth <37 weeks. "AC Stable Low Trajectory" is a binary indicator which takes value 1 if the fetus is in the lower quartile of the Abdominal Circumference distribution both in the second and in the third trimester. "AC Declining Trajectory" is a binary indicator which takes value 1 if the fetus is in the lower quartile of the distribution of the difference between the third and the second trimester Abdominal Circumference. "AC Increasing Trajectory" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the distribution of the difference between the third and the second trimester Abdominal Circumference. "AC Stable High Trajectory" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the Abdominal Circumference distribution both in the second and in the third trimester. *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. AUC_X=Area under the ROC curve for a model which does not include the fetal measures. $AUC_X + fetal$=Area under the ROC curve for a model which also includes the fetal measures. The standard errors are bootstrapped (1,000 replications). p=p-value for the Null Hypothesis that both models have equal AUC values.

Table 6: Conditional Associations between Neonatal Anthropometrics and Measures of Body Composition at Birth

	Fat Mass (kg)					**Lean Mass (kg)**		
Birth Measure	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Weight (z)	0.151***			0.186***	0.242***			0.147***
	(0.007)			(0.012)	(0.009)			(0.015)
Length (z)		0.107***		-0.035***		0.238***		0.095***
		(0.008)		(0.009)		(0.010)		(0.013)
Head Circumference (z)			0.105***	-0.015			0.201***	0.038***
			(0.009)	(0.009)			(0.011)	(0.011)
N	*623*	*622*	*624*	*620*	*623*	*622*	*624*	*620*
R^2	[0.576]	[0.305]	[0.324]	[0.588]	[0.668]	[0.585]	[0.493]	[0.707]
Adjusted R^2	[0.561]	[0.280]	[0.299]	[0.572]	[0.656]	[0.570]	[0.475]	[0.695]
Semi-partial R^2 BW	$0.479^{\dagger}$			$0.215^{\dagger}$	$0.531^{\dagger}$			$0.058^{\dagger}$
Semi-partial R^2 BL		$0.208^{\dagger}$		$0.010^{\dagger}$		$0.447^{\dagger}$		$0.031^{\dagger}$
Semi-partial R^2 BHC			$0.227^{\dagger}$	$0.002^{\dagger}$			$0.355^{\dagger}$	$0.006^{\dagger}$
	Thigh Skinfold (z-score)					**Body Fat (%)**		
Birth Measure	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Weight (z)	0.717***			0.984***	0.023***			0.034***
	(0.019)			(0.034)	(0.002)			(0.003)
Length (z)		0.452***		-0.276***		0.015***		-0.008***
		(0.024)		(0.030)		(0.002)		(0.003)
Head Circumference (z)			0.437***	-0.102***			0.013***	-0.007***
			(0.023)	(0.026)			(0.002)	(0.002)
N	*1,828*	*1,816*	*1,833*	*1,811*	*623*	*622*	*624*	*620*
R^2	[0.496]	[0.215]	[0.232]	[0.528]	[0.346]	[0.201]	[0.193]	[0.367]
Adjusted R^2	[0.489]	[0.205]	[0.222]	[0.522]	[0.322]	[0.171]	[0.164]	[0.342]
Semi-partial R^2 BW	$0.430^{\dagger}$			$0.261^{\dagger}$	$0.231^{\dagger}$			$0.147^{\dagger}$
Semi-partial R^2 BL		$0.149^{\dagger}$		$0.024^{\dagger}$		$0.085^{\dagger}$		$0.010^{\dagger}$
Semi-partial R^2 BHC			$0.166^{\dagger}$	$0.004^{\dagger}$			$0.078^{\dagger}$	$0.010^{\dagger}$

Notes: This table shows the estimated coefficients from ordinary least squares regressions of four different measures of newborn body composition on three neonatal anthropometrics (birth weight, birth length and birth head circumference), standardized using the Child Growth Foundation (CGF) standards. The measures of body composition are fat and lean mass in kilograms and proportion of body fat, all measured using DXA; and thigh skinfold, standardized within the SWS. Each column in each panel comes from a separate regression. All models include binary indicators for white ethnicity, gender, being a first born and year and month of birth. Robust standard errors in parentheses. BW=Birth Weight; BL=Birth Length; BHC=Birth Head Circumference. *** p<0.01, ** p<0.05, * p<0.1.

Table 7: Estimated Effects of Fetal and Neonatal Health Capital on Height and BMI in Early Childhood (6 Years)

						Height (z-score)						
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)	(4a)	(4b)	(4c)	(5a)	(5b)	(5c)
Birth Weight (z)	0.310***	0.175***			-0.130**	-0.135***				-0.080	-0.114**	
	(0.031)	(0.030)			(0.051)	(0.049)				(0.055)	(0.054)	
Birth Length (z)			0.529***	0.361***	0.649***	0.466***				0.548***	0.406***	
			(0.031)	(0.031)	(0.049)	(0.047)				(0.052)	(0.051)	
Fetal Femur Length TR3 (z)							0.355***	0.231***	β_c:0.154	0.178***	0.125***	β_c:0.073
							(0.033)	(0.031)	δ:2.324	(0.034)	(0.032)	δ:2.100
Full controls		✓		✓		✓		✓			✓	
N	*1,067*	*1,067*	*1,067*	*1,067*	*1,067*	*1,067*	*1,067*	*1,067*		*1,067*	*1,067*	
R^2	[0.116]	[0.357]	[0.243]	[0.411]	[0.251]	[0.416]	[0.168]	[0.379]		[0.274]	[0.427]	
Adjusted R^2	[0.098]	[0.294]	[0.227]	[0.354]	[0.234]	[0.359]	[0.148]	[0.317]		[0.255]	[0.369]	
Semi-partial R^2 BW	0.085†	0.022†			0.005†	0.005†				0.001	0.003†	
Semi-partial R^2 BL			0.211†	0.075†	0.135†	0.059†				0.081†	0.039†	
Semi-partial R^2							0.097†	0.035†		0.019†	0.009†	
						BMI (z-score)						
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)	(4a)	(4b)	(4c)	(5a)	(5b)	(5c)
Birth Weight (z)	0.262***	0.222***			0.380***	0.296***				0.297***	0.233***	
	(0.032)	(0.034)			(0.051)	(0.053)				(0.058)	(0.059)	
Birth Length (z)			0.109***	0.085**	-0.256***	-0.206***				-0.245***	-0.198***	
			(0.037)	(0.039)	(0.050)	(0.052)				(0.054)	(0.055)	
Fetal Abdominal Circ. TR3 (z)							0.236***	0.188***	β_c:0.160	0.141***	0.112**	β_c:0.091
							(0.036)	(0.037)	δ:4.092	(0.043)	(0.044)	δ:3.939
Full controls		✓		✓		✓		✓			✓	
N	*1,067*	*1,067*	*1,067*	*1,067*	*1,067*	*1,067*	*1,067*	*1,067*		*1,067*	*1,067*	
R^2	[0.086]	[0.235]	[0.034]	[0.204]	[0.109]	[0.248]	[0.087]	[0.232]		[0.119]	[0.254]	
Adjusted R^2	[0.067]	[0.161]	[0.014]	[0.127]	[0.089]	[0.174]	[0.066]	[0.156]		[0.096]	[0.177]	
Semi-partial R^2 BW	0.061†	0.035†			0.040†	0.022†				0.020†	0.011†	
Semi-partial R^2 BL			0.009†	0.004†	0.021†	0.011†				0.016†	0.009†	
Semi-partial R^2 FAC							0.037†	0.021†		0.010†	0.005†	

Notes: The table shows the estimated coefficients from ordinary least squares regressions of height and BMI at 6 years on birth and fetal measures in the third trimester of gestation (34 weeks). Height, BMI and the birth measures have been standardized using the Child Growth Foundation (CGF) standards; the fetal measures have been standardized according to the Royston [1995] method. Each column comes from a separate regression. Columns (1a) and (1b) display results from a model where birth weight is the only measure of early health included. Columns (2a) and (2b) display results from a model where birth length is the only measure of early health included. Columns (3a) and (3b) display selected results from a model where the three measures of neonatal health (birth weight, length and head circumference) are included. Columns (4a) and (4b) display selected results from a model where the three measures of fetal health at 34 weeks (femur length, abdominal circumference and head circumference) are included. Columns (5a) and (5b) display selected results from a model where all the measures of fetal and neonatal health are included. Columns (4c) and (5c) report the bias-corrected coefficients β_c (computed assuming an equal degree of selection between observables and unobservables) and the coefficients of proportionality δ, following Oster [2017]; both sets are computed assuming R^{max}=1.3× R^2 in columns (4b) and (5b), respectively. The full set of results with all the estimated coefficients on the fetal and neonatal measures is reported in Table A17 in the Appendix. The models in columns (1a), (2a), (3a), (4a) and (5a) include binary indicators for white ethnicity, gender, being a first born, year and month of birth. The models in columns (1b), (2b), (3b), (4b) and (5b) also add a binary indicator for mother's age at birth and the following controls measured at baseline (before conception): binary indicators for the number of children, whether the mother has a degree-level education, belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), owns the house, is single, separated, divorced or widowed, whether she receives welfare benefits, is in fair, bad or very bad health, whether she has been under stress in the last four weeks, whether she was working last week, whether she is a current smoker, whether she drinks more than 4 units of alcohol per week, whether she does any strenuous exercise in the week, whether she does any moderate exercise in the week, whether the mother's partner belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), whether the mother's father belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled); continuous variables for mother's birth weight, pre-pregnancy weight, height, BMI, head circumference, leg length, waist circumference, skinfolds (sum of triceps, biceps, subscapular and suprailiac) and her daily energy intake (kilocalories), paternal height, weight and birth weight, grandmaternal and grandpaternal height and weight, and the Townsend Deprivation Index; missing values for social class of the mother, the mother's father and the mother's partner have been replaced with zeros and a binary indicator for missing is included; missing values for maternal birth weight and head circumference, for paternal height, weight and birth weight, for grandmaternal weight and grandpaternal height and weight are replaced with the sample means of the non-missing observations and binary indicators for missing are included. Robust standard errors in parentheses. All models are estimated on a balanced sample of 1,048 observations. *** p<0.01, ** p<0.05, * p<0.1, † <0.1.

Table 8: Effects of Prenatal Health, Birth and Postnatal Health on Childhood Health

	Health at Year 6			
	(1)	(2)	(3)	(4)
Size TR3	0.192***		0.138***	0.069***
	(0.022)		(0.025)	(0.023)
Head TR3	0.361***		0.063*	-0.003
	(0.028)		(0.035)	(0.026)
Length TR3	0.253***		0.171***	0.088***
	(0.024)		(0.025)	(0.021)
Size Birth		0.415***	0.331***	0.160***
		(0.027)	(0.032)	(0.027)
Head Birth		0.670***	0.643***	0.263***
		(0.032)	(0.042)	(0.035)
Length Birth		0.489***	0.397***	0.173***
		(0.031)	(0.034)	(0.028)
Size Y1				0.417***
				(0.021)
Head Y1				0.626***
				(0.025)
Length Y1				0.475***
				(0.022)
Child FE	✓	✓	✓	✓
Test for equality of lagged terms (p-value)				
TR3	0.000		0.031	0.013
Birth		0.000	0.000	0.014
Y1				0.000
N	*3,846*	*3,846*	*3,846*	*3,846*
# of children	1,289	1,289	1,289	1,289

Notes: This table shows the estimated coefficients from ordinary least squares regressions of health at 6 years (weight, height and head circumference) on postnatal (1 year of age), birth and fetal health in the third trimester of gestation, controlling for child fixed effects. The size measure we use is abdominal circumference for the third trimester, and weight at birth and postnatally; the length measure we use is femur length for the third trimester, and body length at birth and postnatally. All columns allow all measures of prenatal, birth and year 1 health to have different effects on the measure of health at age 6. The models also include dummies for type of measure. The postnatal and birth measures z-scores have been computed using the Child Growth Foundation standards. The fetal size z-scores have been computed according to the Royston [1995] method. Standard errors in parentheses are clustered at the level of the child. TR3=34 weeks. *** p<0.01, ** p<0.05, * p<0.1.

Table 9: Estimated Effects of Birth Health on Anthropometrics and Cognition in Childhood (CNLSY)

	Panel A: Height (z-score)				**Panel B: BMI (z-score)**			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Birth Weight (z)	0.183***		0.125***	0.118***	0.194***		0.215***†	0.212***†
	(0.037)		(0.041)	(0.041)	(0.039)		(0.042)	(0.043)
Birth Length (z)		0.136***	0.101***	0.119***		0.025	-0.036	-0.047
		(0.026)	(0.029)	(0.030)		(0.027)	(0.028)	(0.029)
Mother FE	✓	✓	✓	✓	✓	✓	✓	✓
N	*7,237*	*7,237*	*7,237*	*7,065*	*7,218*	*7,218*	*7,218*	*7,048*
# mothers	1,738	1,738	1,738	1,720	1,736	1,736	1,736	1,702
	Panel C: PPVT				**Panel D: WISC Memory for Digit Span**			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Birth Weight (z)	0.397		-0.151	0.161	0.151		0.065	0.070
	(0.607)		(0.642)	(0.653)	(0.102)		(0.116)	(0.116)
Birth Length (z)		0.822**	0.864**	0.699*		0.164**	0.146*	0.172**
		(0.375)	(0.402)	(0.423)		(0.071)	(0.081)	(0.083)
Mother FE	✓	✓	✓	✓	✓	✓	✓	✓
N	*3,585*	*3,585*	*3,585*	*3,451*	*5,613*	*5,613*	*5,613*	*5,488*
# mothers	1,534	1,534	1,534	1,513	1,655	1,655	1,655	1,637
	Panel E: PIAT Math				**Panel F: PIAT Reading Recognition**			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Birth Weight (z)	0.745**		0.265	0.300	1.159***		0.838**	1.024**
	(0.377)		(0.405)	(0.413)	(0.381)		(0.409)	(0.425)
Birth Length (z)		0.897***	0.823***	0.902***		0.784***	0.550*	0.512
		(0.266)	(0.287)	(0.297)		(0.283)	(0.305)	(0.321)
Mother FE	✓	✓	✓	✓	✓	✓	✓	✓
N	*7,130*	*7,130*	*7,130*	*6,967*	*7,124*	*7,124*	*7,124*	*6,962*
# mothers	1,691	1,691	1,691	1,671	1,691	1,691	1,691	1,671

Notes: This table displays ordinary least squares estimates of two anthropometric and three cognitive outcomes in childhood (ages 7-11) on birth weight and birth length. Both birth measures have been standardized using the growth chart developed by Olsen et al. [2010] for the United States. Only those cases reporting that birth length is not an estimate have been included. Values lying outside three times the interquartile range from the first or third quartile of the birth weight and birth length distribution have been removed as extreme outliers (Tukey's method). Additionally, values of the Olsen z-scores smaller than -4 or greater than 4 have been removed. Controls included in all the estimated specifications not shown in the tables are: gestational age and indicators for the child being male, for birth order, for the mother being 20 years old or younger, and for being older than 35 years, for age at measurement (in years), and for year-of-birth-specific bi-monthly dummies. The specifications in column (7) also include the following prenatal variables: pre-pregnancy weight and gestational weight gain, and binary indicators for whether the first prenatal care visit took place in the first trimester, for whether the mother was drinking in pregnancy 1 day per week or more, and for whether she was smoking <1 pack per day or 1 pack or more per day. The sample only includes children of white ethnicity. The standard errors (in parentheses) are clustered at the level of the mother. *** p<0.01, ** p<0.05, * p<0.1. †: the coefficients on birth weight and birth length are statistically significantly different (two-sided tests).

Table 10: Estimated Effects of Early Life Health on Anthropometric and Cognitive Outcomes in Childhood (PtA)

	Panel A: Height			**Panel B: BMI**		
	(1)	(2)	(3)	(1)	(2)	(3)
Birth Weight (z)	0.146		-0.343	0.228**		0.224**
	(0.401)		(0.480)	(0.107)		(0.109)
Birth Length (z)		0.913**	1.089**†		0.123	0.008
		(0.394)	(0.495)		(0.122)	(0.125)
Mother FE	✓	✓	✓	✓	✓	✓
N	*1,349*	*1,349*	*1,349*	*1,291*	*1,291*	*1,291*
# mothers	1,208	1,208	1,208	1,153	1,153	1,153
	Panel C: PPVT			**Panel D: WRAT Math Scale**		
	(1)	(2)	(3)	(1)	(2)	(3)
Birth Weight (z)	0.262		-0.312	0.437		0.007
	(0.554)		(0.690)	(0.394)		(0.398)
Birth Length (z)		1.098	1.259		1.065***	1.062***†
		(0.813)	(0.985)		(0.359)	(0.367)
Mother FE	✓	✓	✓	✓	✓	✓
N	*1,372*	*1,372*	*1,372*	*1,328*	*1,328*	*1,328*
# mothers	1,231	1,231	1,231	1,199	1,199	1,199
	Panel E: WRAT Reading			**Panel F: WISC Verbal Digit**		
	(1)	(2)	(3)	(1)	(2)	(3)
Birth Weight (z)	-0.399		-1.013	0.470*		0.095
	(0.731)		(0.772)	(0.245)		(0.257)
Birth Length (z)		0.998	1.494*†		0.895***	0.846***†
		(0.728)	(0.790)		(0.257)	(0.282)
Mother FE	✓	✓	✓	✓	✓	✓
N	*1,326*	*1,326*	*1,326*	*1,342*	*1,342*	*1,342*
# mothers	1,198	1,198	1,198	1,210	1,210	1,210

Notes: This table displays ordinary least squares estimates of anthropometric and cognitive outcomes in childhood (age 7) on birth weight and birth length. Both birth measures have been standardized using the growth chart developed by Olsen et al. [2010] for the United States. Values lying outside three times the interquartile range from the first or third quartile of the birth weight and birth length distribution have been removed as extreme outliers (Tukey's method). Controls included in all the estimated specifications not shown in the tables are: gestational age and indicators for the child being male, of white ethnicity, for being a first born, for number of previous births, for the mother being 20 years old or younger, and for being older than 35 years, for age at measurement (in years for the anthropometric outcomes and also in months for the cognitive outcomes), and for year of birth. The standard errors (in parentheses) are clustered at the level of the mother. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. †: the coefficients on birth weight and birth length are statistically significantly different (two-sided tests).

Table 11: Prenatal and Birth Health Capital and Childhood Overweight at 6 Years

	Overweight							
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)	(4a)	(4b)
Fetal Abdominal Circumference TR2 (z)	0.033***	0.030***			0.025	0.018		0.012
	(0.012)	(0.012)			(0.015)	(0.015)		(0.015)
Fetal Abdominal Circumference Growth TR2-TR3 (z)	0.060***	0.045***			0.043**	0.027		0.013
	(0.014)	(0.013)			(0.018)	(0.017)		(0.017)
Fetal Abdominal Circumference Growth TR3-Birth (z)	0.036***	0.022*			0.020	0.004		0.001
	(0.014)	(0.013)			(0.018)	(0.017)		(0.017)
Fetal Abdominal Circumference Slow Growth TR2-Birth	0.151***	0.126**			0.133**	0.115**		0.126**
	(0.056)	(0.054)			(0.056)	(0.055)		(0.050)
Fetal Abdominal Circumference Fast Growth TR2-Birth	-0.117**	-0.134***			-0.114**	-0.129**		-0.151***
	(0.054)	(0.052)			(0.055)	(0.053)		(0.053)
Birth Weight (z)			0.081***	0.069***	0.038	0.043*	0.077***	0.069***
			(0.020)	(0.020)	(0.028)	(0.025)	(0.020)	(0.026)
Birth Length (z)			-0.043**	-0.029	-0.031	-0.020	-0.044**	-0.034
			(0.020)	(0.020)	(0.022)	(0.022)	(0.020)	(0.023)
Full Controls		✓		✓		✓	✓	✓
Postnatal Growth							✓	✓
p-value joint significance Fetal	*0.000*	*0.000*			*0.007*	*0.006*		*0.015*
p-value joint significance Birth			*0.000*	*0.001*	*0.128*	*0.262*	*0.000*	*0.029*
p-value joint significance Postnatal							*0.000*	*0.000*
AUC	0.686	0.794	0.666	0.773	0.696	0.795	0.821	0.836
p-value AUC					0.020	0.011		0.019
N	*1,097*	*1,035*	*1,097*	*1,035*	*1,097*	*1,035*	*956*	*956*

Notes: This table shows average marginal effects from probit models of the probability of being overweight (BMI-for-age $>85^{th}$ percentile according to the Child Growth Foundation standards) at 6 years on patterns of fetal growth starting the second trimester and birth outcomes. Models in (1a), (2a) and (3a) include binary indicators for white ethnicity, gender, being a first born and year and season of birth. Models in (1b), (2b), (3b), (4a) and (4b) include binary indicators for white ethnicity, male, and being a first born, and controls for year and season of birth, number of children and mother's age at birth, and the following controls measured at baseline (before conception): whether the mother has a degree-level education, belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), owns the house, is single, separated, divorced or widowed, whether she receives welfare benefits, is in fair, bad or very bad health, whether she has been under stress in the last four weeks, whether she was working last week, whether she is a current smoker, whether she drinks more than 4 units of alcohol per week, whether she does any strenuous exercise in the week, whether she does any moderate exercise in the week, whether the mother's partner belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), whether the mother's father belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled); continuous variables for mother's birth weight, pre-pregnancy weight, height, BMI, head circumference, leg length, waist circumference, skinfolds (sum of triceps, biceps, subscapular and suprailiac) and her daily energy intake (kilocalories), paternal height, weight and birth weight, grandmaternal and grandpaternal height and weight, and the Townsend Deprivation Index; missing values for social class of the mother, the mother's father and the mother's partner have been replaced with zeros and a binary indicator for missing is included; missing values for maternal birth weight and head circumference, for paternal height, weight and birth weight, for grandmaternal weight and grandpaternal height and weight are replaced with the sample means of the non-missing observations and binary indicators for missing are included. "Fetal Abdominal Circumference Growth TR2-TR3 (z)" is a measure of conditional growth between weeks 19 and 34, computed according to the Royston [1995] method. "Fetal Abdominal Circumference Growth TR3-Birth (z)" is a measure of conditional growth between weeks 34 and birth. "Fetal Abdominal Circumference Slow Growth TR2-Birth" is a binary indicator which takes value 1 if the fetus is in the lower quartile of the Abdominal Circumference growth distribution both between weeks 19-34 and between week 34 and birth. "Fetal Abdominal Circumference Fast Growth TR2-Birth" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the Abdominal Circumference growth distribution both between weeks 19-34 and between week 34 and birth. The birth outcomes z-scores have been computed using the Child Growth Foundation standards. *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. AUC=Area under the ROC curve. The standard errors are bootstrapped (1,000 replications). p=p-value for the Null Hypothesis that the models in (2a) and (3a), in (2b) and (3b), and in (4a) and (4b), respectively, have equal AUC values.

Table 12: Prenatal and Birth Health Capital and Childhood Respiratory Health at 6 Years

	Asthma (GP-Diagnosed) or Wheezing							
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)	(4a)	(4b)
Fetal Abdominal Circumference Fast Growth TR2-Birth	-0.168**	-0.190***			-0.127*	-0.144**		-0.199***
	(0.069)	(0.070)			(0.072)	(0.072)		(0.073)
Fetal Head Circumference Accelerated Growth TR2-Birth	-0.073**	-0.069**			-0.080**	-0.075**		-0.087***
	(0.033)	(0.032)			(0.032)	(0.032)		(0.032)
Symmetric Abdominal/Head Circumference Growth TR2-TR3	-0.064**	-0.054*			-0.073**	-0.063**		-0.061*
	(0.031)	(0.031)			(0.031)	(0.031)		(0.032)
Low Birth Weight			0.234**	0.206**	0.233**	0.212**	0.178**	0.190**
			(0.092)	(0.086)	(0.093)	(0.087)	(0.091)	(0.091)
High Birth Weight			-0.083**	-0.106**	-0.066	-0.076*	-0.100**	-0.059
			(0.040)	(0.042)	(0.042)	(0.044)	(0.044)	(0.045)
Low Apgar 1M			0.073**	0.076**	0.080**	0.083**	0.077**	0.086**
			(0.034)	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)
Small Birth Head Circumference			0.076**	0.076**	0.080**	0.078**	0.087**	0.088**
			(0.035)	(0.035)	(0.035)	(0.035)	(0.036)	(0.036)
Full Controls		✓		✓		✓	✓	✓
Postnatal Growth							✓	✓
p-value joint significance Fetal	*0.000*	*0.000*			*0.000*	*0.000*		*0.000*
p-value joint significance Birth			*0.001*	*0.001*	*0.000*	*0.002*	*0.002*	*0.004*
p-value joint significance Postnatal							*0.644*	*0.619*
AUC	0.619	0.695	0.631	0.691	0.662	0.714	0.694	0.719
p-value AUC					0.018	0.015		0.010
N	*1,115*	*1,051*	*1,115*	*1,051*	*1,115*	*1,051*	*996*	*996*

Notes: This table shows average marginal effects from probit models of the probability of having asthma or wheezing at 6 years on patterns of fetal growth starting the second trimester and birth outcomes. Models in (1a), (2a) and (3a) include binary indicators for white ethnicity, gender, being a first born and year and season of birth. Models in (1b), (2b), (3b), (4a) and (4b) include binary indicators for white ethnicity, male, and being a first born, and controls for year and season of birth, number of children and mother's age at birth, and the following controls measured at baseline (before conception): whether the mother has a degree-level education, belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), owns the house, is single, separated, divorced or widowed, whether she receives welfare benefits, is in fair, bad or very bad health, whether she has been under stress in the last four weeks, whether she was working last week, whether she is a current smoker, whether she drinks more than 4 units of alcohol per week, whether she does any strenuous exercise in the week, whether she does any moderate exercise in the week, whether the mother's partner belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), whether the mother's father belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled); continuous variables for mother's birth weight, pre-pregnancy weight, height, BMI, head circumference, leg length, waist circumference, skinfolds (sum of triceps, biceps, subscapular and suprailiac) and her daily energy intake (kilocalories), paternal height, weight and birth weight, grandmaternal and grandpaternal height and weight, and the Townsend Deprivation Index; missing values for social class of the mother, the mother's father and the mother's partner have been replaced with zeros and a binary indicator for missing is included; missing values for maternal birth weight and head circumference, for paternal height, weight and birth weight, for grandmaternal weight and grandpaternal height and weight are replaced with the sample means of the non-missing observations and binary indicators for missing are included. "Fetal Abdominal Circumference Fast Growth TR2-Birth" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the Abdominal Circumference growth distribution both between weeks 19-34 and between week 34 and birth. "Fetal Head Circumference Accelerated Growth TR2-Birth" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the distribution of the difference between the Head Circumference growth between week 34 and birth and between weeks 19-34. "Fetal Symmetric Abdominal/Head Circumference Growth TR2-TR3" is a binary indicator which takes value 1 if the fetus is above the lower quartile and below the upper quartile of the distribution of the difference between the Abdominal Circumference growth and the Head Circumference growth between weeks 19 and 34. "Low Apgar 1 Minute" is a binary indicator which takes value 1 if the Apgar score is less than 8. Preterm is a binary indicator which takes value 1 if the gestational age at birth is less than 37 weeks. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Robust standard errors in parentheses. AUC=Area under the ROC curve. The standard errors are bootstrapped (1,000 replications). p=p-value for the Null Hypothesis that the models in (2a) and (3a), in (2b) and (3b), and in (4a) and (4b), respectively, have equal AUC values.

Table 13: Prenatal, Birth, Postnatal Health Capital and Childhood Hyperactivity Problems at 3 Years

	Hyperactivity Problems (SDQ)							
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)	(4a)	(4b)
Fetal Abdominal Circumference Slow Growth TR2-Birth	0.075*	0.089**			0.065	0.084*		0.097**
	(0.042)	(0.043)			(0.044)	(0.045)		(0.045)
Fetal Femur Length Slow Growth TR2-Birth	0.062	0.098**			0.047	0.089*		0.097**
	(0.046)	(0.045)			(0.048)	(0.047)		(0.047)
Fetal Head Circumference Fast Growth TR2-Birth	-0.081*	-0.105**			-0.079	-0.108**		-0.126**
	(0.048)	(0.051)			(0.050)	(0.054)		(0.054)
Fetal Head Circumference Accelerated Growth TR2-Birth	-0.053**	-0.062**			-0.054**	-0.062**		-0.064**
	(0.026)	(0.025)			(0.026)	(0.026)		(0.026)
Symmetric Head Circumference/Femur Length Growth TR2-TR3	-0.035*	-0.044**			-0.034*	-0.043**		-0.043**
	(0.020)	(0.020)			(0.020)	(0.020)		(0.020)
Short Birth Length			0.065*	0.066*	0.033	0.031	0.074*	0.035
			(0.038)	(0.038)	(0.040)	(0.039)	(0.039)	(0.041)
Asymmetric SGA			0.043	0.046	0.023	0.013	0.068	0.025
			(0.047)	(0.046)	(0.049)	(0.047)	(0.046)	(0.047)
Full Controls		✓		✓		✓	✓	✓
Postnatal Growth							✓	✓
p-value joint significance Fetal	*0.000*	*0.000*			*0.011*	*0.001*		*0.000*
p-value joint significance Birth			*0.061*	*0.140*	*0.863*	*0.914*	*0.035*	*0.866*
p-value joint significance Postnatal							*0.049*	*0.013*
AUC	0.629	0.705	0.594	0.683	0.629	0.705	0.697	0.722
p-value AUC					0.008	0.022		0.012
N	*1,428*	*1,336*	*1,428*	*1,336*	*1,428*	*1,336*	*1,267*	*1,267*

Notes: This table shows average marginal effects from probit models of the probability of having ADHD (a score greater than 5 on the Strength and Difficulties Questionnaire Hyperactivity scale) at 3 years on patterns of fetal growth starting the second trimester and birth outcomes. Models in (1a), (2a) and (3a) include binary indicators for white ethnicity, gender, being a first born and year and season of birth. Models in (1b), (2b) and (3b) include binary indicators for white ethnicity, male, and being a first born, and controls for year and season of birth, number of children and mother's age at birth, and the following controls measured at baseline (before conception): whether the mother has a degree-level education, belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), owns the house, is single, separated, divorced or widowed, whether she receives welfare benefits, is in fair, bad or very bad health, whether she has been under stress in the last four weeks, whether she was working last week, whether she is a current smoker, whether she drinks more than 4 units of alcohol per week, whether she does any strenuous exercise in the week, whether she does any moderate exercise in the week, whether the mother's partner belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), whether the mother's father belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled); continuous variables for mother's birth weight, pre-pregnancy weight, height, BMI, head circumference, leg length, waist circumference, skinfolds (sum of triceps, biceps, subscapular and suprailiac) and her daily energy intake (kilocalories), paternal height, weight and birth weight, grandmaternal and grandpaternal height and weight, and the Townsend Deprivation Index; missing values for social class of the mother, the mother's father and the mother's partner have been replaced with zeros and a binary indicator for missing is included; missing values for maternal birth weight and head circumference, for paternal height, weight and birth weight, for grandmaternal weight and grandpaternal height and weight are replaced with the sample means of the non-missing observations and binary indicators for missing are included. "Fetal Abdominal Circumference Slow Growth TR2-Birth" is a binary indicator which takes value 1 if the fetus is in the lower quartile of the Abdominal Circumference growth distribution both between weeks 19-34 and between week 34 and birth. "Fetal Femur Length Slow Growth TR2-Birth" is a binary indicator which takes value 1 if the fetus is in the lower quartile of the Femur Length growth distribution both between weeks 19-34 and between week 34 and birth. "Fetal Head Circumference Fast Growth TR2-Birth" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the Head Circumference growth distribution both between weeks 19-34 and between week 34 and birth. "Fetal Head Circumference Accelerated Growth TR2-Birth" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the distribution of the difference between the Head Circumference growth between week 34 and birth and between weeks 19-34. "Symmetric HC/FL Growth TR2-TR3" is a binary indicator which takes value 1 if the fetus is above the lower quartile and below the upper quartile of the distribution of the difference between the Head Circumference growth and the Femur Length growth between weeks 19 and 34. "Low Apgar 1 Minute" is a binary indicator which takes value 1 if the Apgar score is less than 8. Preterm is a binary indicator which takes value 1 if the gestational age at birth is less than 37 weeks. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Robust standard errors in parentheses. AUC=Area under the ROC curve. The standard errors are bootstrapped (1,000 replications). p=p-value for the Null Hypothesis that the models in (2a) and (3a), in (2b) and (3b), and in (4a) and (4b), respectively, have equal AUC values.

ONLINE APPENDIX - NOT FOR PUBLICATION

Beyond Birth Weight - The Origins of Health Capital

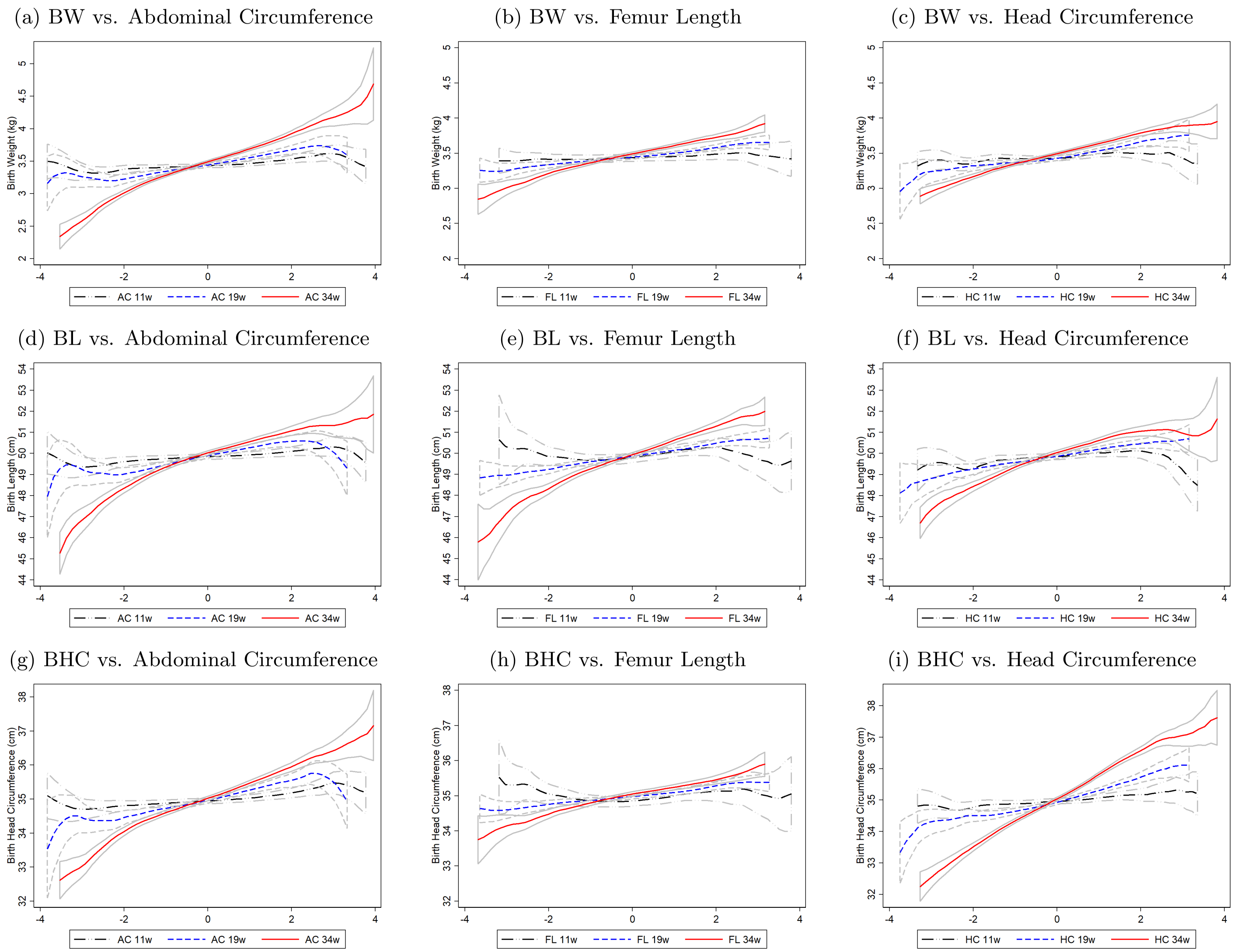
Gabriella Conti, Mark A. Hanson, Hazel Inskip, Sarah Crozier, Cyrus Cooper, and Keith M. Godfrey

Figure A1: Fetal Measurements from Ultrasound Scans

(a) Abdominal Circumference (b) Head Circumference (c) Femur Length

Notes: These ultrasounds are not based on the SWS sample, and are shown for illustrative purposes only.

Figure A2: Birth Health Capital and Fetal Health Capital in the Three Trimesters of Pregnancy



Notes: The graphs above are based on the fetal growth sample, SWS data. Each panel shows kernel-weighted local polynomial smoothing graphs with bandwidth 0.8 and with confidence intervals of one anthropometric birth measure (birth weight in kilograms in panels a-c, birth length in centimetres in panels d-f, birth head circumference in centimetres in panel g-i) on one fetal anthropometric measure (abdominal circumference in panels a-d-g, femur length in panels b-e-h, head circumference in panels c-f-i), for each of the three periods of gestation at which it has been measured (11, 19 and 34 weeks). Abbreviations: BW=Birth Weight; BL=Birth Length; BHC=Birth Head Circumference.

Table A1: Baseline (pre-pregnancy) Characteristics, Fetal and Non-Fetal Growth Samples (SWS)

	(1) Mean FGS	(2) N FGS	(3) Mean NFGS	(4) N NFGS	(5) p-value
Child is male	0.51	1,973	0.53	1,167	0.217
Mother's Age at birth	30.92	1,974	30.24	1,167	0.000
Child is Firstborn	0.52	1,981	0.50	1,172	0.180
White ethnicity	0.95	1,982	0.96	1,173	0.701
No. of children	0.68	1,981	0.76	1,172	0.028
Mother has a University Degree	0.25	1,978	0.17	1,169	0.000
Mother is High Social Class	0.42	1,982	0.33	1,174	0.000
Mother is Low Social Class	0.19	1,982	0.26	1,174	0.000
Partner is High Social Class	0.31	1,982	0.27	1,174	0.013
Partner is Low Social Class	0.36	1,982	0.36	1,174	0.772
Mother's father is High Social Class	0.21	1,982	0.17	1,174	0.012
Mother's father is Low Social Class	0.53	1,982	0.57	1,174	0.027
Mother is Single	0.45	1,982	0.51	1,172	0.001
Mother is Separated/Divorced/Widowed	0.05	1,982	0.07	1,172	0.035
Family Receives Welfare Benefits	0.12	1,982	0.20	1,173	0.000
Townsend Deprivation Index	-0.06	1,969	0.30	1,164	0.002
House Owner	0.66	1,981	0.55	1,172	0.000
Mother Birth Weight	3.25	1,982	3.25	1,174	0.987
Mother Weight (kg)	67.19	1,967	67.24	1,164	0.925
Mother Height (cm)	163.41	1,968	162.89	1,171	0.030
Mother Body Mass Index	25.14	1,964	25.30	1,164	0.372
Mother Head Circumference (cm)	55.08	1,982	55.01	1,174	0.207
Mother Leg Length (cm)	98.54	1,964	98.35	1,164	0.303
Mother Waist Circumference (cm)	79.94	1,960	80.35	1,161	0.306
Mother Sum of Skinfolds (mm)	72.05	1,949	71.81	1,152	0.830
Mother in Fair, Bad or Very Bad Health	0.18	1,982	0.27	1,173	0.000
Mother is Stressed	0.46	1,978	0.47	1,172	0.528
Father Birth Weight (kg)	3.41	1,982	3.38	1,174	0.086
Father Height (cm)	179.38	1,982	178.59	1,174	0.002
Father Weight (kg)	83.27	1,982	82.73	1,174	0.236
Mother's mother Weight (kg)	57.23	1,982	57.43	1,174	0.516
Mother's mother Height (cm)	162.93	1,946	162.28	1,144	0.013
Mother's father Weight (kg)	82.25	1,982	82.31	1,174	0.894
Mother's father Height (cm)	176.45	1,982	176.13	1,174	0.263
Mother Works (last week)	0.81	1,982	0.78	1,172	0.048
Mother Smokes	0.25	1,982	0.32	1,171	0.000
Mother Drinks >4 units alcohol/w	0.55	1,982	0.53	1,172	0.253
Kilocalories per day	2.09	1,982	2.17	1,172	0.002
Any Strenuous Exercise in the week	0.66	1,968	0.63	1,169	0.098
Any Moderate Exercise in the week	0.65	1,980	0.64	1,173	0.473

Notes: Own calculations from the SWS data. The SWS uses the measure of Social Class based on Occupation (SC, formerly Registrar General's Social Class): I is Professional, II is Management and technical, IIIN is Skilled non-manual, IIIM is Skilled manual, IV is Partly skilled and V is Unskilled. High Social Class is defined as I or II, low Social Class as IIIM, IV or V. The sum of skinfolds includes triceps, biceps, subscapular and suprailiac. The variable "mother in fair, bad or very bad health" is constructed on the basis of the following variable "How is your health in general? Would you say..." Answers "very good" or "good" are coded as 0, answers "fair", "bad" and "very bad" are coded as 1. The variable "mother is stressed" is constructed on the basis of the following variable "How much stress in daily living in the last 4 weeks?" Answers "none" or "just a bit" are coded as 0, answers "a good bit", "quite a lot" and "a great deal" are coded as 1. Missing values for social class of the mother, the mother's father and the mother's partner have been replaced with zeros; missing values for maternal birth weight and head circumference, for paternal height, weight and birth weight, for mother's mother weight and mother's father height and weight have been replaced with the sample means of the non-missing observations in the overall sample. In column (5) we report p-values for two-sided t-tests for differences in means (with unequal variances) for the continuous variables, and tests for the equality of proportions for the binary variables between the fetal and non-fetal growth sample. Abbreviations: N=sample size. FGS=Fetal Growth Sample. NFGS=Non-Fetal Growth Sample.

Table A2: Summary Statistics: Prenatal, Birth and Postnatal Development

	(1) Mean/Prop.	(2) SD	(3) Min.	(4) Max.	(5) N
Panel A: Prenatal					
Head Circumference 11w (*z*-score)	0.01	0.96	-3.48	3.36	1,255
Head Circumference 19w (*z*-score)	0.03	1.01	-3.75	3.16	1,941
Head Circumference 34w (*z*-score)	-0.01	1.01	-3.27	3.83	1,846
HC Declining Trajectory	0.25	-	0	1	1,811
HC Increasing Trajectory	0.25	-	0	1	1,811
HC Conditional Growth 11-19w (*z*-score)	0.12	0.90	-2.77	2.97	1,247
HC Conditional Growth 19-34w (*z*-score)	-0.03	1.06	-4.02	4.70	1,818
HC Conditional Growth 34w-birth (*z*-score)	0.01	0.98	-2.80	3.35	1,748
HC Slow Growth 19w-birth	0.06	-	0	1	1,722
HC Fast Growth 19w-birth	0.06	-	0	1	1,722
HC Accelerated Growth 19w-birth	0.25	-	0	1	1,722
Abdominal Circumference 11w (*z*-score)	0.02	0.99	-3.84	3.78	1,175
Abdominal Circumference 19w (*z*-score)	0.01	0.97	-3.89	3.33	1,932
Abdominal Circumference 34w (*z*-score)	0.01	1.02	-3.53	3.96	1,920
AC Declining Trajectory	0.25	-	0	1	1,871
AC Increasing Trajectory	0.25	-	0	1	1,871
AC Stable Low Trajectory	0.13	-	0	1	1,871
AC Stable High Trajectory	0.13	-	0	1	1,871
AC Conditional Growth 11-19w (*z*-score)	0.06	0.89	-2.48	2.70	1,167
AC Conditional Growth 19-34w (*z*-score)	0.00	1.05	-3.79	4.07	1,878
AC Conditional Growth 34w-birth (*z*-score)	0.00	1.00	-4.45	3.47	1,813
AC Slow Growth 19w-birth	0.06	-	0	1	1,777
AC Fast Growth 19w-birth	0.06	-	0	1	1,777
Asymmetric HC/AC Growth 19-34w	0.25	-	0	1	1,808
Asymmetric AC/HC Growth 19-34w	0.25	-	0	1	
Symmetric AC/HC Growth 19-34w	0.50	-	0	1	1,808
Femur Length 11w (*z*-score)	-0.01	1.01	-3.18	3.80	468
Femur Length 19w (*z*-score)	0.03	1.00	-3.64	3.28	1,943
Femur Length 34w (*z*-score)	0.00	1.00	-3.69	3.16	1,918
FL Declining Trajectory	0.25	-	0	1	1,880
FL Increasing Trajectory	0.25	-	0	1	1,880
FL Slow Growth 19w-birth	0.05	-	0	1	1,765
FL Fast Growth 19w-birth	0.05	-	0	1	1,765
FL Accelerated Growth 19w-birth	0.25	-	0	1	
Symmetric HC/FL Growth 19-34w	0.50	-	0	1	1,811
Panel B: Birth					
Weight (kg)	3.45	0.54	0.48	5.41	1,957
Weight CGF (*z*-score)	0.03	0.95	-3.69	3.73	1,957
Low Birth Weight (<2,500 grams)	0.04	-	0	1	1,957
Small-for-gestational-age (SGA)	0.08	-	0	1	1,957
SGA Asymmetric	0.05	-	0	1	1,982
High Birth Weight (≥4,000 grams)	0.13	-	0	1	1,957
Large-for-gestational-age (LGA)	0.09	-	0	1	1,957
Gestational Age (weeks)	39.77	1.83	26.29	43.00	1,974
Premature (<37 weeks gestation)	0.06	-	0	1	1,974
Crown-Heel Length (cm)	49.88	2.04	41.30	56.23	1,824
Crown-Heel Length CGF (*z*-score)	-0.41	0.86	-3.83	2.51	1,823
Short Crown-Heel Length	0.08	-	0	1	1,824
Head Circumference (cm)	34.99	1.36	29.60	40.93	1,842
Head Circumference CGF (*z*-score)	0.09	0.95	-2.81	4.39	1,842
Small Head Circumference	0.66	-	0	1	1,842
Percent Fat from DXA	0.15	0.04	0.04	0.32	625
Fat Mass (kg)	0.53	0.20	0.08	1.56	625
Lean Mass (kg)	2.92	0.31	1.97	3.95	625
Thigh Skinfold (*z*-score)	0.01	1.00	-2.46	4.58	1,834
Apgar Score 1 minute	8.29	1.56	0	10	1,900
Panel C: Postnatal Period					
Height CGF 6y (*z*-score)	0.18	0.97	-2.79	3.46	1,281
BMI CGF 6y (*z*-score)	0.15	0.99	-2.83	4.16	1,276
Overweight 6y	0.17	-	0	1	1,276
Asthma (GP diagnosed) or Wheezing 6y	0.22	-	0	1	1,294
Hyperactivity Problems (SDQ) 3y	0.19	-	0	1	1,649
WPPSI Verbal Scale 4y	112.57	14.63	59	153	174
WPPSI General Language Scale 4y	103.82	11.61	70	131	174
NEPSY Sentence Repetition Scale 4y	10.60	2.32	4	18	168

Notes: Own calculations from the SWS data. "AC/HC/FL Declining Trajectory" is a binary indicator which takes value 1 if the fetus is in the lower quartile of the distribution of the difference between the third and the second trimester AC/HC/FL. "AC/HC/FL Increasing Trajectory" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the distribution of the difference between the third and the second trimester AC/HC/FL. "HC/FL Accelerated Growth 19w-birth" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the distribution of the difference in the Head Circumference/Length growth between week 34 and birth and between weeks 19-34. "AC Stable Low Trajectory" is a binary indicator which takes value 1 if the fetus is in the lower quartile of the Abdominal Circumference distribution both in the second and in the third trimester. "AC Stable High Trajectory" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the Abdominal Circumference distribution both in the second and in the third trimester. "AC/HC/FL Slow Growth 19w-Birth" is a binary indicator which takes value 1 if the fetus is in the lower quartile of the Abdominal Circumference/Head Circumference/Femur Length growth distribution both between weeks 19-34 and between week 34 and birth. "AC/HC/FL Fast Growth 19w-Birth" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the Abdominal Circumference/Head Circumference/Femur Length growth distribution both between weeks 19-34 and between week 34 and birth. "Asymmetric HC/AC Growth 19-34w" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the distribution of the difference between the Head Circumference growth and the Abdominal Circumference growth between weeks 19 and 34. "Symmetric HC/FL Growth 19-34w" is a binary indicator which takes value 1 if the fetus is between the lower and the upper quartile of the distribution of the difference between the Head Circumference growth and the Femur Length growth between weeks 19 and 34. "Short Crown-Heel Length" at birth is a binary indicator which takes value 1 if the Crown-Heel Length is shorter than 47 cm. "Small Head Circumference" at birth is a binary indicator which takes value 1 if the Head Circumference is smaller than 35.56 cm. Abbreviations: SDQ=Strengths and Difficulties Questionnaire. WPPSI=Wechsler Preschool & Primary Scale of Intelligence. NEPSY = Neuropsychological Assessment. Prop.=proportion. SD = Standard Deviation (only reported for continuous variables). Min. = Minimum. Max. = Maximum. N = sample size. CGF = Child Growth Foundation. y=years.

Table A3: Summary Statistics: Baseline (preconception) Characteristics

	(1) Mean/Prop.	(2) SD	(3) Min.	(4) Max.	(5) N
Panel A: Preconception Parental Demographic and Socioeconomic Characteristics					
Child is male	0.51	-	0	1	1,973
Mother's Age at birth	30.92	3.75	21	42	1,974
Child is Firstborn	0.52	-	0	1	1,981
White Ethnicity	0.95	-	0	1	1,982
No. of children	0.68	0.89	0	8	1,981
Mother has a University Degree	0.25	-	0	1	1,978
Mother is High Social Class	0.42	-	0	1	1,982
Mother is Low Social Class	0.19	-	0	1	1,982
Partner is High Social Class	0.31	-	0	1	1,982
Partner is Low Social Class	0.36	-	0	1	1,982
Mother's father is High Social Class	0.21	-	0	1	1,982
Mother's father is Low Social Class	0.53	-	0	1	1,982
Mother is Single	0.45	-	0	1	1,982
Mother is Separated/Divorced/Widowed	0.05	-	0	1	1,982
Family Receives Welfare Benefits	0.12	-	0	1	1,982
Townsend Deprivation Index	-0.06	3.06	-5.83	8.22	1,969
House Owner	0.66	-	0	1	1,981
Panel B: Preconception Parental Physical and Mental Health					
Mother Birth Weight (kg)	3.25	0.52	0.91	5.31	1,982
Mother Weight (kg)	67.19	13.40	40	146	1,967
Mother Height (cm)	163.41	6.34	142.00	188.30	1,968
Mother Body Mass Index	25.14	4.65	16.42	48.84	1,964
Mother Head Circumference (cm)	55.08	1.43	50.40	60.30	1,982
Mother Leg Length (cm)	98.54	4.85	82.00	118.20	1,964
Mother Waist Circumference (cm)	79.94	10.65	58.10	134.30	1,960
Mother Sum of Skinfolds (mm)	72.05	29.96	19.10	196.00	1,949
Mother in Fair, Bad or Very Bad Health	0.18	-	0	1	1,982
Mother is Stressed	0.46	-	0	1	1,978
Father Birth Weight (kg)	3.41	0.51	0.96	5.44	1,982
Father Height (cm)	179.38	6.57	152.40	203.20	1,982
Father Weight (kg)	83.27	12.38	50.79	148.00	1,982
Mother's mother Weight (kg)	57.23	8.20	37.80	125.00	1,982
Mother's mother Height (cm)	162.93	6.92	134.60	185.40	1,946
Mother's father Weight (kg)	82.25	12.37	38.10	190.70	1,982
Mother's father Height (cm)	176.45	7.47	148.00	208.30	1,982
Mother Works (last week)	0.81	-	0	1	1,982
Mother Smokes	0.25	-	0	1	1,982
Mother Drinks >4 units alcohol/week	0.55	-	0	1	1,982
Kilocalories per day	2.09	0.59	0.51	5.04	1,982
Any Strenuous Exercise in the week	0.66	-	0	1	1,968
Any Moderate Exercise in the week	0.65	-	0	1	1,980

Notes: Own calculations from the SWS data. The SWS uses the measure of Social Class based on Occupation (SC, formerly Registrar General's Social Class): I is Professional, II is Management and technical, IIIN is Skilled non-manual, IIIM is Skilled manual, IV is Partly skilled and V is Unskilled. High Social Class is defined as I or II, low Social Class as IIIm, IV or V. The sum of skinfolds includes triceps, biceps, subscapular and suprailiac. The variable "mother in fair, bad or very bad health" is constructed on the basis of the following variable "How is your health in general? Would you say..." Answers "very good" or "good" are coded as 0, answers "fair", "bad" and "very bad" were coded as 1. The variable "mother is stressed" is constructed on the basis of the following variable "How much stress in daily living in the last 4 weeks?" Answers "none" or "just a bit" are coded as 0, answers "a good bit", "quite a lot" and "a great deal" are coded as 1. Missing values for social class of the mother, the mother's father and the mother's partner have been replaced with zeros; missing values for maternal birth weight and head circumference, for paternal height, weight and birth weight, for mother's mother weight and mother's father height and weight have been replaced with the sample means of the non-missing observations. In all the analyses, when we use these variables we also include binary indicators which take value one when the original observation has a missing value (we detail this in the notes to the respective tables). The prevalence of missing data varies between 3% for mother Social Class to a maximum of 24% for mother's partner Social Class; most of these variables are missing in 12%-15% of the observations. Abbreviations: Prop.=proportion. SD = Standard Deviation (only reported for continuous variables). Min.=Minimum. Max.=Maximum. N=sample size. CGF=Child Growth Foundation.

Table A4: Summary Statistics CNLSY

	(1) N	(2) Mean	(3) SD	(4) Min.	(5) Max.
Panel A: Birth Variables					
Birth Weight (g)	3,224	3392.58	553.54	1020.58	5159.61
Birth Length (cm)	3,224	51.27	3.28	33.02	60.96
Birth Weight (z-score)	3,224	0.25	0.97	-3.99	3.89
Birth Length (z-score)	3,224	0.51	1.17	-3.85	3.95
Panel B: Outcomes					
Height (cm)	7,237	137.59	12.68	101.60	180.34
Height (z-score)	7,237	0.33	1.14	-3.93	4
BMI	7,218	18.23	7.01	11.69	378.58
BMI (z-score)	7,218	0.26	1.22	-3.98	3.40
PPVT	3,585	101.97	16.48	20	160
PIAT Math	7,130	106.04	13.14	65	135
Memory for Digit Span	5,613	10.36	3.02	0	19
PIAT Reading Recognition	7,124	107.70	13.55	65	135
Age at measurement	8,684	9.45	1.69	7	12
Panel C: Base Controls					
Male	3,224	0.51	0.50	0	1
Birth order	3,224	1.74	0.90	1	5
Gestational age	3,224	38.54	1.82	27	41
Mother $\leq$ 20y	3,224	0.20	0.40	0	1
Mother $>$ 35y	3,224	0.04	0.19	0	1
Panel D: Investments in Pregnancy					
Prenatal care 1^{st} trimester	3,158	0.85	0.36	0	1
Drinking $\geq$ 1 day/week	3,221	0.04	0.19	0	1
Smoking $<$ 1 pack/day	3,218	0.21	0.41	0	1
Smoking $\geq$ 1 pack/day	3,218	0.11	0.31	0	1
Gestational weight gain (kg)	3,224	14.51	6.42	0	48.53
Pre-pregnancy weight (kg)	3,224	61.06	13.81	37.65	226.80

Notes: Birth weight and birth length have been standardized using the growth chart developed by Olsen et al. [2010] for the United States. Only those cases reporting that birth length is not an estimate have been included. Values lying outside three times the interquartile range from the first or third quartile of the birth weight and birth length distribution have been removed as extreme outliers (Tukey's method). Additionally, values of the Olsen z-scores smaller than -4 or greater than 4 have been removed. Height, weight and BMI have been converted in z-scores using the 2000 CDC Growth Reference. The cognitive test scores are derived on an age-specific basis from the child's raw score using national norming samples. The sample only includes children of white ethnicity. PPVT: Peabody Picture Vocabulary Test. PIAT: Peabody Individual Achievement Test. SD = Standard Deviation. Min. = Minimum. Max. = Maximum. N = sample size.

Table A5: Summary Statistics PtA

	(1) N	(2) Mean	(3) SD	(4) Min.	(5) Max.
Panel A: Birth Variables					
Birth Weight (kg)	1,422	2.992	0.547	0.992	4.933
Birth Length (cm)	1,422	48.93	2.76	37	59
Birth Weight (z-score)	1,422	-0.366	1.101	-3.722	3.854
Birth Length (z-score)	1,422	-0.259	1.036	-3.734	3.479
Panel B: Outcomes					
Height (cm)	1,396	123.55	5.85	102	141
BMI	1,335	15.56	1.48	11.50	21.41
PPVT	1,383	58.50	7.88	11	89
WISC Verbal Comprehension Scale	1,408	8.44	2.37	2	18
WISC Verbal Digit Scale	1,409	9.08	2.89	2	20
WRAT Reading Scale	1,393	31.44	10.05	0	71
WRAT Math Scale	1,395	19.28	3.98	0	31
Panel C: Base Controls					
Male	1,422	0.454	0.498	0	1
White	1,422	0.180	0.384	0	1
First born	1,415	0.304	0.460	0	1
Gestational age	1,422	38.28	2.45	27	41
Mother $\leq$ 20y	1,422	0.350	0.477	0	1
Mother $>$ 35y	1,422	0.089	0.285	0	1
Previous births	1,415	2.23	2.30	0	13
Year of birth	1,422	62.7	1.5	60	65
Age at anthro measurement (y)	1,363	7.3	0.5	6	10
Age at cognitive measurement (y)	1,353	6.3	0.5	6	9
Age at cognitive measurement (m)	1,353	7.9	4.4	0	11
Year at PPVT assessment	1,381	70.7	1.6	60	73
Month at PPVT assessment	1,382	6.5	3.5	1	12

Notes: Birth weight and birth length have been standardized using the growth chart developed by Olsen et al. [2010] for the United States. Values lying outside three times the interquartile range from the first or third quartile of the birth weight and birth length distribution have been removed as extreme outliers (Tukey's method). WISC: Wechsler Intelligence Scale for Children. WRAT: Wide Range Achievement Test. SD = Standard Deviation. Min. = Minimum. Max. = Maximum. N = sample size.

Table A6: Conditional Associations between Measures of Fetal and Neonatal Health Capital: Birth Weight and Gestational Age, Extended Set of Covariates

	Birth Weight (kg)			Gestational Age (weeks)			Birth Weight (z-score)		
	TR1	**TR2**	**TR3**	**TR1**	**TR2**	**TR3**	**TR1**	**TR2**	**TR3**
Fetal Measure	(1a)	(1b)	(1c)	(2a)	(2b)	(2c)	(3a)	(3b)	(3c)
Abdominal Circumference (z)	0.035**	0.103***	0.259***	-0.392***	-0.371***	-0.129***	0.246***	0.394***	0.614***
	(0.016)	(0.013)	(0.010)	(0.051)	(0.047)	(0.040)	(0.029)	(0.022)	(0.017)
N	*1,097*	*1,794*	*1,790*	*1,105*	*1,808*	*1,801*	*1,097*	*1,794*	*1,790*
R^2	[0.230]	[0.220]	[0.452]	[0.148]	[0.105]	[0.080]	[0.282]	[0.332]	[0.564]
Adjusted R^2	[0.157]	[0.176]	[0.421]	[0.067]	[0.055]	[0.028]	[0.213]	[0.294]	[0.540]
Semi-partial R^2	0.004†	0.029†	0.240†	0.042†	0.033†	0.007†	0.058†	0.143†	0.369†
Head Circumference (z)	0.027*	0.080***	0.209***	-0.450***	-0.404***	-0.062	0.256***	0.352***	0.471***
	(0.016)	(0.013)	(0.012)	(0.050)	(0.045)	(0.039)	(0.027)	(0.022)	(0.021)
N	*1,169*	*1,803*	*1,717*	*1,179*	*1,817*	*1,727*	*1,169*	*1,803*	*1,717*
R^2	[0.207]	[0.208]	[0.355]	[0.131]	[0.113]	[0.073]	[0.272]	[0.307]	[0.397]
Adjusted R^2	[0.136]	[0.163]	[0.317]	[0.055]	[0.063]	[0.018]	[0.208]	[0.268]	[0.361]
Semi-partial R^2	0.002	0.018†	0.145†	0.050†	0.041†	0.001†	0.059†	0.118†	0.200†
Femur Length (z)	-0.005	0.075***	0.166***	-0.338***	-0.334***	-0.091**	0.140***	0.313***	0.396***
	(0.026)	(0.013)	(0.012)	(0.088)	(0.044)	(0.042)	(0.043)	(0.022)	(0.022)
N	*445*	*1,805*	*1,788*	*446*	*1,819*	*1,799*	*445*	*1,805*	*1,788*
R^2	[0.353]	[0.206]	[0.305]	[0.239]	[0.101]	[0.075]	[0.368]	[0.285]	[0.339]
Adjusted R^2	[0.186]	[0.161]	[0.265]	[0.043]	[0.051]	[0.023]	[0.205]	[0.245]	[0.302]
Semi-partial R^2	0.000	0.017†	0.093†	0.030†	0.029†	0.003†	0.016†	0.097†	0.145†

Notes: This table shows the estimated coefficients from ordinary least squares regressions of three measures of health at birth (as reported in the top row) on three measures of fetal size (as reported in the first column), by trimester of gestation. The results in each cell come from separate regressions of each birth measure on each fetal measure separately. All models include binary indicators for white ethnicity, male, being a first born, year and month of birth and mother's age at birth, and the following controls measured at baseline (before conception): binary indicators for the number of children, whether the mother has a degree-level education, belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), owns the house, is single, separated, divorced or widowed, whether she receives welfare benefits, is in fair, bad or very bad health, whether she has been under stress in the last four weeks, whether she was working last week, whether she is a current smoker, whether she drinks more than 4 units of alcohol per week, whether she does any strenuous exercise in the week, whether she does any moderate exercise in the week, whether the mother's partner belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), whether the mother's father belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled); continuous variables for mother's birth weight, pre-pregnancy weight, height, BMI, head circumference, leg length, waist circumference, skinfolds (sum of triceps, biceps, subscapular and suprailiac) and her daily energy intake (kilocalories), paternal height, weight and birth weight, grandmaternal and grandpaternal height and weight, and the Townsend Deprivation Index; missing values for social class of the mother, the mother's father and the mother's partner have been replaced with zeros and a binary indicator for missing is included; missing values for maternal birth weight and head circumference, for paternal height, weight and birth weight, for grandmaternal weight and grandpaternal height and weight are replaced with the sample means of the non-missing observations and binary indicators for missing are included. Birth weight is measured in kilograms; gestational age in weeks; birth weight z-score has been computed using the Child Growth Foundation standards. The fetal size z-scores have been computed according to the Royston [1995] method. TR1=11 weeks; TR2=19 weeks; TR3=34 weeks.
*** $p<0.01$, ** $p<0.05$, * $p<0.1$, † $p<0.1$. Robust standard errors in parentheses.

Table A7: Conditional Associations between Measures of Fetal and Neonatal Health Capital: Birth Weight, Length and Head Circumference, and Apgar Score, Extended Set of Covariates

	Birth Weight (z-score)				**Birth Length (z-score)**		**Birth Head Circ. (z-score)**		**APGAR 1M**	
	TR2	**TR3**	**TR2**	**TR3**	**TR2**	**TR3**	**TR2**	**TR3**	**TR2**	**TR3**
Fetal Measure	(1a)	(1b)	(1c)	(1d)	(2a)	(2b)	(3a)	(3b)	(4a)	(4b)
Abdominal Circumference (z)	0.263***	0.476***	β_c:0.247	β_c:0.483	0.135***	0.251***	0.106***	0.186***	0.028	-0.080
	(0.034)	(0.020)	δ:7.420	δ:1.539	(0.032)	(0.020)	(0.034)	(0.020)	(0.067)	(0.049)
Head Circumference (z)	0.127***	0.152***	β_c:0.127	β_c:-0.013	0.090***	0.122***	0.428***	0.607***	0.059	0.106**
	(0.036)	(0.020)	δ:19.783	δ:0.950	(0.031)	(0.019)	(0.035)	(0.020)	(0.067)	(0.050)
Femur Length (z)	0.049	0.139***	β_c:0.034	β_c:-0.160	0.170***	0.293***	-0.094***	0.012	-0.058	-0.002
	(0.031)	(0.020)	δ:2.680	δ:0.636	(0.029)	(0.019)	(0.031)	(0.017)	(0.065)	(0.046)
N	*1,789*	*1,716*			*1,668*	*1,621*	*1,686*	*1,636*	*1,735*	*1,674*
R^2	[0.342]	[0.598]			[0.374]	[0.551]	[0.341]	[0.642]	[0.065]	[0.075]
Adjusted R^2	[0.303]	[0.574]			[0.335]	[0.522]	[0.301]	[0.619]	[0.009]	[0.018]
Semi-partial R^2 AC	$0.025^{\dagger}$	$0.140^{\dagger}$			$0.008^{\dagger}$	$0.046^{\dagger}$	$0.004^{\dagger}$	$0.021^{\dagger}$	0.000	0.001
Semi-partial R^2 HC	$0.006^{\dagger}$	$0.014^{\dagger}$			$0.003^{\dagger}$	$0.011^{\dagger}$	$0.065^{\dagger}$	$0.231^{\dagger}$	0.000	$0.003^{\dagger}$
Semi-partial R^2 FL	$0.001^{\dagger}$	$0.014^{\dagger}$			$0.014^{\dagger}$	$0.076^{\dagger}$	$0.004^{\dagger}$	0.000	0.000	0.000

Notes: This table shows the estimated coefficients from ordinary least squares regressions of four measures of health at birth on three measures of fetal size (as reported in the first column), by trimester of gestation, in columns (1a), (1b), (2a), (2b), (3a), (3b), (4a) and (4b). Columns (1c) and (1d) report the bias-corrected coefficients β_c (computed assuming an equal degree of selection between observables and unobservables), and the coefficients of proportionality δ, following Oster [2017]; both sets of coefficients have been computed assuming R^{max}=1.3× R^2 in columns (1a) and (1b). All models include binary indicators for white ethnicity, male, being a first born, year and month of birth and mother's age at birth, and the following controls measured at baseline (before conception): binary indicators for the number of children, whether the mother has a degree-level education, belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), owns the house, is single, separated, divorced or widowed, whether she receives welfare benefits, is in fair, bad or very bad health, whether she has been under stress in the last four weeks, whether she was working last week, whether she is a current smoker, whether she drinks more than 4 units of alcohol per week, whether she does any strenuous exercise in the week, whether she does any moderate exercise in the week, whether the mother's partner belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), whether the mother's father belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled); continuous variables for mother's birth weight, pre-pregnancy weight, height, BMI, head circumference, leg length, waist circumference, skinfolds (sum of triceps, biceps, subscapular and suprailiac) and her daily energy intake (kilocalories), paternal height, weight and birth weight, grandmaternal and grandpaternal height and weight, and the Townsend Deprivation Index; missing values for social class of the mother, the mother's father and the mother's partner have been replaced with zeros and a binary indicator for missing is included; missing values for maternal birth weight and head circumference, for paternal height, weight and birth weight, for grandmaternal weight and grandpaternal height and weight are replaced with the sample means of the non-missing observations and binary indicators for missing are included. The birth measures z-scores have been computed using the Child Growth Foundation standards. The fetal size z-scores have been computed according to the Royston [1995] method. TR2=19 weeks; TR3=34 weeks. AC=Abdominal Circumference; HC=Head Circumference; FL=Femur Length. *** p<0.01, ** p<0.05, * p<0.1, † p<0.1. Robust standard errors in parentheses.

Table A8: Conditional Associations between Measures of Fetal (Second and Third Trimester) and Neonatal Health Capital: Birth Weight, Length and Head Circumference, and Apgar Score

	Birth Weight (z-score)		**Birth Length (z-score)**		**Birth Head Circ. (z-score)**		**APGAR 1M**	
Fetal Measure	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)	(4a)	(4b)
Abdominal Circumference TR2 (z)	-0.005	-0.002	-0.022	-0.019	-0.033	-0.032	0.042	0.047
	(0.027)	(0.028)	(0.027)	(0.028)	(0.025)	(0.027)	(0.068)	(0.073)
Head Circumference TR2 (z)	-0.005	0.006	0.004	0.011	0.110***	0.128***	0.062	0.037
	(0.028)	(0.030)	(0.027)	(0.027)	(0.026)	(0.027)	(0.070)	(0.071)
Femur Length TR2 (z)	0.026	0.023	0.071***	0.065**	-0.002	-0.026	-0.102	-0.107
	(0.027)	(0.028)	(0.027)	(0.027)	(0.024)	(0.025)	(0.067)	(0.073)
Abdominal Circumference TR3 (z)	0.477***	0.469***	0.237***	0.245***	0.180***	0.177***	-0.124**	-0.087*
	(0.020)	(0.022)	(0.021)	(0.022)	(0.020)	(0.022)	(0.050)	(0.052)
Head Circumference TR3 (z)	0.175***	0.152***	0.144***	0.117***	0.597***	0.573***	0.098**	0.093*
	(0.021)	(0.021)	(0.021)	(0.021)	(0.020)	(0.022)	(0.049)	(0.052)
Femur Length TR3 (z)	0.158***	0.127***	0.315***	0.265***	-0.002	0.007	0.035	0.040
	(0.021)	(0.023)	(0.020)	(0.021)	(0.017)	(0.020)	(0.048)	(0.052)
N	*1,781*	*1,671*	*1,687*	*1,582*	*1,703*	*1,597*	*1,738*	*1,630*
R^2	[0.564]	[0.599]	[0.483]	[0.556]	[0.628]	[0.648]	[0.026]	[0.075]
Adjusted R^2	[0.557]	[0.573]	[0.474]	[0.526]	[0.621]	[0.624]	[0.010]	[0.013]

Notes: This table shows the estimated coefficients from ordinary least squares regressions of four measures of health at birth on six measures of fetal size (as reported in the first column), in the second and third trimester of gestation. All models include binary indicators for white ethnicity, male, being a first born and year and month of birth. Models in columns (1b), (2b), (3b) and (4b) also include mother's age at birth, and the following controls measured at baseline (before conception): binary indicators for the number of children, whether the mother has a degree-level education, belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), owns the house, is single, separated, divorced or widowed, whether she receives welfare benefits, is in fair, bad or very bad health, whether she has been under stress in the last four weeks, whether she was working last week, whether she is a current smoker, whether she drinks more than 4 units of alcohol per week, whether she does any strenuous exercise in the week, whether she does any moderate exercise in the week, whether the mother's partner belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), whether the mother's father belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled); continuous variables for mother's birth weight, pre-pregnancy weight, height, BMI, head circumference, leg length, waist circumference, skinfolds (sum of triceps, biceps, subscapular and suprailiac) and her daily energy intake (kilocalories), paternal height, weight and birth weight, grandmaternal and grandpaternal height and weight, and the Townsend Deprivation Index; missing values for social class of the mother, the mother's father and the mother's partner have been replaced with zeros and a binary indicator for missing is included; missing values for maternal birth weight and head circumference, for paternal height, weight and birth weight, for grandmaternal weight and grandpaternal height and weight are replaced with the sample means of the non-missing observations and binary indicators for missing are included. The birth measures z-scores have been computed using the Child Growth Foundation standards. The fetal size z-scores have been computed according to the Royston [1995] method. TR2=19 weeks; TR3=34 weeks. *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses.

Table A9: Conditional Associations between Measures of Fetal and Neonatal Health Capital: Birth Weight, Length and Head Circumference. SEM Results

	First measure	**Second measure**	**Third measure**	**Birth Weight**	**Birth Length**	**Birth Head C.**
	Panel A: Second Trimester					
	(1)	(2)	(3)	(4)	(5)	(6)
AC19	1.000	1.012***	1.009***	0.284***	0.143***	0.114***
	(0.000)	(0.010)	(0.010)	(0.034)	(0.032)	(0.034)
HC19	1.000	1.000***	1.002***	0.069**	0.062*	0.379***
	(0.000)	(0.008)	(0.008)	(0.034)	(0.032)	(0.034)
FL19	1.000	1.024***	1.031***	0.105***	0.238***	-0.037
	(0.000)	(0.014)	(0.013)	(0.033)	(0.031)	(0.033)
	Panel B: Third Trimester					
	(1)	(2)	(3)	(4)	(5)	(6)
AC34	1.000	1.012***	1.007***	0.528***	0.260***	0.213***
	(0.000)	(0.008)	(0.008)	(0.021)	(0.021)	(0.020)
HC34	1.000	1.027***	1.019***	0.130***	0.131***	0.592***
	(0.000)	(0.009)	(0.010)	(0.021)	(0.021)	(0.020)
FL34	1.000	1.015***	1.020***	0.170***	0.362***	0.011
	(0.000)	(0.011)	(0.011)	(0.019)	(0.019)	(0.018)
N	*1,982*	*1,982*	*1,982*	*1,982*	*1,975*	*1,975*

Notes: This table shows structural equation modelling results on the associations between three measures of health at birth and three measures of fetal size in middle and end of gestation (as reported in the first column). Estimation method is maximum likelihood. Columns (1)-(3) presents the results for the measurement system: each measure of fetal health at each trimester is proxied by three indicators, the first of which is normalized to 1 for identification. These indicators are the residuals from a regression of the measurements (taken at three points in time) on gestational age, and on binary indicators for white ethnicity, male, being a first born and year and month of birth. Columns (4)-(6) present the loadings of each measure of health at birth on the corresponding fetal factor. The birth measures z-scores have been computed using the Child Growth Foundation standards. The fetal size z-scores have been computed according to the Royston [1995] method. AC=Abdominal Circumference; HC=Head Circumference; FL=Femur Length. *** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses.

Table A10: Factor analysis and structural equation model for the specific prenatal, birth and postnatal health measures

	TR1 (1)	**TR2** (2)	**TR3** (3)	**Birth** (4)	**Year1** (5)	**Year6** (6)
	Panel A: Factor analysis (method of principal factors)					
Var. 1^{st} factor	79%	69%	43%	66%	48%	55%
	Panel B: Structural equation model with independent errors					
Size	1	1	1	1	1	1
Head	0.965***	1.053***	0.853***	0.784***	0.549***	0.567***
	(0.020)	(0.023)	(0.045)	(0.022)	(0.033)	(0.034)
Length	0.920***	0.960***	0.652***	0.754***	0.681***	0.726***
	(0.022)	(0.023)	(0.036)	(0.020)	(0.035)	(0.034)
Var(H^*_{it})	0.819***	0.710***	0.691***	0.814***	1.055***	0.986***
	(0.042)	(0.031)	(0.045)	(0.033)	(0.061)	(0.056)
	Panel C: Uniqueness					
Size	0.168	0.252	0.328	0.076	0.060	0.001
Head	0.148	0.221	0.499	0.437	0.733	0.718
Length	0.243	0.347	0.705	0.381	0.533	0.444
	Panel D: Structural equation model with correlated errors					
$Cov(e_{i,size}, e_{i,head})$	0.000	0.000	0.000	0.000	0.000	0.000
	(0.037)	(0.028)	(0.027)	(0.026)	(0.032)	(0.033)
$Cov(e_{i,size}, e_{i,length})$	0.000	0.000	0.000	0.000	0.000	0.000
	(0.036)	(0.027)	(0.026)	(0.024)	(0.032)	(0.034)
$Cov(e_{i,head}, e_{i,length})$	0.000	0.000	0.000	0.000	0.000	0.000
	(0.035)	(0.028)	(0.025)	(0.022)	(0.029)	(0.031)

Notes: All measurements are standardized. Results from structural equation models assume a single factor and constrain the factor loading for size to be 1. Uniqueness is computed as $\frac{Var(e_{imt})}{\beta_m^2 Var(H^*_{it})+Var(e_{imt})}$, given the model $H_{imt} = \beta_m H^*_{it} + e_{imt}$ and $e_{imt} = \upsilon_{imt} + \varepsilon_{imt}$. *** p<0.01, ** p<0.05, * p<0.1.

Table A11: Correlations between the prenatal, birth and postnatal health measures

	AC11	HC11	CRL11	AC19	HC19	FL19	AC34	HC34	FL34	BW	BHC	BL	WT1Y	HC1Y	HT1Y	BW6Y	HC6Y	HT6Y
AC11	1																	
HC11	0.8377	1																
CRL11	0.7807	0.7939	1															
AC19	0.6906	0.6875	0.6666	1														
HC19	0.7296	0.779	0.7228	0.729	1													
FL19	0.6803	0.6791	0.6463	0.6914	0.6634	1												
AC34	0.395	0.3607	0.3827	0.5344	0.44	0.3563	1											
HC34	0.3413	0.37	0.3526	0.4208	0.5351	0.3183	0.5628	1										
FL34	0.3334	0.3203	0.3149	0.3916	0.3316	0.4918	0.4433	0.359	1									
BW	0.313	0.3017	0.3398	0.3967	0.357	0.3304	0.6794	0.5156	0.4496	1								
BHC	0.3048	0.2992	0.3314	0.36	0.4432	0.2977	0.5551	0.7222	0.3163	0.7134	1							
BL	0.2645	0.266	0.2825	0.3385	0.3165	0.3407	0.5405	0.4254	0.5464	0.7626	0.5685	1						
WT1Y	0.0876	0.0735	0.066	0.2011	0.1295	0.1357	0.321	0.2017	0.2854	0.3541	0.2739	0.4141	1					
HC1Y	0.0425	0.0565	0.0505	0.1225	0.202	-0.0011	0.2238	0.4502	0.0918	0.2702	0.5553	0.2782	0.474	1				
HT1Y	0.0693	0.0828	0.0647	0.1324	0.119	0.1573	0.1841	0.1423	0.3904	0.3191	0.2191	0.5497	0.6718	0.3242	1			
WT6Y	0.0991	0.0843	0.0841	0.1704	0.1306	0.1612	0.2619	0.1863	0.2314	0.3312	0.234	0.3498	0.5985	0.3085	0.4926	1		
HC6Y	0.0326	0.0543	0.0395	0.0982	0.1743	0.0054	0.2137	0.4195	0.0971	0.2551	0.5306	0.2813	0.3899	0.8162	0.292	0.4875	1	
HT6Y	0.0811	0.0825	0.0606	0.1547	0.128	0.1934	0.1772	0.1506	0.347	0.2825	0.1816	0.4743	0.5403	0.2561	0.7099	0.7482	0.3739	1

Notes: AC11: Abdominal Circumference at 11 weeks (1^{st} trimester). HC11: Head Circumference at 11 weeks (1^{st} trimester). CRL11: Crown-Rump Length at 11 weeks (1^{st} trimester). AC19: Abdominal Circumference at 19 weeks (2^{nd} trimester). HC19: Head Circumference at 19 weeks (2^{nd} trimester). FL19: Femur Length at 19 weeks (2^{nd} trimester). AC34: Abdominal Circumference at 34 weeks (3^{rd} trimester). HC34: Head Circumference at 34 weeks (3^{rd} trimester). FL34: Femur Length at 34 weeks (3^{rd} trimester). BW: Birth Weight. BHC: Birth Head Circumference. BL: Birth Length. WT1Y: Weight at 1 Year. HC1Y: Head Circumference at 1 Year. HT1Y: Height at 1 Year. WT6Y: Weight at 6 Years. HC6Y: Head Circumference at 6 Years. HT6Y: Height at 6 Years.

Table A12: Replication of Table 2 on the Birthright Data

	Birth Weight (kg)			
	19 weeks		28 weeks	
Fetal Measure	(1a)	(1b)	(2a)	(2b)
Abdominal Circumference (z)	0.064***	0.090*	0.178***	0.167***
	(0.022)	(0.051)	(0.021)	(0.030)
	[0.017]	[0.015]	[0.148]	[0.147]
	406	*406*	*399*	*399*
Head Circumference (z)	0.055***	0.027	0.144***	0.043
	(0.021)	(0.054)	(0.023)	(0.034)
	[0.012]	[0.015]	[0.096]	[0.147]
	406	*406*	*399*	*399*
Femur Length (z)	0.042**	-0.058	0.106***	-0.030
	(0.021)	(0.049)	(0.023)	(0.032)
	[0.006]	[0.015]	[0.051]	[0.147]
	406	*406*	*399*	*399*

Notes: This table presents the replication of Table 2 on the Birthright data. The estimates reported in columns (1a) and (2a) are from separate regressions of birth weight on each fetal measure separately; those reported in columns (1b) and (2b) are from regressions of birth weight on all three fetal measures at 19 and 28 weeks of gestation, respectively. All analyses are restricted to term babies (at least 37 weeks of gestation); they also exclude babies with major congenital abnormalities, stillbirths, neonatal deaths, those delivered in other maternity hospitals, those whose scan dates differ from their last menstrual period dates by more than 21 days, and those not fulfilling the study criteria. The measures of fetal size are z-scores, adjusted for gestational age at measurement. *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. In square brackets we report the adjusted R^2. In italics we report the sample size.

Table A13: Replication of Table 3 on the Birthright Data

	BW (z)	**BHC (z)**	**BL (z)**	**APG1**
Fetal Measure	(1)	(2)	(3)	(4)
Abdominal Circumference (z)	0.437***	0.088	0.245***	-0.198*
	(0.060)	(0.062)	(0.064)	(0.106)
Head Circumference (z)	0.090	0.666***	0.138*	0.169
	(0.067)	(0.067)	(0.070)	(0.104)
Femur Length (z)	0.047	-0.170***	0.223***	-0.040
	(0.066)	(0.060)	(0.066)	(0.091)
	399	*390*	*384*	*399*

Notes: This table presents the replication of Table 3 on the Birthright data. The estimates reported are from regressions of the birth measures listed in the first row on all three fetal measures in the third trimester of gestation (34 weeks). All analyses are restricted to term babies (at least 37 weeks of gestation); they also exclude babies with major congenital abnormalities, stillbirths, neonatal deaths, those delivered in other maternity hospitals, those whose scan dates differ from their last menstrual period dates by more than 21 days, and those not fulfilling the study criteria. All measures of fetal and birth size are z-scores, adjusted for gestational age at measurement. *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. In italics we report the sample size. APG1=Apgar at 1 minute. BHC=Birth Head Circumference. BL=Birth Length. BW=Birth Weight.

Table A14: In Utero Growth Patterns in Second and Third Trimester and Birth Outcomes, Full Results

	LBW (1)	**SGA** (2)	**HBW** (3)	**LGA** (4)	**Preterm** (5)
AC Stable Low Trajectory	0.047***	0.142***	-0.167***	-	0.021*
	(0.009)	(0.014)	(0.040)	(-)	(0.012)
AC Declining Trajectory	0.030***	0.070***	-0.066***	-0.026	0.021*
	(0.009)	(0.014)	(0.024)	(0.021)	(0.011)
AC Increasing Trajectory	0.009	0.010	0.089***	0.076***	0.022*
	(0.011)	(0.017)	(0.017)	(0.016)	(0.012)
AC Stable High Trajectory	-0.017	-0.117***	0.154***	0.180***	0.041***
	(0.017)	(0.043)	(0.018)	(0.016)	(0.012)
HC Declining Trajectory	0.016**	-0.001	-0.039*	0.011	0.019*
	(0.007)	(0.014)	(0.021)	(0.018)	(0.010)
HC Increasing Trajectory	-0.016	-0.032*	0.030*	0.007	-0.010
	(0.010)	(0.016)	(0.018)	(0.017)	(0.013)
FL Declining Trajectory	0.021***	0.016	-0.037*	-0.014	0.007
	(0.007)	(0.014)	(0.021)	(0.019)	(0.010)
FL Increasing Trajectory	0.004	0.001	0.033*	0.040**	-0.002
	(0.008)	(0.016)	(0.017)	(0.016)	(0.012)
N	*1,781*	*1,781*	*1,781*	*1,553*	*1,792*
AUC_X	0.676	0.632	0.630	0.645	0.573
	(0.042)	(0.024)	(0.018)	(0.022)	(0.037)
$AUC_X + fetal$	0.906	0.817	0.799	0.817	0.704
	(0.017)	(0.017)	(0.014)	(0.017)	(0.033)
$p - value$	*0.000*	*0.000*	*0.000*	*0.000*	*0.002*

Notes: This table shows average marginal effects from probit models of five measures of health at birth (as reported in the top row) on patterns of fetal growth between the second and the third trimester. All models include binary indicators for white ethnicity, gender, being a first born and year and season of birth. LBW=Low Birth Weight: binary indicator for birth weight <2,500g. SGA=Small-for-Gestational Age: binary indicator for birth weight $<10^{th}$ percentile; HBW=High Birth Weight: binary indicator for birth weight >4,000g; LGA=Large-for-Gestational Age: binary indicator for birth weight $>90^{th}$ percentile; Preterm: binary indicator for gestational age at birth <37 weeks. "AC Stable Low Trajectory" is a binary indicator which takes value 1 if the fetus is in the lower quartile of the Abdominal Circumference distribution both in the second and in the third trimester. "AC/FL/HC Declining Trajectory" is a binary indicator which takes value 1 if the fetus is in the lower quartile of the distribution of the difference between the third and the second trimester Abdominal Circumference/Femur Length/Head Circumference. "AC/FL/HC Increasing Trajectory" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the distribution of the difference between the third and the second trimester Abdominal Circumference/Femur Length/Head Circumference. "AC Stable High Trajectory" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the Abdominal Circumference distribution both in the second and in the third trimester. The binary indicators for Head Circumference and Femur Length are defined in a similar way. *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. AUC_X=Area under the ROC curve for a model which does not include the fetal measures. $AUC_X + fetal$=Area under the ROC curve for a model which also includes the fetal measures. The standard errors are bootstrapped (1,000 replications). p=p-value for the Null Hypothesis that both models have equal AUC values.

Table A15: In Utero Growth Patterns in Second and Third Trimester and Birth Outcomes, Extended Set of Covariates

	LBW (1)	**SGA** (2)	**HBW** (3)	**LGA** (4)	**Preterm** (5)
AC Stable Low Trajectory	0.054***	0.123***	-0.142***	-	0.020
	(0.010)	(0.014)	(0.039)	(-)	(0.012)
AC Declining Trajectory	0.031***	0.069***	-0.076***	-0.032	0.020*
	(0.008)	(0.014)	(0.024)	(0.021)	(0.010)
AC Increasing Trajectory	0.007	0.001	0.082***	0.071***	0.025**
	(0.011)	(0.016)	(0.017)	(0.017)	(0.011)
AC Stable High Trajectory	-0.010	-0.116***	0.137***	0.163***	0.038***
	(0.016)	(0.038)	(0.018)	(0.015)	(0.012)
HC Declining Trajectory	0.019***	-0.004	-0.033	0.017	0.023**
	(0.007)	(0.014)	(0.021)	(0.017)	(0.009)
HC Increasing Trajectory	-0.010	-0.014	0.031*	0.006	-0.011
	(0.009)	(0.016)	(0.017)	(0.017)	(0.012)
FL Declining Trajectory	0.022***	0.009	-0.026	-0.020	0.004
	(0.007)	(0.014)	(0.020)	(0.019)	(0.009)
FL Increasing Trajectory	-0.001	-0.001	0.011	0.017	-0.006
	(0.008)	(0.015)	(0.017)	(0.017)	(0.012)
N	*1,671*	*1,671*	*1,671*	*1,458*	*1,681*
AUC_X	0.692	0.776	0.755	0.748	0.668
	(0.041)	(0.020)	(0.017)	(0.022)	(0.035)
$AUC_X + fetal$	0.930	0.868	0.848	0.853	0.792
	(0.013)	(0.013)	(0.012)	(0.016)	(0.027)
$p - value$	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*

Notes: This table shows average marginal effects from probit models of five measures of health at birth (as reported in the top row) on patterns of fetal growth between the second and the third trimester. All models include binary indicators for white ethnicity, male, and being a first born, and controls for year and season of birth, number of children and mother's age at birth, and the following controls measured at baseline (before conception): whether the mother has a degree-level education, belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), owns the house, is single, separated, divorced or widowed, whether she receives welfare benefits, is in fair, bad or very bad health, whether she has been under stress in the last four weeks, whether she was working last week, whether she is a current smoker, whether she drinks more than 4 units of alcohol per week, whether she does any strenuous exercise in the week, whether she does any moderate exercise in the week, whether the mother's partner belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), whether the mother's father belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled); continuous variables for mother's birth weight, pre-pregnancy weight, height, BMI, head circumference, leg length, waist circumference, skinfolds (sum of triceps, biceps, subscapular and suprailiac) and her daily energy intake (kilocalories), paternal height, weight and birth weight, grandmaternal and grandpaternal height and weight, and the Townsend Deprivation Index; missing values for social class of the mother, the mother's father and the mother's partner have been replaced with zeros and a binary indicator for missing is included; missing values for maternal birth weight and head circumference, for paternal height, weight and birth weight, for grandmaternal weight and grandpaternal height and weight are replaced with the sample means of the non-missing observations and binary indicators for missing are included. LBW=Low Birth Weight: binary indicator for birth weight <2,500g. SGA=Small-for-Gestational Age: binary indicator for birth weight $<10^{th}$ percentile; HBW=High Birth Weight: binary indicator for birth weight >4,000g; LGA=Large-for-Gestational Age: binary indicator for birth weight $>90^{th}$ percentile; Preterm: binary indicator for gestational age at birth <37 weeks. "AC Stable Low Trajectory" is a binary indicator which takes value 1 if the fetus is in the lower quartile of the Abdominal Circumference distribution both in the second and in the third trimester. "AC/FL/HC Declining Trajectory" is a binary indicator which takes value 1 if the fetus is in the lower quartile of the distribution of the difference between the third and the second trimester Abdominal Circumference/Femur Length/Head Circumference. "AC/FL/HC Increasing Trajectory" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the distribution of the difference between the third and the second trimester Abdominal Circumference/Femur Length/Head Circumference. "AC Stable High Trajectory" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the Abdominal Circumference distribution both in the second and in the third trimester. The binary indicators for Head Circumference and Femur Length are defined in a similar way. *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. AUC_X=Area under the ROC curve for a model which does not include the fetal measures. $AUC_X + fetal$=Area under the ROC curve for a model which also includes the fetal measures. The standard errors are bootstrapped (1,000 replications). p=p-value for the Null Hypothesis that both models have equal AUC values.

Table A16: Conditional Associations between Neonatal Anthropometrics and Measures of Body Composition at Birth, Extended Set of Covariates

	Fat Mass (kg)				Lean Mass (kg)			
Birth Measure	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Weight (z)	0.149***			0.181***	0.238***			0.158***
	(0.007)			(0.014)	(0.010)			(0.017)
Length (z)		0.105***		-0.030***		0.231***		0.085***
		(0.009)		(0.011)		(0.012)		(0.014)
Head Circumference (z)			0.096***	-0.017*			0.187***	0.033**
			(0.009)	(0.010)			(0.012)	(0.013)
N	*587*	*586*	*588*	*584*	*587*	*586*	*588*	*584*
R^2	[0.644]	[0.443]	[0.442]	[0.653]	[0.727]	[0.648]	[0.582]	[0.752]
Adjusted R^2	[0.578]	[0.340]	[0.339]	[0.587]	[0.677]	[0.583]	[0.505]	[0.705]
Semi-partial R^2 BW	$0.347^\dagger$			$0.165^\dagger$	$0.385^\dagger$			$0.055^\dagger$
Semi-partial R^2 BL		$0.144^\dagger$		$0.006^\dagger$		$0.301^\dagger$		$0.019^\dagger$
Semi-partial R^2 BHC			$0.144^\dagger$	$0.002^\dagger$			$0.237^\dagger$	$0.004^\dagger$

	Thigh Skinfold (z-score)				Body Fat (%)			
Birth Measure	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Weight (z)	0.730***			0.968***	0.023***			0.033***
	(0.020)			(0.036)	(0.002)			(0.003)
Length (z)		0.460***		-0.243***		0.015***		-0.007**
		(0.027)		(0.034)		(0.002)		(0.003)
Head Circumference (z)			0.411***	-0.107***			0.012***	-0.008***
			(0.026)	(0.027)			(0.002)	(0.003)
N	*1,719*	*1,708*	*1,724*	*1,703*	*587*	*586*	*588*	*584*
R^2	[0.534]	[0.281]	[0.285]	[0.558]	[0.446]	[0.336]	[0.322]	[0.465]
Adjusted R^2	[0.506]	[0.238]	[0.243]	[0.531]	[0.344]	[0.214]	[0.197]	[0.363]
Semi-partial R^2 BW	$0.378^\dagger$			$0.237^\dagger$	$0.169^\dagger$			$0.116^\dagger$
Semi-partial R^2 BL		$0.125^\dagger$		$0.016^\dagger$		$0.059^\dagger$		$0.006^\dagger$
Semi-partial R^2 BHC			$0.129^\dagger$	$0.005^\dagger$			$0.045^\dagger$	$0.011^\dagger$

Notes: This table shows the estimated coefficients from ordinary least squares regressions of four different measures of newborn body composition on three neonatal anthropometrics (birth weight, birth length and birth head circumference), standardized using the Child Growth Foundation (CGF) standards. The measures of body composition are fat and lean mass in kilograms and proportion of body fat, all measured using DXA; and thigh skinfold, standardized within the SWS. Each column in each panel comes from a separate regression. All models include binary indicators for white ethnicity, gender, being a first born, year and month of birth and mother's age at birth, and the following controls measured at baseline (before conception): binary indicators for the number of children, whether the mother has a degree-level education, belongs to high social class (I: professional or II: management and technical), or low to social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), owns the house, is single, separated, divorced or widowed, whether she receives welfare benefits, is in fair, bad or very bad health, whether she has been under stress in the last four weeks, whether she was working last week, whether she is a current smoker, whether she drinks more than 4 units of alcohol per week, whether she does any strenuous exercise in the week, whether she does any moderate exercise in the week, whether the mother's partner belongs to high social class (I: professional or II: management and technical), or low to social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), whether the mother's father belongs to high social class (I: professional or II: management and technical), or low to social class (IIIM: skilled manual, IV: partly skilled or V: unskilled); continuous variables for mother's birth weight, pre-pregnancy weight, height, BMI, head circumference, leg length, waist circumference, skinfolds (sum of triceps, biceps, subscapular and suprailiac) and her daily energy intake (kilocalories), paternal height, weight and birth weight, grandmaternal and grandpaternal height and weight, and the Townsend Deprivation Index; missing values for social class of the mother, the mother's father and the mother's partner have been replaced with zeros and a binary indicator for missing is included; missing values for maternal birth weight and head circumference, for paternal height, weight and birth weight, for grandmaternal weight and grandpaternal height and weight are replaced with the sample means of the non-missing observations and binary indicators for missing are included. Robust standard errors in parentheses. BW=Birth Weight; BL=Birth Length; BHC=Birth Head Circumference. *** p<0.01, ** p<0.05, * p<0.1.

Table A17: Estimated Effects of Fetal and Neonatal Health Capital on Height and BMI in Early Childhood (6 Years), Full Results with Extended Set of Controls

	Panel A: Height (z-score)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Birth Weight (z)	0.175***			-0.135***		-0.114**	-0.068
	(0.030)			(0.049)		(0.054)	(0.047)
Birth Length (z)		0.361***		0.466***		0.406***	0.098***
		(0.031)		(0.047)		(0.051)	(0.046)
Birth Head Circumference (z)			0.135***	0.006		0.069	0.036
			(0.029)	(0.038)		(0.049)	(0.048)
Fetal Abdominal Circumference TR3 (z)					-0.004	-0.065*	-0.058*
					(0.034)	(0.037)	(0.033)
Fetal Femur Length TR3 (z)					0.231***	0.125***	0.062**
					(0.031)	(0.032)	(0.028)
Fetal Head Circumference TR3 (z)					0.001	-0.070*	-0.058*
					(0.032)	(0.041)	(0.035)
Postnatal Weight 1Y (z)							0.138***
							(0.032)
Postnatal Height 1Y (z)							0.435***
							(0.033)
Postnatal Head Circumference 1Y (z)							0.009
							(0.027)
N	*1,067*	*1,067*	*1,067*	*1,067*	*1,067*	*1,067*	*978*
Adjusted R^2	[0.294]	[0.354]	[0.286]	[0.359]	[0.317]	[0.369]	[0.581]
	Panel B: BMI (z-score)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Birth Weight (z)	0.222***			0.296***		0.233***	0.172***
	(0.034)			(0.053)		(0.059)	(0.055)
Birth Length (z)		0.085**		-0.206***		-0.198***	-0.168***
		(0.039)		(0.052)		(0.055)	(0.057)
Birth Head Circumference (z)			0.185***	0.087**		0.093*	-0.004
			(0.032)	(0.042)		(0.056)	(0.056)
Fetal Abdominal Circumference TR3 (z)					0.188***	0.112**	0.055
					(0.037)	(0.044)	(0.042)
Fetal Femur Length TR3 (z)					-0.059	-0.031	-0.049
					(0.037)	(0.038)	(0.035)
Fetal Head Circumference TR3 (z)					0.042	-0.027	-0.011
					(0.037)	(0.048)	(0.045)
Postnatal Weight 1Y (z)							0.508***
							(0.038)
Postnatal Height 1Y (z)							-0.193***
							(0.039)
Postnatal Head Circumference 1Y (z)							0.054
							(0.036)
N	*1,067*	*1,067*	*1,067*	*1,067*	*1,067*	*1,067 978*	
Adjusted R^2	[0.161]	[0.127]	[0.151]	[0.174]	[0.156]	[0.177]	[0.346]
	Panel C: Weight (z-score)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Birth Weight (z)	0.260***			0.129**		0.101*	0.087*
	(0.032)			(0.052)		(0.058)	(0.052)
Birth Length (z)		0.274***		0.132***		0.106*	-0.051
		(0.035)		(0.051)		(0.054)	(0.052)
Birth Head Circumference (z)			0.209***	0.063		0.108**	0.025
			(0.031)	(0.041)		(0.054)	(0.051)
Fetal Abdominal Circumference TR3 (z)					0.127***	0.034	-0.004
					(0.037)	(0.043)	(0.039)
Fetal Femur Length TR3 (z)					0.092***	0.046	-0.003
					(0.035)	(0.037)	(0.033)
Fetal Head Circumference TR3 (z)					0.029	-0.064	-0.046
					(0.037)	(0.047)	(0.042)
Postnatal Weight 1Y (z)							0.430***
							(0.036)
Postnatal Height 1Y (z)							0.118***
							(0.037)
Postnatal Head Circumference 1Y (z)							0.043
							(0.034)
N	*1,067*	*1,067*	*1,067*	*1,067*	*1,067*	*1,067*	*978*
Adjusted R^2	[0.217]	[0.213]	[0.202]	[0.223]	[0.202]	[0.224]	[0.443]

Notes: The table shows the estimated coefficients from ordinary least squares regressions of height and BMI at 6 years on birth and fetal measures in the third trimester of gestation (34 weeks). Height, BMI and the birth measures have been standardized using the Child Growth Foundation (CGF) standards; the fetal measures have been standardized using the Royston [1995] method. Each column comes from a separate regression. The measures of postnatal conditional growth in column (7) are obtained as the residual of a regression of height and weight at 1 year on birth length and weight, respectively. All models include binary indicators for white ethnicity, gender, being a first born, year and month of birth and mother's age at birth, and the following controls measured at baseline (before conception): binary indicators for the number of children, whether the mother has a degree-level education, belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), owns the house, is single, separated, divorced or widowed, whether she receives welfare benefits, is in fair, bad or very bad health, whether she has been under stress in the last four weeks, whether she was working last week, whether she is a current smoker, whether she drinks more than 4 units of alcohol per week, whether she does any strenuous exercise in the week, whether she does any moderate exercise in the week, whether the mother's partner belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), whether the mother's father belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled); continuous variables for mother's birth weight, pre-pregnancy weight, height, BMI, head circumference, leg length, waist circumference, skinfolds (sum of triceps, biceps, subscapular and suprailiac) and her daily energy intake (kilocalories), paternal height, weight and birth weight, grandmaternal and grandpaternal height and weight, and the Townsend Deprivation Index; missing values for social class of the mother, the mother's father and the mother's partner have been replaced with zeros and a binary indicator for missing is included; missing values for maternal birth weight and head circumference, for paternal height, weight and birth weight, for grandmaternal weight and grandpaternal height and weight are replaced with the sample means of the non-missing observations and binary indicators for missing are included. Robust standard errors in parentheses. In square brackets we report the adjusted R^2. All models are estimated on a balanced sample of 1,067 observations, with the exception of the one including postnatal outcomes, which is based on 978 observations. *** p<0.01, ** p<0.05, * p<0.1.

Table A18: Estimated Effects of Fetal and Neonatal Health Capital on IQ in Early Childhood (4 Years)

			WPPSI: Verbal			
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
Conditional HC Growth TR1-2 (z-score)	4.673***	7.981***	3.756**	8.237***	4.219**	8.766***
	(1.701)	(2.710)	(1.848)	(2.640)	(2.069)	(2.895)
Conditional HC Growth TR2-3 (z-score)	0.213	1.708	0.993	-0.135	1.391	-0.274
	(2.406)	(2.341)	(2.569)	(3.240)	(2.679)	(3.340)
Birth Head Circumference (z-score)			1.271	1.910	0.591	2.833
			(2.602)	(3.026)	(2.711)	(3.189)
Conditional Head Growth 0-1Y					-1.773	-3.899
					(1.997)	(3.582)
Full Controls		✓		✓		✓
N	*98*	*93*	*96*	*92*	*94*	*90*
R^2	[0.124]	[0.628]	[0.129]	[0.668]	[0.142]	[0.683]
Adjusted R^2	[0.012]	[0.145]	[0.003]	[0.204]	[0.003]	[0.194]
			WPPSI: General language			
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
Conditional HC Growth TR1-2 (z-score)	3.038**	7.346***	2.528*	7.507***	2.333*	7.435***
	(1.393)	(1.549)	(1.324)	(1.618)	(1.387)	(1.753)
Conditional HC Growth TR2-3 (z-score)	2.349	7.279***	3.635**	7.479***	3.980***	7.752***
	(1.758)	(1.348)	(1.402)	(2.297)	(1.447)	(2.418)
Birth Head Circumference (z-score)			0.208	-0.504	0.199	-0.425
			(1.593)	(2.524)	(1.670)	(2.655)
Conditional Head Growth 0-1Y					-0.690	-0.974
					(1.263)	(1.835)
Full Controls		✓		✓		✓
N	*98*	*93*	*96*	*92*	*94*	*90*
R^2	[0.110]	[0.742]	[0.162]	[0.742]	[0.170]	[0.744]
Adjusted R^2	[-0.004]	[0.406]	[0.041]	[0.382]	[0.035]	[0.348]
			NEPSY: Sentence repetition			
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
Conditional HC Growth TR1-2 (z-score)	0.374	0.900***	0.306	0.847***	0.191	0.817**
	(0.336)	(0.308)	(0.344)	(0.300)	(0.375)	(0.339)
Conditional HC Growth TR2-3 (z-score)	0.526*	0.397	0.416	-0.037	0.501	0.048
	(0.303)	(0.281)	(0.402)	(0.391)	(0.369)	(0.409)
Birth Head Circumference (z-score)			0.187	0.632	0.152	0.644
			(0.387)	(0.445)	(0.374)	(0.492)
Conditional Head Growth 0-1Y					0.080	-0.247
					(0.311)	(0.539)
Full Controls		✓		✓		✓
N	*94*	*90*	*93*	*89*	*91*	*87*
R^2	[0.075]	[0.792]	[0.081]	[0.809]	[0.102]	[0.802]
Adjusted R^2	[-0.049]	[0.500]	[-0.057]	[0.520]	[-0.049]	[0.468]

Notes: The table shows the estimated coefficients from ordinary least squares regressions of different measures of verbal IQ at 4 years on head circumference growth since early gestation until the first year of life. WPPSI: Wechsler Preschool and Primary Scale of Intelligence; NEPSY: NEuroPSYchological Assessment. The fetal conditional growth z-scores have been computed according to the Royston [1995] method. The birth measures have been standardized using the Child Growth Foundation (CGF) standards. The measures of postnatal conditional growth are obtained as the residual of a regression of head circumference at 1 year on birth head circumference. Each column comes from a separate regression. Models in (1a), (2a) and (3a) include binary indicators for white ethnicity, gender, being a first born and year and season of birth. Models in (1b), (2b), (3b), (4a) and (4b) include binary indicators for white ethnicity, male, and being a first born, and controls for year and season of birth, number of children and mother's age at birth, and the following controls measured at baseline (before conception): whether the mother has a degree-level education, belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), owns the house, is single, separated, divorced or widowed, whether she receives welfare benefits, is in fair, bad or very bad health, whether she has been under stress in the last four weeks, whether she was working last week, whether she is a current smoker, whether she drinks more than 4 units of alcohol per week, whether she does any strenuous exercise in the week, whether she does any moderate exercise in the week, whether the mother's partner belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), whether the mother's father belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled); continuous variables for mother's birth weight, pre-pregnancy weight, height, BMI, head circumference, leg length, waist circumference, skinfolds (sum of triceps, biceps, subscapular and suprailiac) and her daily energy intake (kilocalories), paternal height, weight and birth weight, grandmaternal and grandpaternal height and weight, and the Townsend Deprivation Index; missing values for social class of the mother, the mother's father and the mother's partner have been replaced with zeros and a binary indicator for missing is included; missing values for maternal birth weight and head circumference, for paternal height, weight and birth weight, for grandmaternal weight and grandpaternal height and weight are replaced with the sample means of the non-missing observations and binary indicators for missing are included. Robust standard errors in parentheses. In square brackets we report the R^2 (first row) and the adjusted R^2 (second row). In italics we report the sample size. *** p<0.01, ** p<0.05, * p<0.1.

Table A19: Estimated Effects of Birth Health on Anthropometrics and Cognition in Childhood (CNLSY)

				Panel A: Height (z-score)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Birth Weight (z)	0.246***	0.183***			0.173***	0.125***	0.118***
	(0.023)	(0.037)			(0.026)	(0.041)	(0.041)
Birth Length (z)			0.189***	0.136***	0.116***	0.101***	0.119***
			(0.018)	(0.026)	(0.021)	(0.029)	(0.030)
Mother FE		✓		✓		✓	✓
N	*7,237*	*7,237*	*7,237*	*7,237*	*7,237*	*7,237*	*7,065*
# mothers		1,738		1,738		1,738	1,720
				Panel B: BMI (z-score)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Birth Weight (z)	0.174***	0.194***			0.203***	0.215***	0.212***
	(0.023)	(0.039)			(0.026)	(0.042)	(0.043)
Birth Length (z)			0.041**	0.025	-0.045**	-0.036	-0.047
			(0.019)	(0.027)	(0.021)	(0.028)	(0.029)
Mother FE		✓		✓		✓	✓
N	*7,218*	*7,218*	*7,218*	*7,218*	*7,218*	*7,218*	*7,048*
# mothers		1,736		1,736		1,736	1,702
				Panel C: PPVT			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Birth Weight (z)	1.304***	0.397			1.170***	-0.151	0.161
	(0.372)	(0.607)			(0.425)	(0.642)	(0.653)
Birth Length (z)			0.702**	0.822**	0.210	0.864**	0.699*
			(0.300)	(0.375)	(0.343)	(0.402)	(0.423)
			(0.300)	(0.372)	(0.343)	(0.401)	(0.416)
Mother FE		✓		✓		✓	✓
N	*3,585*	*3,585*	*3,585*	*3,585*	*3,585*	*3,585*	*3,451*
# mothers		1,534		1,534		1,534	1,513
				Panel D: WISC Memory for Digit Span			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Birth Weight (z)	0.142**	0.151			0.143**	0.065	0.070
	(0.061)	(0.102)			(0.069)	(0.116)	(0.116)
Birth Length (z)			0.057	0.164**	-0.002	0.146*	0.172**
			(0.048)	(0.071)	(0.055)	(0.081)	(0.083)
Mother FE		✓		✓		✓	✓
N	*5,613*	*5,613*	*5,613*	*5,613*	*5,613*	*5,613*	*5,488*
# mothers		1,655		1,655		1,655	1,637
				Panel E: PIAT Math			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Birth Weight (z)	0.840***	0.745**			0.678**	0.265	0.300
	(0.245)	(0.377)			(0.276)	(0.405)	(0.413)
Birth Length (z)			0.541***	0.897***	0.254	0.823***	0.902***
			(0.205)	(0.266)	(0.231)	(0.287)	(0.297)
Mother FE		✓		✓		✓	✓
N	*7,130*	*7,130*	*7,130*	*7,130*	*7,130*	*7,130*	*6,967*
# mothers		1,691		1,691		1,691	1,671
				Panel F: PIAT Reading Recognition			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Birth Weight (z)	0.815***	1.159***			0.865***	0.838**	1.024**
	(0.270)	(0.381)			(0.311)	(0.409)	(0.425)
Birth Length (z)			0.283	0.784***	-0.080	0.550*	0.512
			(0.222)	(0.283)	(0.255)	(0.305)	(0.321)
Mother FE		✓		✓		✓	✓
N	*7,124*	*7,124*	*7,124*	*7,124*	*7,124*	*7,124*	*6,962*
# mothers		1,691		1,691		1,691	1,671

Notes: This table displays ordinary least squares estimates of two anthropometric and three cognitive outcomes in childhood (ages 7-11) on birth weight and birth length. Both birth measures have been standardized using the growth chart developed by Olsen et al. [2010] for the United States. Only those cases reporting that birth length is not an estimate have been included. Values lying outside three times the interquartile range from the first or third quartile of the birth weight and birth length distribution have been removed as extreme outliers (Tukey's method). Additionally, values of the Olsen z-scores smaller than -4 or greater than 4 have been removed. Controls included in all the estimated specifications not shown in the tables are: gestational age and indicators for the child being male, for birth order, for the mother being 20 years old or younger, and for being older than 35 years, for age at measurement (in years), and for year-of-birth-specific bi-monthly dummies. The specifications in column (7) also include the following prenatal variables: pre-pregnancy weight and gestational weight gain, and binary indicators for whether the first prenatal care visit took place in the first trimester, for whether the mother was drinking in pregnancy 1 day per week or more, and for whether she was smoking $<$1 pack per day or 1 pack or more per day. The sample only includes children of white ethnicity. The standard errors (in parentheses) are clustered at the level of the mother. *** p$<$0.01, ** p$<$0.05, * p$<$0.1. †: the coefficients on birth weight and birth length are statistically significantly different (two-sided tests).

Table A20: Estimated Effects of Birth Health on Anthropometric and Cognitive Outcomes in Childhood (PtA)

			Panel A: Height			
	(1)	(2)	(3)	(4)	(5)	(6)
Birth Weight (z)	1.457***	0.146			0.917***	-0.343
	(0.152)	(0.401)			(0.223)	(0.480)
Birth Length (z)			1.509***	0.913**	0.830***	1.089**†
			(0.161)	(0.394)	(0.233)	(0.495)
Mother FE		✓		✓		✓
N	*1,349*	*1,349*	*1,349*	*1,349*	*1,349*	*1,349*
# mothers		1,208		1,208		1,208
			Panel B: BMI			
	(1)	(2)	(3)	(4)	(5)	(6)
Birth Weight (z)	0.208***	0.228**			0.284***†	0.224**
	(0.044)	(0.107)			(0.057)	(0.109)
Birth Length (z)			0.093**	0.123	-0.118**	0.008
			(0.045)	(0.122)	(0.059)	(0.125)
Mother FE		✓		✓		✓
N	*1,291*	*1,291*	*1,291*	*1,291*	*1,291*	*1,291*
# mothers		1,153		1,153		1,153
			Panel C: PPVT			
	(1)	(2)	(3)	(4)	(5)	(6)
Birth Weight (z)	0.449**	0.262			0.366	-0.312
	(0.228)	(0.554)			(0.289)	(0.690)
Birth Length (z)			0.395*	1.098	0.128	1.259
			(0.237)	(0.813)	(0.300)	(0.985)
Mother FE		✓		✓		✓
N	*1,372*	*1,372*	*1,372*	*1,372*	*1,372*	*1,372*
# mothers		1,231		1,231		1,231
			Panel D: WRAT Math Scale			
	(1)	(2)	(3)	(4)	(5)	(6)
Birth Weight (z)	0.432***	0.437			0.444***†	0.007
	(0.119)	(0.394)			(0.154)	(0.398)
Birth Length (z)			0.305**	1.065***	-0.019	1.062***†
			(0.129)	(0.359)	(0.168)	(0.367)
Mother FE		✓		✓		✓
N	*1,328*	*1,328*	*1,328*	*1,328*	*1,328*	*1,328*
# mothers		1,199		1,199		1,199
			Panel E: WRAT Reading Scale			
	(1)	(2)	(3)	(4)	(5)	(6)
Birth Weight (z)	0.794***	-0.399			0.769**	-1.013
	(0.284)	(0.731)			(0.363)	(0.772)
Birth Length (z)			0.598**	0.998	0.038	1.494*†
			(0.298)	(0.728)	(0.381)	(0.790)
Mother FE		✓		✓		✓
N	*1,326*	*1,326*	*1,326*	*1,326*	*1,326*	*1,326*
# mothers		1,198		1,198		1,198
			Panel F: WISC Verbal Digit Scale			
	(1)	(2)	(3)	(4)	(5)	(6)
Birth Weight (z)	0.305***	0.470*			0.366***†	0.095
	(0.085)	(0.245)			(0.116)	(0.257)
Birth Length (z)			0.174*	0.895***	-0.094	0.846***†
			(0.090)	(0.257)	(0.122)	(0.282)
Mother FE		✓		✓		✓
N	*1,342*	*1,342*	*1,342*	*1,342*	*1,342*	*1,342*
# mothers		1,210		1,210		1,210
			Panel G: WISC Verbal Comprehension Scale			
	(1)	(2)	(3)	(4)	(5)	(6)
Birth Weight (z)	0.186***	0.082			0.209**†	-0.247
	(0.070)	(0.243)			(0.095)	(0.285)
Birth Length (z)			0.117	0.614**	-0.036	0.741**†
			(0.074)	(0.247)	(0.101)	(0.303)
Mother FE		✓		✓		✓
N	*1,341*	*1,341*	*1,341*	*1,341*	*1,341*	*1,341*
# mothers		1,209		1,209		1,209

Notes: This table displays ordinary least squares estimates of anthropometric and cognitive outcomes in childhood (age 7) on birth weight and birth length. Both birth measures have been standardized using the growth chart developed by Olsen et al. [2010] for the United States. Values lying outside three times the interquartile range from the first or third quartile of the birth weight and birth length distribution have been removed as extreme outliers (Tukey's method). Controls included in all the estimated specifications not shown in the tables are: gestational age and indicators for the child being male, of white ethnicity, for being a first born, for number of previous births, for the mother being 20 years old or younger, and for being older than 35 years, for age at measurement (in years for the anthropometric outcomes and also in months for the cognitive outcomes), and for year of birth. The standard errors (in parentheses) are clustered at the level of the mother. *** p<0.01, ** p<0.05, * p<0.1. †: the coefficients on birth weight and birth length are statistically significantly different (two-sided tests).

Table A21: Prenatal, Birth, Postnatal Health Capital and Childhood Overweight at 6 Years

	Overweight							
	(1a)	(2a)	(3a)	(1b)	(2b)	(3b)	(4a)	(4b)
Fetal Abdominal Circumference TR2 (z)	0.033***	0.030***			0.025	0.018		0.012
	(0.012)	(0.012)			(0.015)	(0.015)		(0.015)
Fetal Abdominal Circumference Growth TR2-TR3 (z)	0.060***	0.045***			0.043**	0.027		0.013
	(0.014)	(0.013)			(0.018)	(0.017)		(0.017)
Fetal Abdominal Circumference Growth TR3-Birth	0.036***	0.022*			0.020	0.004		0.001
	(0.014)	(0.013)			(0.018)	(0.017)		(0.017)
Fetal Abdominal Circumference Slow Growth TR2-Birth	0.151***	0.126**			0.133**	0.115**		0.126**
	(0.056)	(0.054)			(0.056)	(0.055)		(0.050)
Fetal Abdominal Circumference Fast Growth TR2-Birth	-0.117**	-0.134***			-0.114**	-0.129**		-0.151***
	(0.054)	(0.052)			(0.055)	(0.053)		(0.053)
Fetal Femur Length Slow Growth TR2-Birth	0.052	0.028			0.026	0.015		0.013
	(0.054)	(0.051)			(0.057)	(0.054)		(0.057)
Fetal Femur Length Fast Growth TR2-Birth	-0.085*	-0.082			-0.083	-0.084		-0.068
	(0.051)	(0.050)			(0.054)	(0.052)		(0.052)
Fetal Femur Length Accelerated Growth TR2-Birth	0.022	0.031			0.028	0.033		0.038
	(0.025)	(0.024)			(0.025)	(0.025)		(0.024)
Fetal Head Circumference Growth TR3-Birth	0.022*	0.029**			0.018	0.024*		0.013
	(0.013)	(0.012)			(0.014)	(0.013)		(0.013)
Fetal Head Circumference Fast Growth TR2-Birth	0.039	0.024			0.022	0.010		0.022
	(0.048)	(0.047)			(0.049)	(0.048)		(0.043)
Fetal Asymmetric AC/HC Growth TR2-TR3	0.038	0.028			0.037	0.030		0.026
	(0.027)	(0.026)			(0.027)	(0.026)		(0.026)
Birth Weight (z)			0.081***	0.069***	0.038	0.043*	0.077***	0.069***
			(0.020)	(0.020)	(0.028)	(0.025)	(0.020)	(0.026)
Birth Length (z)			-0.043**	-0.029	-0.031	-0.020	-0.044**	-0.034
			(0.020)	(0.020)	(0.022)	(0.022)	(0.020)	(0.023)
High Birth Weight			0.039	0.006	0.042	0.021	0.005	0.017
			(0.036)	(0.034)	(0.037)	(0.036)	(0.035)	(0.036)
Low Apgar 1M			0.038	0.024	0.030	0.022	0.009	0.011
			(0.031)	(0.031)	(0.031)	(0.030)	(0.032)	(0.033)
Low Apgar 5M			0.087	0.066	0.094	0.068	0.110*	0.107
			(0.069)	(0.065)	(0.069)	(0.066)	(0.065)	(0.066)
Postnatal Weight Growth 0-1Y (z)							0.116***	0.109***
							(0.015)	(0.015)
Postnatal Height Growth 0-1Y (z)							-0.039***	-0.033**
							(0.014)	(0.014)
Full Controls		✓		✓		✓	✓	✓
Postnatal Growth							✓	✓
p-value joint significance Fetal	*0.000*	*0.000*			*0.007*	*0.006*		*0.015*
p-value joint significance Birth			*0.000*	*0.001*	*0.128*	*0.262*	*0.000*	*0.029*
p-value joint significance Postnatal							*0.000*	*0.000*
AUC	0.686	0.794	0.666	0.773	0.696	0.795	0.821	0.836
p-value AUC					0.020	0.011		0.019
N	*1,097*	*1,035*	*1,097*	*1,035*	*1,097*	*1,035*	*956*	*956*

Notes: This table shows average marginal effects from probit models of the probability of being overweight (BMI-for-age $>85^{th}$ percentile according to the Child Growth Foundation standards) at 6 years on patterns of fetal growth starting the second trimester and birth outcomes. Models in (1a), (2a) and (3a) include binary indicators for white ethnicity, gender, being a first born and year and season of birth. Models in (1b), (2b), (3b), (4a) and (4b) include binary indicators for white ethnicity, male, and being a first born, and controls for year and season of birth, number of children and mother's age at birth, and the following controls measured at baseline (before conception): whether the mother has a degree-level education, belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), owns the house, is single, separated, divorced or widowed, whether she receives welfare benefits, is in fair, bad or very bad health, whether she has been under stress in the last four weeks, whether she was working last week, whether she is a current smoker, whether she drinks more than 4 units of alcohol per week, whether she does any strenuous exercise in the week, whether she does any moderate exercise in the week, whether the mother's partner belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), whether the mother's father belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled); continuous variables for mother's birth weight, pre-pregnancy weight, height, BMI, head circumference, leg length, waist circumference, skinfolds (sum of triceps, biceps, subscapular and suprailiac) and her daily energy intake (kilocalories), paternal height, weight and birth weight, grandmaternal and grandpaternal height and weight, and the Townsend Deprivation Index; missing values for social class of the mother, the mother's father and the mother's partner have been replaced with zeros and a binary indicator for missing is included; missing values for maternal birth weight and head circumference, for paternal height, weight and birth weight, for grandmaternal weight and grandpaternal height and weight are replaced with the sample means of the non-missing observations and binary indicators for missing are included. "Fetal Abdominal Circumference Growth TR2-TR3 (z)" is a measure of conditional growth between weeks 19 and 34, computed according to the Royston [1995] method. "Fetal Abdominal Circumference Growth TR3-Birth (z)" is a measure of conditional growth between weeks 34 and birth. "Fetal Abdominal Circumference Slow Growth TR2-Birth" is a binary indicator which takes value 1 if the fetus is in the lower quartile of the Abdominal Circumference growth distribution both between weeks 19-34 and between week 34 and birth. "Fetal Abdominal Circumference Fast Growth TR2-Birth" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the Abdominal Circumference growth distribution both between weeks 19-34 and between week 34 and birth. "Fetal Femur Length Slow Growth TR2-Birth" is a binary indicator which takes value 1 if the fetus is in the lower quartile of the Femur Length growth distribution both between weeks 19-34 and between week 34 and birth. "Fetal Femur Length Fast Growth TR2-Birth" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the Femur Length growth distribution both between weeks 19-34 and between week 34 and birth. "Fetal Femur Length Accelerated Growth TR2-Birth" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the distribution of the difference between the Femur Length growth between week 34 and birth and between weeks 19-34. "Fetal Head Circumference Growth TR3-Birth (z)" is a measure of conditional growth between weeks 34 and birth. "Fetal Head Circumference Fast Growth TR2-Birth" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the Head Circumference growth distribution both between weeks 19-34 and between week 34 and birth. "Fetal Asymmetric AC/HC Growth TR2-TR3" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the distribution of the difference between the Abdominal Circumference growth and the Head Circumference growth between weeks 19 and 34. The birth outcomes z-scores have been computed using the Child Growth Foundation standards. The measures of postnatal conditional growth are standardized residuals of regressions of weight and height at one year on their respective birth measures. *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses. AUC=Area under the ROC curve. The standard errors are bootstrapped (1,000 replications). p=p-value for the Null Hypothesis that the models in (2a) and (3a), in (2b) and (3b), and in (4a) and (4b), respectively, have equal AUC values.

Table A22: Prenatal and Birth Health Capital and Childhood Respiratory Health at 6 Years

	Asthma (GP-Diagnosed) or Wheezing							
	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)	(4a)	(4b)
Fetal Abdominal Circumference Fast Growth TR2-Birth	-0.168**	-0.190***			-0.127*	-0.144**		-0.199***
	(0.069)	(0.070)			(0.072)	(0.072)		(0.073)
Fetal Head Circumference Accelerated Growth TR2-Birth	-0.073**	-0.069**			-0.080**	-0.075**		-0.087***
	(0.033)	(0.032)			(0.032)	(0.032)		(0.032)
Fetal Asymmetric HC/AC Growth TR2-TR3	0.016	0.042			0.010	0.035		0.033
	(0.035)	(0.035)			(0.036)	(0.036)		(0.037)
Fetal Symmetric AC/HC Growth TR2-TR3	-0.064**	-0.054*			-0.073**	-0.063**		-0.061*
	(0.031)	(0.031)			(0.031)	(0.031)		(0.032)
Birth Head Circumference			0.044**	0.048***	0.045**	0.047***	0.049***	0.047***
			(0.017)	(0.017)	(0.018)	(0.017)	(0.018)	(0.018)
Low Birth Weight			0.234**	0.206**	0.233**	0.212**	0.178**	0.190**
			(0.092)	(0.086)	(0.093)	(0.087)	(0.091)	(0.091)
High Birth Weight			-0.083**	-0.106**	-0.066	-0.076*	-0.100**	-0.059
			(0.040)	(0.042)	(0.042)	(0.044)	(0.044)	(0.045)
Low Apgar 1M			0.073**	0.076**	0.080**	0.083**	0.077**	0.086**
			(0.034)	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)
Low Apgar 5M			0.061	0.009	0.054	0.004	0.032	0.018
			(0.080)	(0.073)	(0.078)	(0.073)	(0.076)	(0.077)
Small Birth Head Circumference			0.076**	0.076**	0.080**	0.078**	0.087**	0.088**
			(0.035)	(0.035)	(0.035)	(0.035)	(0.036)	(0.036)
Short Birth Length			-0.095	-0.069	-0.099	-0.078	-0.068	-0.077
			(0.064)	(0.062)	(0.064)	(0.062)	(0.063)	(0.063)
Asymmetric SGA			0.040	0.039	0.034	0.030	0.024	0.016
			(0.059)	(0.057)	(0.058)	(0.056)	(0.060)	(0.059)
Preterm			0.061	0.035	0.059	0.038	0.044	0.044
			(0.068)	(0.069)	(0.068)	(0.069)	(0.072)	(0.070)
Postnatal Weight Growth 0-1Y (z)							0.013	0.015
							(0.015)	(0.015)
Postnatal Head Growth 0-1Y (z)							-0.001	-0.007
							(0.015)	(0.015)
Full Controls		✓		✓		✓	✓	✓
Postnatal Growth							✓	✓
p-value joint significance Fetal	*0.000*	*0.000*			*0.000*	*0.000*		*0.000*
p-value joint significance Birth			*0.001*	*0.001*	*0.000*	*0.002*	*0.002*	*0.004*
p-value joint significance Postnatal							*0.644*	*0.619*
AUC	0.619	0.695	0.631	0.691	0.662	0.714	0.694	0.719
p-value AUC					0.018	0.015		0.010
N	*1,115*	*1,051*	*1,115*	*1,051*	*1,115*	*1,051*	*996*	*996*

Notes: This table shows average marginal effects from probit models of the probability of having asthma or wheezing at 6 years on patterns of fetal growth starting the second trimester and birth outcomes. Models in (1a), (2a) and (3a) include binary indicators for white ethnicity, gender, being a first born and year and season of birth. Models in (1b), (2b), (3b), (4a) and (4b) include binary indicators for white ethnicity, male, and being a first born, and controls for year and season of birth, number of children and mother's age at birth, and the following controls measured at baseline (before conception): whether the mother has a degree-level education, belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), owns the house, is single, separated, divorced or widowed, whether she receives welfare benefits, is in fair, bad or very bad health, whether she has been under stress in the last four weeks, whether she was working last week, whether she is a current smoker, whether she drinks more than 4 units of alcohol per week, whether she does any strenuous exercise in the week, whether she does any moderate exercise in the week, whether the mother's partner belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), whether the mother's father belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled); continuous variables for mother's birth weight, pre-pregnancy weight, height, BMI, head circumference, leg length, waist circumference, skinfolds (sum of triceps, biceps, subscapular and suprailiac) and her daily energy intake (kilocalories), paternal height, weight and birth weight, grandmaternal and grandpaternal height and weight, and the Townsend Deprivation Index; missing values for social class of the mother, the mother's father and the mother's partner have been replaced with zeros and a binary indicator for missing is included; missing values for maternal birth weight and head circumference, for paternal height, weight and birth weight, for grandmaternal weight and grandpaternal height and weight are replaced with the sample means of the non-missing observations and binary indicators for missing are included. "Fetal Abdominal Circumference Fast Growth TR2-Birth" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the Abdominal Circumference growth distribution both between weeks 19-34 and between week 34 and birth. "Fetal Head Circumference Accelerated Growth TR2-Birth" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the distribution of the difference between the Head Circumference growth between week 34 and birth and between weeks 19-34. "Fetal Asymmetric HC/AC Growth 19-34w" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the distribution of the difference between the Head Circumference growth and the Abdominal Circumference growth between weeks 19 and 34. "Fetal Symmetric Abdominal/Head Circumference Growth TR2-TR3" is a binary indicator which takes value 1 if the fetus is above the lower quartile and below the upper quartile of the distribution of the difference between the Abdominal Circumference growth and the Head Circumference growth between weeks 19 and 34. "Low Apgar 1 Minute" is a binary indicator which takes value 1 if the Apgar score is less than 8. Preterm is a binary indicator which takes value 1 if the gestational age at birth is less than 37 weeks. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Robust standard errors in parentheses. AUC=Area under the ROC curve. The standard errors are bootstrapped (1,000 replications). p=p-value for the Null Hypothesis that the models in (2a) and (3a), in (2b) and (3b), and in (4a) and (4b), respectively, have equal AUC values.

Table A23: Prenatal, Birth, Postnatal Health Capital and Childhood Hyperactivity Problems at 3 Years

	Hyperactivity Problems (SDQ)							
	(1a)	(2a)	(3a)	(1b)	(2b)	(3b)	(4a)	(4b)
Fetal Abdominal Circumference Slow Growth TR2-Birth	0.075*	0.089**			0.065	0.084*		0.097**
	(0.042)	(0.043)			(0.044)	(0.045)		(0.045)
Fetal Femur Length Slow Growth TR2-Birth	0.062	0.098**			0.047	0.089*		0.097**
	(0.046)	(0.045)			(0.048)	(0.047)		(0.047)
Fetal Femur Length Accelerated Growth TR2-Birth	-0.039	-0.037			-0.038	-0.037		-0.035
	(0.024)	(0.024)			(0.024)	(0.024)		(0.025)
Fetal Head Circumference Slow Growth TR2-Birth	0.069*	0.004			0.068	0.007		-0.017
	(0.042)	(0.044)			(0.044)	(0.045)		(0.045)
Fetal Head Circumference Fast Growth TR2-Birth	-0.081*	-0.105**			-0.079	-0.108**		-0.126**
	(0.048)	(0.051)			(0.050)	(0.054)		(0.054)
Fetal Head Circumference Accelerated Growth TR2-Birth	-0.053**	-0.062**			-0.054**	-0.062**		-0.064**
	(0.026)	(0.025)			(0.026)	(0.026)		(0.026)
Fetal Asymmetric HC/AC Growth TR2-TR3	0.021	0.030			0.018	0.028		0.036
	(0.024)	(0.024)			(0.025)	(0.025)		(0.025)
Fetal Symmetric HC/FL Growth TR2-TR3	-0.035*	-0.044**			-0.034*	-0.043**		-0.043**
	(0.020)	(0.020)			(0.020)	(0.020)		(0.020)
Birth Head Circumference (z)			-0.016	-0.011	0.003	0.006	-0.015	0.000
			(0.012)	(0.012)	(0.013)	(0.013)	(0.012)	(0.014)
Short Birth Length			0.065*	0.066*	0.033	0.031	0.074*	0.035
			(0.038)	(0.038)	(0.040)	(0.039)	(0.039)	(0.041)
Asymmetric SGA			0.043	0.046	0.023	0.013	0.068	0.025
			(0.047)	(0.046)	(0.049)	(0.047)	(0.046)	(0.047)
Large-for-Gestational Age			-0.028	-0.025	-0.024	-0.016	-0.030	-0.019
			(0.042)	(0.041)	(0.041)	(0.040)	(0.041)	(0.041)
Postnatal Weight Growth 0-1Y (z)							0.019	0.024*
							(0.012)	(0.012)
Postnatal Head Growth 0-1Y (z)							-0.030**	-0.035***
							(0.012)	(0.012)
Full Controls		✓		✓		✓	✓	✓
Postnatal Growth							✓	✓
p-value joint significance Fetal	*0.000*	*0.000*			*0.011*	*0.001*		*0.000*
p-value joint significance Birth			*0.061*	*0.140*	*0.863*	*0.914*	*0.035*	*0.866*
p-value joint significance Postnatal							*0.049*	*0.013*
AUC	0.629	0.705	0.594	0.683	0.629	0.705	0.697	0.722
p-value AUC					0.008	0.022		0.012
N	*1,428*	*1,336*	*1,428*	*1,336*	*1,428*	*1,336*	*1,267*	*1,267*

Notes: This table shows average marginal effects from probit models of the probability of having ADHD (a score greater than 5 on the Strength and Difficulties Questionnaire Hyperactivity scale) at 3 years on patterns of fetal growth starting the second trimester and birth outcomes. Models in (1a), (2a) and (3a) include binary indicators for white ethnicity, gender, being a first born and year and season of birth. Models in (1b), (2b), (3b), (4a) and (4b) include binary indicators for white ethnicity, male, and being a first born, and controls for year and season of birth, number of children and mother's age at birth, and the following controls measured at baseline (before conception): whether the mother has a degree-level education, belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), owns the house, is single, separated, divorced or widowed, whether she receives welfare benefits, is in fair, bad or very bad health, whether she has been under stress in the last four weeks, whether she was working last week, whether she is a current smoker, whether she drinks more than 4 units of alcohol per week, whether she does any strenuous exercise in the week, whether she does any moderate exercise in the week, whether the mother's partner belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled), whether the mother's father belongs to high social class (I: professional or II: management and technical), or to low social class (IIIM: skilled manual, IV: partly skilled or V: unskilled); continuous variables for mother's birth weight, pre-pregnancy weight, height, BMI, head circumference, leg length, waist circumference, skinfolds (sum of triceps, biceps, subscapular and suprailiac) and her daily energy intake (kilocalories), paternal height, weight and birth weight, grandmaternal and grandpaternal height and weight, and the Townsend Deprivation Index; missing values for social class of the mother, the mother's father and the mother's partner have been replaced with zeros and a binary indicator for missing is included; missing values for maternal birth weight and head circumference, for paternal height, weight and birth weight, for grandmaternal weight and grandpaternal height and weight are replaced with the sample means of the non-missing observations and binary indicators for missing are included. "Fetal Abdominal Circumference Slow Growth TR2-Birth" is a binary indicator which takes value 1 if the fetus is in the lower quartile of the Abdominal Circumference growth distribution both between weeks 19-34 and between week 34 and birth. "Fetal Femur Length Slow Growth TR2-Birth" is a binary indicator which takes value 1 if the fetus is in the lower quartile of the Femur Length growth distribution both between weeks 19-34 and between week 34 and birth. "Fetal Femur Length Accelerated Growth TR2-Birth" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the distribution of the difference between the Femur Length growth between week 34 and birth and between weeks 19-34. "Fetal Head Circumference Slow Growth TR2-Birth" is a binary indicator which takes value 1 if the fetus is in the lower quartile of the Head Circumference growth distribution both between weeks 19-34 and between week 34 and birth. "Fetal Head Circumference Fast Growth TR2-Birth" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the Head Circumference growth distribution both between weeks 19-34 and between week 34 and birth. "Fetal Head Circumference Accelerated Growth TR2-Birth" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the distribution of the difference between the Head Circumference growth between week 34 and birth and between weeks 19-34. "Fetal Asymmetric HC/AC Growth 19-34w" is a binary indicator which takes value 1 if the fetus is in the upper quartile of the distribution of the difference between the Head Circumference growth and the Abdominal Circumference growth between weeks 19 and 34. "Fetal Symmetric HC/FL Growth TR2-TR3" is a binary indicator which takes value 1 if the fetus is above the lower quartile and below the upper quartile of the distribution of the difference between the Head Circumference growth and the Femur Length growth between weeks 19 and 34. "Low Apgar 1 Minute" is a binary indicator which takes value 1 if the Apgar score is less than 8. Preterm is a binary indicator which takes value 1 if the gestational age at birth is less than 37 weeks. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Robust standard errors in parentheses. AUC=Area under the ROC curve. The standard errors are bootstrapped (1,000 replications). p=p-value for the Null Hypothesis that the models in (2a) and (3a), in (2b) and (3b), and in (4a) and (4b), respectively, have equal AUC values.