Pre-pregnancy BMI and Gestational Weight Gain: The relationship between maternal weight gain, birth outcomes and children's cognitive ability *

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March 25, 2014

Abstract

Important indicators of maternal health during pregnancy are pre-pregnancy weight and gestational weight gain. Both excessive and insufficient weight gain during pregnancy have been linked to adverse birth and cognitive outcomes for children. We use the National Longitudinal Survey of Youth mother/child data to examine the effect of maternal pre-pregnancy weight and gestational weight gain on several birth outcomes and measures of early childhood cognitive ability. Similar to previous literature, in OLS models we find that obese and underweight mothers experience adverse birth outcomes and their children score lower on tests of cognitive ability and have more behavior problems even after controlling for a rich array of covariates–the only exception is that obese mother are less likely to have a preterm birth or a low birth weight baby. However, controlling for unobservable maternal specific characteristics through the use of sibling comparisons renders nearly all of these associations insignificant. We do find that obesity still exerts a protective effect against having a low birth weight or preterm infant while inadequate weight gain during pregnancy leads to a higher likelihood of preterm birth and low birth weight. These findings indicate that maternal weight gain, while posing risks to the mother's health, may not be as dangerous to the infant as inadequate weight gain.

1 Introduction and Previous Literature

Obesity is fast becoming the most common complication of pregnancy in the United States (McDonald, 2010; Lu et al., 2001), and is estimated to affect nearly 40 percent of pregnant

*Preliminary and incomplete; please do not cite or quote. The authors are grateful to Cynthia Bansak for helpful comments on an earlier draft. All errors remain our own.

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women (Gueilinck et al., 2008). Medical professionals have long stressed the dangers of obesity and excessive weight gain during pregnancy and highlighted how they might affect the pregnancy and the health of the fetus. For example, overweight and obese expectant mothers experience higher rates of maternal mortality and gestational diabetes, the latter of which is associated with adverse outcomes for children at birth (e.g., Boney 2005; Whitaker 2004). An increasing awareness of these links has led to repeated updating of weight gain recommendations. As recently as 2009 the Institute of Medicine (IOM) issued revised guidelines for healthy pregnancy weight gain. There already exist large literatures on the direct effects of obesity on one's own health and on the health of a child and complications during pregnancy are associated with increased medical care costs (Huynh et al. 2013).

At the opposite end of the spectrum, there are also concerns about insufficient weight gain during pregnancy. Women who fall into the underweight category at the time of conception are advised to gain additional weight during pregnancy. These women experience higher rates of preterm birth and have lower birth weight babies (Ehrenberg, 2003). The purpose off this research is to examine how maternal pre-pregnancy BMI and gestational weight gain (GWG) affect both birth outcomes and early childhood cognitive ability controlling for characteristics of a mother that do not change over time.

1.1 The Fetal Origins Hypothesis

The idea that pregnancy is a critical time for children's development and that mother's decisions and environmental exposures during pregnancy can have profound effects on birth outcomes is omnipresent in the medical literature, and gaining traction in the economics literature. In the epidemiological literature, the fetal origins hypothesis posits that in utero nutrition can have profound and lasting impacts on adult health (Almond and Currie, 2011).

Our work draws on previous research indicating that maternal health and stress can to be passed from mother to child in utero (e.g. Catalano 2003; Lawlor et al. 2011; Almond and Currie 2011, Van Lieshout et al., 2013). Though our data do not allow us to explore the medical or physiological mechanisms, we link several birth outcomes and early childhood measures of cognitive ability to maternal pre-pregnancy BMI, and GWG. The advantage of our approach lies in our use of data that allows us to compare siblings so that we can control for genetic factors and other time-invariant, unobserved mother characteristics that may affect our outcomes. We discuss this in more detail below.

1.2 Maternal Pre-pregnancy BMI, GWG, and birth outcomes

The relationship between maternal obesity and birth weight is believed to be passed from mothers to children through high concentrations of glucose and fatty acids that pass through the placenta. Mothers with high pre-pregnancy BMI and those who gain excessive amounts of weight during pregnancy have more fat and thus deliver greater concentrations of glucose and fatty acids to the developing fetus (Catalano, 2003; Lawlor et al., 2011). The resulting increase in fetal insulin accelerates fetal growth and predisposes the child to weight gain later in life. This leads to both high birth weights and higher numbers of obese and overweight children (Lawlor et al., 2011).

A number of studies in the medical literature have established a correlation between mother's health and birth outcomes. Obese mothers have been shown to give birth to very large babies (Ehrenberg et al., 2004), which places both mother and baby at risk for birth trauma (Lu et al., 2001). They are also more likely to give birth by cesarean section (c-section) (Norh et al., 2008; Weiss et al., 2003). Gaining weight over and above the IOM recommendations has been additionally related to the same adverse outcomes, but most studies caution that the potential adverse high levels of gestational weight gain are conditional on the mother's pre-pregnancy weight (Nohr et al., 2008; Margerison-Zilko et al., 2010; Abrams et al., 2000). Some studies have also shown that obese women have a greater risk of preterm birth (McDonald et al., 2010).[1]

A shortcoming of many of the studies listed above is that they are mostly based on cross-sectional comparisons between individuals and thus cannot control for shared genetics between a mother and her baby. Even when longitudinal data is available (e.g. Margerison-Zilko et al., 2010; Tanda et al., 2013), it is not used in a way that makes a causal interpretation possible. It could be that a third factor, unobserved to the researcher, is causing both the maternal weight and the outcome of interest. One way of controlling for these shared maternal-child characteristics is to make within-family comparisons, because maternal characteristics such as genetic make-up and socioeconomic background are fixed and are therefore fully controlled for, regardless of whether they are measured or measurable.

We are aware of only two papers that make use of this method to examine maternal obesity and birth weight and none that examines the effect of maternal obesity on the probability of a c-section. Ludwig and Currie (2010) examine a sample of all births in Michigan and New Jersey over the time frame from 1989 to 2003 to examine the effect of maternal GWG on infant birth weight. They report that maternal weight gain during pregnancy increases birth weight independently of genetic factors. However, they do not have information on the mother's pre-pregnancy weight so are missing a key control we include. Lawlor et al., (2011) explore the effect of maternal weight gain on birth weight. Their across-sibling comparisons using a sample from Sweden reveal that women who gained weight in pregnancy have larger babies. However, they lack a good measure of maternal

[1] For the sake of brevity, we list here only a small sample of the studies. For a recent review of this literature see Yu et al., (2013).

weight gain (they do not have pre-pregnancy weight so they compare pre-delivery weight with the mother's weight at her first antenatal visit).

The birth outcomes of underweight women have received comparably little attention compared to those of obese and overweight mothers. Medical studies in this area such as Ehernberg et al. (2003) show that underweight mothers are at greater risk for perineal tears, preterm births and low birth weight babies, but have a lower risk for c-section. These medical studies do not use sibling comparisons so can be thought of only as indicative of a correlation.

However, several papers in the economics and epidemiological literature use the timing of Ramadan, the Dutch Hunger Winter, and influenza pandemics as natural experiments to causally identify the adverse effects of extreme undernutrition in pregnancy via fasting (Almond 2006; Almond and Muzumder 2011; Schulz, 2010; Stein et al., 1995; Prentice, 1983; Ravelli, 1976). Almond and Muzumder (2011) provide a summary of much of this research, demonstrating how fasting during pregnancy can lead to a variety of adverse outcomes including low birth weight.

1.3 Maternal Pre-pregnancy BMI, GWG and early childhood cognitive ability

A number of recent papers in the medical literature have focused on the effect of maternal pre-pregnancy BMI and/or GWG and measures of children's cognitive ability (Neggers et al., 2003; Hinkle et al., 2012; Hinkle et al., 2013; Tanda et al, 2013; Van Lieshout, 2013) and behavioral outcomes (Van Lieshout et al., 2013). These studies have all found that children born to mothers who were obese at the time of conception have lower scores on tests of cognitive ability and are more likely to have behavior problems even after adjusting for a wide array of covariates. Other studies find no effect of obesity in pregnancy on early childhood cognitive ability (e.g. Brion et al., 2011). Like most of the literature reviewed here, these medical studies do not compare siblings and some of the findings might be driven by genetic or other time-invariant maternal factors unobserved to the researcher.

A number of studies that have made use of the natural experiment afforded by the Dutch Hunger Winter have reported that the children of mothers with insufficient nutrition during pregnancy have lower cognitive ability, higher rates of obesity, and more behavioral problems (Schulz, 2010; Roseboom 2011). Almond, Muzumder and Ewjik (2001) use the plausibly exogenous timing of Ramadan to show that undernutrition leads to lower test scores.

We contribute to the literature linking pre-pregnancy BMI and GWG and children's outcomes in several important ways. Using a sample that spans the entire U.S., we examine a wide array of birth outcomes and several measures of early childhood cognitive ability. The sample we use contains a rich array of family background charcacteristics and measures of socioeconomic status as well as detailed information on each pregnancy. Key to our empirical method, we observe siblings born to the same mother allowing us to make within-family comparisons to control for unobservable factors such as genetics. By using maternal fixed effects we can come closer to a causal interpretation of the effect of maternal obesity on birth outcomes and early childhood cognitive ability. In the next section, we discuss our data and the specific outcomes that we study.

2 Data and outcomes

We use the National Longitudinal Survey of Youth 1979 (NLSY79) cohort for our analysis. The NLSY79 sampled 12,686 individuals between the ages of 14 and 21 in 1979 with annual interviews conducted until 1994 and subsequent interviews every other year up to the year 2010 (the most recent year available at the time of this paper). The respondents report data on their labor market experience, births, and marriages every survey round. Children who were born to women in the NLSY79 have been surveyed biannually since 1986. In addition, and crucial to this study, the NLSY collected information on the height and weight of respondents. Height was collected in 1985 and 2006, while weight is collected every round. As noted earlier, the most recent data available are from the 2010 survey, when the respondents were ages 45-53. Thus, for nearly all women in the sample, complete fertility histories are observed. In fact, 99.97 percent of births used in this study occur by 2000 and the most recent births we observe in our sample occurred in 2004. These data do not provide a nationally representative sample of children or young adults, although they are appropriately regarded as representative of the population of offspring born to U.S. women who were aged 14–22 in 1979 (Wu and Li, 2005).

In the first survey after a pregnancy, women were asked about the pregnancy, including their weight before and at delivery, birth weight of the child, mode of delivery and length of gestation. A drawback of these measures is that they are self-reported and thus subject to recall error. In addition, as they grow older, the children are issued a battery of test of cognitive ability and mother's assess their child's behavior. Combining data from the mother and child surveys together gives us a panel data set with multiple observed births for each mother, which is important for the estimation strategy described below.

Our key explanatory variable of interest is the mother's weight. We measure maternal weight in two different ways. We first examine pre-pregnancy BMI. Women in the NLSY were asked about their height in two time periods (1985, 2006) and their weight before and after each pregnancy. We use these self-reported heights and weights to create pre-pregnancy BMI and define three categories using the World Health Organization Cutoffs. Underweight corresponds to a BMI of less than or equal to 18.5, BMI in the recommended range is between 18.5 and 24.9, overweight women are those with a BMI ranging from 25 to 29.9 and obese women have a BMI greater than or equal to 30. The NLSY also asked women about their weight change during pregnancy and we use this information to determine if the mother gained an excessive amount of weight during pregnancy. To determine what constitutes excessive weight gain, we use guidelines for pregnancy weight gain based on a woman's pre-pregnancy BMI as determined by the IOM (2009). These guidelines state that women who begin pregnancy underweight (BMI $\leq$18.5) should gain no more than 40 lbs, those whose BMI is in the recommended range should gain no more than 35, those who are overweight, 30 and those who are obese at the time of conception should gain a maximum of 25 additional pounds while pregnant. A summary of these recommendations is in table 1. In what follows, we first describe the sample for the outcomes we observe at the birth of a child. We then turn our attention to describing the cognitive outcomes.

2.1 Outcomes observed at birth

In our first set of analyses, we examine a variety of outcomes that have been shown in the medical literature to be related to pre-pregnancy BMI and GWG. These include macrosomia which is defined as birth weight in excess of 9.92 pounds (Stotland, Caughey, Breed & Escobar, 2004; American College of Obstetricians and Gynecologists, 2000), large for gestational age (LGA), small for gestational age (SGA), whether the mother had a cesarean section, whether the baby was low birth weight (5.5 lbs at birth or less), and whether the baby was born prematurely (before 37 weeks). We calculate LGA and SGA using mother's self reports of child birth weight and gestational age combined with US national reference data, using separate cutoffs for boys and girls (cutofffs obtained from Oken et al., 2003). We also examine how many days the mother and the infant spent in the hospital following the birth, how many times the infant was taken to the doctor for an illness during the first year of life, whether the mother breastfed and, conditional on breastfeeding, how many weeks she breastfed the infant.

In this sample, each observation is at the year of the birth of a child. Thus, mothers may appear multiple times, once for each birth. We start with a sample of all women in the NLSY who report having given birth between 1979 and 2010 (N=9563). We exclude 1952 women with missing information on BMI or implausible BMI values (less than 15 or greater than 60). We also drop those observations with reported birth weight in excess of 13 lbs (4 dropped), or less than 32 ounces (22 dropped) and those with a gestational age greater than 44 weeks (75 dropped) as is common in this literature (e.g. Margerison-Zilko et al., 2010). We drop women who gave birth after the age of 40 (none of these 14 women were obese) and an additional three women who did not report marital status or education.[2] This leaves us with a final sample of 7496 births.[3] Of those, 1604 mothers have one birth in the sample, 1549 have two births in the sample, 612 have three births, 172 have four births, 32 have five births, 12 have 6 births and 3 have seven births.[4]

Table 2 presents descriptive statistics for the outcome variables and measures of weight for mothers for the full sample and also by the pre-pregnancy BMI of the mother. Overall, 22 percent of the births were via c-section [5], 9 percent were LGA, 17 percent were SGA, 2 percent were macrosomic, 9 percent were low birth weight and 12 percent were premature

[2] As is common is survey data, a significant number of women do not report their income. Rather than delete them, we measure income categorically including a category for missing. These categories are adjusted for inflation.

[3] At this point in our sample creation, we would have dropped women whose pregnancies resulted in multiple births since that is associated with weight gain and many of the outcomes we study. However, there were no women with multiple births in our sample once we had employed the other selectioon criteria.

[4] Although the NLSY does not ask directly about gestational diabetes, respondents are asked retrospectively if they have ever been diagnosed with diabetes. We match that with information on her child's year of birth and identified 46 women who were diagnosed with diabetes when they would have been pregnant. If we drop these women, as Ludwig and Currie (2010) do, the results we present below are virtually identical.

[5] Although this may seem lower than the natinal rate, recall that our data are observed from 1979 to 2004. Our annual c-section rates are similar to those in the U.S.

(i.e. born before 37 weeks). As expected, infants whose mothers were obese before pregnancy were more likely to be born via c-section, were more likely to be macrosomic or to be LGA, but less likely to be SGA, low birth weight or premature. Weeks of gestation did not vary systematically across pre-pregnancy BMI. Mothers who were obese pre-pregnancy weigh more at the delivery of their child but do not gain as much weight as do women in the other pre-pregnancy BMI categories, which is in line with the IOM guidelines discussed above. Over one third of the infants were born to mothers who gained weight in excess of the IOM guidelines and this percentage is well over half for those born to mothers who were overweight or obese during pregnancy. In contrast, mother's whose pre-pregnancy BMI was in the underweight category are more likely to have SGA or low birth weight infants and to deliver prematurely but they are less likely to have c-sections or LGA babies.

Infants born to women who are underweight pre-pregnancy spend over a day longer in the hospital at birth and are the least likey to be breastfed. Infants born to overweight and obese mothers pre-pregnancy experience more doctor visits (other than the standard well-baby check ups) in the first year of life. Breastfeeding initiation is highest among those whose pre-pregnancy weight is in the recommended category. Overall, about 70 percent of the mothers in our sample spend 3 or fewer days in the hospital after they give birth with a few (116) reporting that they did not even stay overnight with 97 percent of the sample spending less than a week in the hospital. Two-thirds of the infants spend 3 or fewer days in the hospital after birth, and 93 percent spend a week or less. Of those who breastfeed, 12 percent do so for a week or less, about 30 percent of the sample does so for four weeks or less, 55 percent do so for 12 weeks or less and 75 percent breastfeed for 28 weeks or less. Nearly 43 percent of the infants in our sample never see a doctor for an illness in the first year of life. Another 25 percent only have one illness related physician visit in the first year.

In table 3, we present the means of our control variables again for the whole sample and by the mother's pre-pregnancy BMI categories. There are some notable patterns across the pre-pregnancy BMI categories–as women get older and have more children they gain weight which is to be expected. Women are more likely to be underweight when they are younger, less educated and single. In addition, underweight women are less likely to take prenatal vitamins. We see little variation in gender of the child, month of first prenatal visit, alcohol or cigarette use in pregnancy or weeks of gestation across the pre-pregnancy BMI categories.

2.2 Cognitive and Behavioral Outcomes

We examine four measures of cognitive ability and one behavioral outcome. Recent research on human capital formation suggests that in addition to cognitive skills (as measured here by test scores), non-cognitive skills are important determinants of subsequent socioeconomic success (e.g. Heckman and Krueger, 2005). As a measure of a child's non-cognitive development, we use the Behavioral Problems Index (BPI) which measures the frequency, range and type of behavior problems of children aged four and over. The BPI is completed at each interview for children ages four to fourteen years of age and older and rates the child on the following six problem areas: antisocial, anxious-depressed, hyperactive, headstrong, dependent, and peer-conflicting behaviors which is then aggregated into an index.

The cognitive outcomes are captured by the child's standardized score on the Peabody Picture Vocabulary Test (PPVTZ), given at ages 3 to 5, and standardized scores on the Peabody Individual Assessment Tests of Mathematics (MATHZ), Reading Comprehension (COMPZ), and Reading Recognition (RECOGZ), which indicate academic achievement for children aged five and above. For each of these measures, we utilize the standardized score in order to account for differences in the test by year and age of child. In our models, we control for the age of the child at the assessment.

The PPVT consists of 175 vocabulary items of increasing difficulty and is considered to be important indicator of schooling outcomes (Baker et al., 1993). The PPVT was administered to children aged three and older in 1986, with additional assessments for previously untested age-eligible children in 1988, 1990, 1992,1994, and 1996. We limit our PPVT sample to those who took the test between the ages of 36 to 60 months because we have no information on school quality, which might be an important determinant of scores. Descriptive statistics for the PPVT sample, disaggregated by the mother's pre-pregnancy BMI, are shown in table 4. As in the at-birth outcome sample, we see some evidence that the children of mothers who are under- or overweight before pregnancy have slightly worse outcomes.

The PIAT reading recognition test consists of 100 items that measure the recognition of printed letters and the ability to read words aloud. The PIAT math test has 100 multiple choice items that test knowledge and application of math concepts and facts. The PIAT tests are given to children ages five and older each survey year, thus we have multiple scores for many of the children in the NLSY. For the PIAT math and reading tests, children were 9 years old on average when they took the tests, with ages ranging from 5 to 18 years old at the time of the test administration. Descriptive statistics for the PIAT reading recognition sample are in table 6 and table 5 has them for the PIAT math sample. Table 7 has descriptives for the reading comprehension sample, again by mother's pre-pregnancy BMI. Finally, descriptive statistics for the sample with measures of behavioral problems are given in table 8. Once again, these descriptive statistics indicate that the children of mothers who are under- or overweight before pregnancy have worse outcomes.

3 Methods: At birth outcomes

Using the sample of mothers with singleton births over the period 1979-2004, we test whether obesity and gestational weight gain are correlated with adverse birth outcomes using a basic OLS regression. This methodology follows the literature very closely.[6] The OLS specification is as follows:

$$y_{im} = \alpha + O_{im}\beta + X_{im}\phi + Z_m\xi + T_i\theta + \epsilon_{im} \tag{3.1}$$

where y is the ith birth outcome for mth mother. O is a vector representing the mother's weight (in some specifications this is an indicator of her pre-pregnancy BMI status and GWG, in another specification it is an indicator or if her GWG was in excess of or below the IOM guidelines for her pre-pregnancy weight). The primary coefficient of interest is the vector β. X_{im} is a vector of variables specific to each birth as shown in table 3 (e.g. mother's education, marital status, mother's age at the birth, parity, whether she smoked, used alcohol or took prenatal vitamins during the pregnancy and the month of her first prenatal visit). The vector Z includes mother's characteristic that do not vary with each child which for our sample are mother's race and her age at her first birth. T_i is a linear time trend. In the specification for c-section we also control for whether the mother had previously had a c-section and in the c-section and number of days that the infant was in the hospital models we also control for gestational age.

3.1 Maternal Fixed Effects

Genetics and other time-invariant characteristics of the mother may affect our outcomes of interest. These characteristics might include chronic health conditions, health habits, or environmental exposure. For this reason, our preferred specification includes mother fixed

[6] Some studies make use of logistic regression. When we do that, our results are not qualitatively different than what we present here.

effects. These specifications allow us to compare births across mothers and are identified off of mothers whose weight status changes over time. The specification is as listed in 3.1 but with mother fixed effects (γ_m) as follows:

$$y_{im} = \alpha + O_{im}\beta + X_{im}\phi + \gamma_m + T_i\theta + \epsilon_{im} \tag{3.2}$$

Note that the Z_m vector drops out from this specification because these characteristic do not vary across children. This specification only includes those mothers who had more than one child in the sample (N=5892) and then is identified off of only those discordant siblings (i.e. siblings whose mother changed pre-pregnancy BMI categories, which in our sample is 2166 children).

4 Results: At Birth Outcomes

Tables 9 and 10 presents the results of regressions of each of our outcomes on mother's weight gain during pregnancy. The variables of interest are either her pre-pregnancy BMI (top panel) and/or whether the mother's weight gain was in excess of the IOM guidelines (bottom panel). These unadjusted regressions (top panel) reveal that infants born to women who were obese before pregnancy were 1.4 percentage points more likely to be macrosomic, and controlling for pre-pregnancy BMI, each additional pound gained by the mother during pregnancy increased the probability of macrosomia by 0.1 percentage points.[7]

Babies born to mothers who are underweight just prior to pregnancy are 5.3 percentage points more likely to be of low birth weight but each additional pound gained in pregnancy reduces that by 0.2 percentage points. In contrast, having an overweight or obese mother has a protective effect on the probability of low birth weight. Babies born to women who are

[7] We do not report the coefficients on control variables here in the interest of brevity. Appendix I provides an almost complete set of covariates as included in Tables 9 and 10.

underweight are 2.9 percentage points more likely to be born early, but there is no significant effect of overweight or obesity on the probability of an early birth. Each additional pound of weight gained, conditional on pre-pregnancy BMI, reduces the probability of an early birth by 0.2 percentage points.

These unconditional results on underweight women and women who gain less than recommended underscore the importance of healthy body weight before becoming pregnant. Women who are underweight when they begin a pregnancy are 6.2 percentage points less likely to have a c-section, but each additional pound they gain in pregnancy increases that probability by 0.3 percentage points. Women who are overweight or obese when they begin a pregnancy are 7.2 (15.6%) percentage points more likely to have a c-section and each additional pound they gain increases that probability by 0.3 ppt. Babies born to underweight women are significantly less likely to be LGA but those born to overweight and obese mothers are 2.7 and 7.6 percentage points more likely to be LGA, respectively. Each additional pound of weight gained during pregnancy, controlling for pre-pregnancy BMI increases the probability of LGA by 0.2 percentage points.

In the lower panel of tables 9 and 10 we combine the information on pregnancy weight gain and pre-pregnancy BMI and control for these with two additional dummy variables. One variable is equal to 1 if maternal weight gain exceeded the IOM guidelines, conditional on pre-pregnancy weight, and the second is equal to 1 if her weight gain was below the guidelines. Here we see that babies born to women who gained in excess of the IOM guidelines are 1.3 percentage points more likely to be macrosomic (which corresponds to a 65 percent increase—1.3/2.00), 1.6 percentage points to be born via c-section and 5.4 percentage points to be LGA. These coefficients are statistically significant. On the other hand, as has been found by other researchers, gaining excess weight in pregnancy significantly reduces the probability of being born preterm (2 percentage points) or being SGA (3.9 percentage points). We find no significant effect of excess weight gain on the probability of being born before low birth weight.

In table 11 and 12, we add the set of control variables shown in table 3 to the models shown in tables 9 and 10. These controls are standard in the literature (see Yu et al., 2013 for a full review) and though we suppress the constants here in the interest of space, the controls (and their means) are shown in table 3 and full specifications are available in Appendix 1. We find that the addition of this relatively rich set of covariates does not qualitatively change our results. The addition of controls changes the point estimates of the effects mentioned above slightly, but not in a statistically significant way.

In tables 14 and 15, we use the same set of covariates but we now take advantage of the longitudinal nature of our data by controlling for maternal fixed effects. These maternal fixed effects rely on within-family variation and capture genetic influences as well as other time-invariant factors we cannot control for in our model as discussed above. Adding these maternal fixed effects attenuates the effects of excessive maternal weight gain on all of our outcomes and the effect of excessive weight gain is no longer significant in the macrosomia, c-section and early birth models. In one specification, mothers who gain weight in excess of the IOM recommendations are 2.17 percentage points more likely to be born LGA, but it is only significant at 10%. The only effect that remain significant at 5% when examining the effects of obesity and excessive weight gain controlling for mother fixed effects are the protective effects of additional weight gain against SGA. Other effects, such as early birth–both as a dummy for preterm birth and increased gestation length–are significant at 90%.[8]

[8]The fixed effect sample here is smaller than the OLS sample. We also performed the OLS specification with the smaller sample. The results are not discussed at length here, but are similar in patterns and significance to the full OLS sample. A sample of OLS results with the fixed effect sample and almost full set of covariate coefficient estimates is presented in Appendix II.

The adverse effects of too little weight gain, however, remain. Examining a wide range of outcomes for mothers who begin their pregnancies in the underweight category or gain less weight than recommended reveals a host of undesirable outcomes that are more likely to occur. Women who gain too little weight during pregnancy experience shorter gestation lengths, are 6.4 percentage points more likely to give birth to low birth weight babies, and the children spend on average 1.8 days more in the hospital following delivery. Women who are underweight before becoming pregnant have much shorter pregnancies when examining outcomes via our within-mother identification strategy.

We also report other outcomes such as number of doctor's visits in the first year of life, which may be an important indicator of child's health, as well as breastfeeding initiation and duration, and the number of days both the mother and child stayed in the hospital following delivery. In most of these situations, even large effects estimated using OLS disappear for adverse outcomes associated with obesity and excess weight gain when controlling for time-invariant mother characteristics. The one exception is women who gain an excessive amount of weight. They are 3.9 percentage points more likely to initiate breastfeeding.

5 Methods: Cognitive and Behavioral outcomes

In order to examine the relationship between our maternal variables of interest and later childhood outcomes, we also estimate models with behavioral and cognitive outcomes as described in section 2.2 as the dependent variables. These include three different Peabody Individual Assessment Tests (PIAT) tests (Math, Reading Recognition and Reading Comprehension), the Peabody Picture Vocabulary Test (PPVT) and the Behavioral Problems Index

(BPI). For these outcomes, children are assessed multiple times, adding a time dimension to our model. The OLS specification is as follows for these outcomes:[9]

$$y_{imt} = \alpha + O_{im}\beta + X_{imt}\phi + Z_m\xi + \tau_t + \epsilon_{imt} \tag{5.1}$$

where y is now the ith child's (child of the mth mother) score on the cognitive outcome in year t. The variable of interest, mother's weight status or weight gain, O, remains as defined in 3.1. τ_t is a vector of year fixed-effects. In many cases, we observe multiple children from the same mother in multiple instances. Despite this additional variation, we still rely upon mother fixed-effects to identify our model because our key variables of interest, mother's pre-pregnancy obesity and GWG, do not vary over the child's life, precluding a child-level fixed-effects model.[10] The vector X now includes some additional controls including child birth weight.

In the previous section, we used breastfeeding and low birth weight as outcomes, but in the models of cognitive ability, we now use them as controls and in these specifications we ignore the endogenous nature of these variables. We include them only to attempt to isolate the effect of mother's pre-pregnancy BMI and GWG on our outcomes of interest. There are several studies that attempt to identify the effect of breastfeeding initiation and duration and low birth weight on early childhood cognition and behavioral problems as well as later life outcomes. Rees and Sabia (2009) use a similar methodology to ours using sibling pairs to show that children who are breastfed spend more years in school and earn higher incomes than children who are not breastfed. In contrast, other work using a similar methodology shows

[9]Specifications with the standardized PPVT score (PPVTZ) as the outcome are estimated with equations 3.1 and 3.2 as described above because we observe one PPVT score for each child. This is because we limit the PPVT sample to only the first time the child took this test if taken before they entered school.

[10]When using these data some researchers have used a GMM estimator that allow for both mother and individual fixed-effects, see James-Burdumy (2005) for further discussion.

these links to be tenuous. Specifically, Colen and Ramey (2014) show that breastfeeding has no effect on early childhood health measures, except for perhaps asthma and Rothstein (2013) reaches a similar conclusion when she compares siblings. Belfield and Kelly (2012) show that extended breastfeeding has a protective effect against obesity and increases cognitive skills. Moreover, these investments in children's health tend to be correlated with socioeconomic status (Tanda, et al., 2014). Mothers who breastfeed longer tend to be more educated and earn higher wages (Ryan, Zhou & Gaston 2004).

Low birth weight has also been linked to lower cognitive ability in children and adverse economic outcomes in adults (Conley & Bennett, 2001; Currie & Almond, 2011; Cheadle & Goosby, 2010). There is also evidence that birth weight has a U-shaped relationship with cognitive ability, so that both high and low birth weight lead to lower standardized test scores (Cesur & Kelly, 2010; Kirkegaard, 2006). Thus our models of cognitive ability also include controls for infant birth weight[11]

5.1 Maternal Fixed Effects

The endogenous nature of investments in children and investments in own health pose a significant estimation problem for this type of analysis. Observable and unobservable investments in children and children's health likely have profound consequences for the outcomes we hope to observe later in life. Maternal pre-pregnancy weight and GWG may affect a child's cognitive ability through other channels in addition to the fetal origins hypothesis discussed earlier. First, maternal obesity may lead to child obesity, which in turn has been shown to have adverse effects on a child's cognitive ability. Second, maternal obesity may be correlated with decreased prenatal investments. Finally, maternal obesity at birth may

[11] In future iterations, we plan to limit our sample to infants born full term who are not low or high birthweight as other researchers have done e.g. Tanda et al., 2013

be correlated with other investments in the child during the first few years of life. To control for unobserved or unobservable investments, we also include mother fixed-effects. The specification is as listed in 5.1 but with mother fixed effects (γ_m) as follows:

$$y_{imt} = \alpha + O_{imt}\beta + X_{imt}\phi + \gamma_m + \tau_t + \epsilon_{imt} \tag{5.2}$$

6 Results: Cognitive and Behavioral outcomes

Tables 13 and 16 shows estimates for the equations 5.1 and 5.2, respectively, on the cognitive and behavioral problems as outcomes. The controls included in the OLS model (5.1) include year fixed effects and a number of controls for maternal and child characteristics as listed in table 3.

These models, estimated with the standardized test score for each child, indicated lower average cognitive ability for children of overweight and obese mothers, with slightly larger point differentials for obese mothers than overweight mothers. Children whose mothers who were overweight before pregnancy post on average 3.36 points lower PPVT scores, 1 point lower PIAT Math scores, 0.93 point lower PIAT Reading Recognition scores, and 0.75 point lower PIAT Reading Comprehension scores, though reading recognition and comprehension scores are only significant at 95%. Differences in behavioral problems index scores are 13.88 for . Children of obese mothers post significantly different scores on all cognitive and behavioral measures. 3.39 points lower PPVT socres, 2.17 points lower PIAT Math, 2.47 points lower PIAT Reading Recognition, 1.93 points lower PIAT reading comprehension. Children of mothers who were obese before becoming pregnany have BPI scores that are 31 points higher, though this association is only significant at 95% while the cognitive scores are significant at 99%.

Children of underweight mothers, in contrast, do not perform significantly worse than children of normal weight mothers on cognitive tests. They do report more behavioral problems as evidenced by the more than 20.56 point higher average BPI score.

There are fewer significant estimated coefficients for these models with regards to weight gain conditional on pre-pregnancy status. Women who gain more weight than recommended by the IOM also have children with worse average test scores on the PIAT Math (by less than 0.81 standardized points) and on the PIAT Reading Recognition test, by 0.74 points. Differences in PIAT Reading Comprehension and behavioral problems index scores are in expected direction, 0.56 points lower and 11.33 points higher, respectively, but are only marginally significant. Women who gain too little weight during pregnancy have children post slightly lower (0.598 points) lower PIAT Math scores, but this effect is only significant at 90%.

Controlling for time-invariant mother characteristics through the use of mother fixed effects, the correlations discussed above all disappear. In only the case of the PIAT Math reading score do children of mothers who are obese and mothers who gained weight in excess of the recommendation post different scores than children of mothers whose weight gain was in the normal range. One extra pound of weight gain translates to 0.03 points higher average PIAT Math scores. The effect of excess weight gain is protective and marginally significant ($p < 0.1$). The effects on pre-pregnancy obesity in the first specifiation (top panel of table 16) and excess weight gain in the second specification (bottome panel of 16) switch signs from the OLS specifications (top and bottom panel of **??**, respectively). This sign change may be due to some compensating behavior by mothers who are aware of low test scores and work with their children to improve performance, highlighting the endogenous nature of later life outcomes. It may also be an anomaly of the fixed effect sample.

7 Discussion and Conclusion

There is a wide range of evidence showing that maternal pre-pregnancy weight BMI and gestational weight gain are associated with adverse birth outcomes and lower scores on tests of cognitive ability. However, almost all of these studies rely on individual comparisons and thus cannot be viewed as causal. Here, we examine whether these correlations stand up to an identification strategy that depends on within-mother variation. We extend the literature by focusing on a national sample of births and consider a wide array of outcomes including birth weight, gestational age, probability of a c-section, whether the mother breastfed, length of breastfeeding, how long mother and infant spent in the hospital in the post-natal period and how often the infant was taken to the doctor for illnesses in the first year of life. We also extend our analysis to examine outcomes beyond the birth including early childhood cognitive and behavioral outcomes.

When focusing on a cross section of births, we find, as have others, that maternal weight gain exceeding the IOM guidelines leads to adverse birth outcomes and lower scores on tests of cognitive ability as well are a higher incidence of behavior problems. The notable exception is that women who gain too much weight are less likely to have preterm or low birth weight infants. However, we find that the addition of mother fixed effects to our specifications attenuates the role of excessive weight gain in pregnancy for most of our outcomes. Maternal obesity is still associated with babies being born in the range of too large for gestational age, but the effects are insignificant for the other outcomes we consider including our cognitive outcomes (with the exception of math scores).

In contrast, for women who do not gain enough weight in pregnancy or start pregnancy underweight we see a similar in that the OLS results show are significant and show that underweight mothers are at a higher risk for adverse birth outcomes. Our mother FE specifications indicate that at least some of these persist and are likely caused by insufficient weight gain. However, we find no effect of insufficient GWG or pre-pregnancy underweight on cognitive outcomes in either our OLS or FE specifications although our OLS models indicate that children born to underweight women have more behavioral problems, this effect disappears in our FE specification.

These results suggest that other time-invariant mother-specific characteristics, such as exercise habits and healthy eating, may be just as or more important than weight or BMI itself for determining healthy pregnancy outcomes. We cannot control for unobservable, time-variant mother-specific characteristics. For instance, if mothers who changed weight categories from one pregnancy to the next were aware of the dangers associated with weight gain and engaged in compensatory behavior to counteract the potential adverse effects of their pre-pregnancy weight status. For instance, the stress brought on by the Super Bowl has been linked to low birth weight. (Dahl et al., 2012). We cannot observe or control for these behaviors and shocks, so if they are systematic, they may bias our fixed effect results toward zero.

Our results have implications for the costs of births in the U.S. which have been estimated to be among the highest in the world (Rosenthal, 2013). In the medical community there is agreement that there are too many c-sections in the U.S., with the rate currently about 33 percent. Our results indicate that reducing maternal obesity rates will not necessarily reduce that rate.

There is some indication that encouraging more weight gain in underweight mothers may have a protective effect against low birth weight. When examining underweight mothers, gestational weight gain counteracted some of the adverse effects of starting a pregnancy at low weight. Unlike the adverse effects associated with obesity and high weight gain, the adverse effects associated with underweight status and lower than recommended weight gain persisted using our fixed effect strategy. Underweight mothers and those who gain less than the recommended amount are more likely to give birth to low birth weight babies, to give birth preterm, and to have their children spend a longer time in the hospital following delivery.

A study of births in 2001 found that the average cost of a hospital stay for a low birth weight baby exceeded $15,000, for a total of $5.8 billion (Russell et al. 2007). These costs reflect almost 47% of the costs of all infant hospitalizations, highlighting the potentially substantial cost savings that could result from a reduction in low birth weight babies.

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8 Tables

	Total Weight Gain		
Pre-pregnancy status	BMI	Range in kg	Range in lbs
Underweight	$> 18.5 kg/m^2$	12.5–18	28–40
Normal weight	$18.5\text{–}24.9 kg/m^2$	11.5–16	25–35
Overweight	$25.0\text{–}29.9 kg/m^2$	7–11.5	15–25
Obese	$\geq 30.0 kg/m^2$	5–9	11–20

Table 1: Recommended healthy weight gain by pre-pregnancy BMI as prescribed by the Institute of Medicine and National Research Council (2009)

		Pre-pregnancy BMI			
Variable	All Women	<18.5	18.5-24.9	25.0-29.9	≥30
LGA	0.09	0.04	0.08	0.10	0.14
SGA	0.17	0.24	0.17	0.14	0.12
Macrosomic	0.02	0.01	0.02	0.02	0.03
C-section	0.22	0.15	0.21	0.27	0.34
Low birth weight	0.09	0.14	0.08	0.07	0.07
Premature	0.12	0.18	0.12	0.11	0.11
Wks gestation	38.62	38.20	38.65	38.66	38.75
	(2.13)	(2.43)	(2.11)	(2.05)	(1.99)
Num. Dr. visits year 1	1.76	1.68	1.71	1.89	1.99
	(3.77)	(3.77)	(3.47)	(4.70)	(3.96)
Num. days mom hosp.	3.45	3.65	3.41	3.44	3.51
	(3.70)	(4.06)	(3.77)	(3.51)	(2.96)
Breastfed	0.47	0.42	0.49	0.44	0.43
Wks breastfed	18.84	19.12	19.10	18.41	16.99
	(21.13)	(21.59)	(21.12)	(21.51)	(19.79)
Num. days baby hosp.	4.46	5.72	4.37	4.14	4.35
	(8.75)	(17.73)	(7.50)	(5.83)	(6.63)
Mom's delivery wt. (lbs)	166.16	137.20	158.22	186.01	223.26
	(30.84)	(17.72)	(20.34)	(23.21)	(37.37)
Mom wt. gain (GWG)	31.60	32.61	32.35	30.48	26.65
	(14.30)	(14.55)	(13.71)	(14.78)	(16.51)
Mom BMI prepreg.	23.06	17.52	21.46	26.91	34.47
	(4.62)	(0.73)	(1.70)	(1.41)	(4.46)
Weight gain >IOM	0.39	0.23	0.35	0.58	0.56
	(0.49)	(0.42)	(0.48)	(0.49)	(0.50)
Weight gain <IOM	0.25	0.39	0.28	0.11	0.17
	(0.44)	(0.49)	(0.45)	(0.31)	(0.37)
Observations	7496	697	4937	1261	601

Standard errors for continuous variables in parentheses

Table 2: Sample outcome means and proportions by pre-pregnancy BMI for at-birth outcomes sample.

Variable	All Women	Pre-pregnancy BMI <18.5	18.5-24.9	25.0-29.9	>30
Not black/hispanic	0.54	0.59	0.57	0.46	0.48
Hispanic	0.19	0.17	0.18	0.23	0.16
Black	0.27	0.25	0.25	0.31	0.36
Child is male	0.51	0.52	0.51	0.52	0.49
Mom's age at first birth	21.95	20.53	21.98	22.24	22.72
	(4.58)	(3.88)	(4.59)	(4.56)	(4.90)
Mom's age at birth of child	25.08	22.99	24.91	26.00	27.04
	(4.76)	(4.48)	(4.71)	(4.59)	(4.71)
Birth order	1.94	1.78	1.89	2.11	2.18
	(1.07)	(1.01)	(1.04)	(1.17)	(1.14)
Mom's yrs of education	12.27	11.60	12.35	12.31	12.25
	(2.37)	(2.23)	(2.38)	(2.41)	(2.18)
Mother is married	0.67	0.57	0.67	0.70	0.65
Mother is sep./div./wid.	0.08	0.10	0.07	0.08	0.09
Income missing	0.10	0.13	0.11	0.07	0.05
Low Income	0.24	0.34	0.23	0.25	0.24
Middle Income	0.28	0.27	0.27	0.30	0.35
Urban residence	0.74	0.72	0.74	0.74	0.74
Urban residence unknown	0.06	0.07	0.06	0.06	0.02
Month of first prenatal visit	2.58	2.62	2.57	2.57	2.62
	(1.63)	(1.56)	(1.60)	(1.71)	(1.74)
Unknown month of	0.03	0.04	0.03	0.03	0.03
first prenatal visit	(0.18)	(0.19)	(0.18)	(0.16)	(0.17)
Took prenatal vitamins	0.90	0.88	0.90	0.90	0.91
Used alc. in preg. <1 per month	0.23	0.23	0.25	0.21	0.19
Used alc. monthly during preg.	0.04	0.04	0.04	0.04	0.03
Used alc. weekly during preg.	0.04	0.04	0.05	0.03	0.04
No smoking during pregnancy	0.997	0.996	0.997	0.998	1.000
	(0.05)	(0.07)	(0.06)	(0.04)	0.00
Had a previous c-section	0.14	0.10	0.13	0.16	0.18
Weeks of gestation	38.62	38.20	38.65	38.66	38.75
	(2.13)	(2.43)	(2.11)	(2.05)	(1.99)
Child birth year	1986.14	1984.31	1985.89	1987.05	1988.37
	(4.70)	(4.16)	(4.61)	(4.77)	(4.76)
Observations	7496	697	4937	1261	601

Standard errors for continuous variables in parentheses

Table 3: Sample means and proportions by pre-pregnancy BMI for control variables for at-birth outcomes sample.

		Pre-pregnancy BMI			
Variable	All Women	<18.5	18.5-24.9	25.0-29.9	>30
PPVTZ	87.44	87.48	89.16	83.49	83.23
	(20.69)	(19.12)	(20.07)	(22.25)	(21.50)
Mom is Hispanic	0.19	0.17	0.19	0.23	0.17
Mom is Black	0.27	0.22	0.26	0.32	0.36
Child is male	0.51	0.51	0.50	0.51	0.50
age, first birth	22.33	21.09	22.28	22.63	23.18
	(4.63)	(3.95)	(4.58)	(4.58)	(5.33)
age, birth of this child	25.72	23.78	25.43	26.58	27.75
	(4.65)	(4.39)	(4.52)	(4.57)	(4.90)
Birth order	2.00	1.84	1.94	2.15	2.20
	(1.10)	(1.06)	(1.05)	(1.22)	(1.12)
mom breastfed	0.49	0.43	0.52	0.45	0.45
Weeks breastfed	9.41	8.17	9.97	8.74	8.01
	(17.70)	(17.37)	(17.78)	(18.23)	(16.30)
preterm	0.12	0.17	0.12	0.11	0.11
low birth weight	0.08	0.12	0.08	0.06	0.06
macrosomic	0.02	0.02	0.02	0.02	0.03
yrs of education	12.63	12.20	12.69	12.68	12.52
	(2.26)	(2.01)	(2.28)	(2.31)	(2.15)
married	0.67	0.57	0.69	0.69	0.65
sep., div. or wid.	0.17	0.21	0.16	0.15	0.17
Low Income	0.25	0.35	0.24	0.24	0.25
Middle Income	0.29	0.25	0.28	0.31	0.33
Lives in urban area	0.75	0.71	0.75	0.78	0.74
Month of first prenatal visit	2.60	2.61	2.61	2.50	2.63
	(1.65)	(1.57)	(1.64)	(1.65)	(1.77)
prenatal vitamins	0.94	0.95	0.94	0.94	0.91
used alc. in preg. <1 per month	0.24	0.26	0.25	0.22	0.20
used alc. monthly during preg.	0.04	0.04	0.04	0.04	0.04
used alc. weekly during preg.	0.04	0.03	0.05	0.03	0.05
no cigarettes while preg.	1.00	1.00	1.00	1.00	1.00
age at assesssment	49.46	49.53	49.30	49.53	50.31
	(6.98)	(7.32)	(6.93)	(6.93)	(7.11)
Observations	4520.00	380.00	2898.00	808.00	434.00

Standard errors for continuous variables in parentheses

Table 4: PPVT. Sample means and proportions by pre-pregnancy BMI for PPVT outcomes and control variables.

Variable	All Children	Pre-pregnancy BMI <18.5	18.5-24.9	25.0-29.9	>30
PIAT Math	100.12	99.03	100.68	99.37	98.55
	(14.05)	(13.04)	(14.10)	(14.20)	(14.24)
Mom is Hispanic	0.20	0.17	0.19	0.23	0.17
Mom is Black	0.32	0.31	0.30	0.34	0.40
Child is male	0.50	0.54	0.50	0.51	0.49
Mom's age at first birth	21.51	20.01	21.45	21.98	22.65
	(4.66)	(3.95)	(4.66)	(4.65)	(4.96)
Mom's age at birth of this child	24.40	22.08	24.07	25.65	26.94
	(5.14)	(4.72)	(5.06)	(4.99)	(4.89)
Birth order of child	1.88	1.67	1.81	2.08	2.17
	(1.06)	(0.97)	(1.02)	(1.14)	(1.16)
breastfeeding initiated	0.43	0.38	0.45	0.41	0.41
weeks breasfted	8.29	7.30	8.71	7.73	7.26
	(17.08)	(16.31)	(17.21)	(17.45)	(16.03)
preterm	0.12	0.17	0.11	0.11	0.10
low birth weight	0.08	0.13	0.08	0.07	0.06
macro	0.02	0.02	0.02	0.02	0.02
Mom's yrs of education	12.60	12.12	12.65	12.64	12.64
	(2.36)	(2.30)	(2.34)	(2.50)	(2.25)
Mother is married	0.62	0.59	0.62	0.64	0.59
Mother is sep., div. or wid.	0.23	0.24	0.24	0.22	0.25
Low Income	0.25	0.29	0.25	0.25	0.27
Middle Income	0.27	0.29	0.27	0.28	0.29
Lives in urban area	0.74	0.76	0.74	0.74	0.70
Month of first prenatal visit	2.62	2.55	2.63	2.57	2.72
	(1.63)	(1.46)	(1.61)	(1.70)	(1.83)
Took prenatal vitamins	0.84	0.79	0.84	0.87	0.89
used alc. in preg. <1 per month	0.23	0.24	0.24	0.20	0.19
used alc. monthly during preg.	0.04	0.04	0.04	0.04	0.04
used alc. weekly during preg.	0.04	0.04	0.05	0.03	0.04
no smoking in pregnancy	0.997	0.999	0.996	0.997	0.999
Child's age at assessment	115.56	118.38	115.97	114.11	112.16
	(33.70)	(34.65)	(33.81)	(33.06)	(32.66)
Observations	27795	2625	18007	4881	2282

Standard errors for continuous variables in parentheses

Table 5: PIAT Math. Sample means and proportions by pre-pregnancy BMI for PIAT Math outcomes and control variables.

Variable	All Children	Pre-pregnancy BMI <18.5	18.5-24.9	25.0-29.9	>30
PIAT reading recognition	103.76	102.56	104.33	103.18	101.89
	(14.84)	(14.43)	(14.74)	(15.07)	(15.29)
Mom is Hispanic	0.20	0.17	0.20	0.23	0.17
Mom is Black	0.32	0.31	0.30	0.34	0.40
Child is male	0.50	0.54	0.50	0.51	0.49
Mom's age at first birth	21.51	20.02	21.45	22.01	22.68
	(4.67)	(3.95)	(4.67)	(4.66)	(4.98)
Mom's age at birth of this child	24.40	22.09	24.07	25.67	26.97
	(5.15)	(4.72)	(5.07)	(5.00)	(4.89)
Birth order of child	1.87	1.67	1.81	2.08	2.17
	(1.06)	(0.97)	(1.02)	(1.14)	(1.17)
breastfeeding intiated	0.43	0.38	0.45	0.41	0.41
weeks breastfed	8.31	7.30	8.74	7.74	7.24
	(17.11)	(16.31)	(17.22)	(17.54)	(16.04)
preterm	0.12	0.17	0.11	0.11	0.10
low birth weight	0.08	0.13	0.08	0.07	0.06
macro	0.02	0.02	0.02	0.02	0.02
Mom's yrs of education	12.60	12.12	12.65	12.65	12.65
	(2.36)	(2.30)	(2.34)	(2.49)	(2.25)
Mother is married	0.62	0.59	0.63	0.64	0.59
Mother is sep., div. or wid.	0.23	0.24	0.24	0.22	0.25
Low Income	0.25	0.28	0.25	0.25	0.27
	(0.44)	(0.45)	(0.43)	(0.43)	(0.44)
Middle Income	0.27	0.28	0.26	0.28	0.29
	(0.44)	(0.45)	(0.44)	(0.45)	(0.45)
Lives in urban area	0.74	0.76	0.74	0.74	0.70
Month of first prenatal visit	2.62	2.55	2.63	2.57	2.71
	(1.63)	(1.46)	(1.61)	(1.70)	(1.84)
Took prenatal vitamins	0.84	0.79	0.84	0.87	0.89
	(0.36)	(0.41)	(0.37)	(0.34)	(0.32)
used alc. in preg. ¡1 per month	0.23	0.24	0.24	0.21	0.19
	(0.42)	(0.43)	(0.43)	(0.40)	(0.39)
used alc. monthly during preg.	0.04	0.04	0.04	0.04	0.03
	(0.20)	(0.20)	(0.20)	(0.20)	(0.18)
used alc. weekly during preg.	0.04	0.04	0.05	0.03	0.04
	(0.21)	(0.18)	(0.22)	(0.17)	(0.20)
did not smoke while pregnant	0.997	0.999	0.996	0.997	0.999
Child's age at assessment	115.75	118.42	116.14	114.37	112.49
	(33.65)	(34.70)	(33.76)	(32.99)	(32.62)
Observations	27682	2618	17945	4849	2270

Standard errors for continuous variables in parentheses

Table 6: PIAT Reading Recognition. Sample means and proportions by pre-pregnancy BMI for PIAT Reading Recognition outcomes and control variables.

		Pre-pregnancy BMI			
Variable	All Children	<18.5	18.5-24.9	25.0-29.9	>30
PIAT reading comprehension	101.11	100.54	101.61	100.36	99.30
	(14.01)	(13.83)	(13.93)	(14.12)	(14.38)
Mom is Hispanic	0.19	0.16	0.19	0.22	0.17
Mom is Black	0.32	0.33	0.31	0.35	0.39
Child is male	0.50	0.53	0.49	0.50	0.47
Mom's age at first birth	21.45	19.83	21.38	21.98	22.84
	(4.78)	(3.98)	(4.78)	(4.75)	(5.10)
Mom's age at birth of this child	24.22	21.75	23.87	25.61	27.14
	(5.36)	(4.85)	(5.28)	(5.19)	(4.99)
Birth order of child	1.84	1.63	1.77	2.05	2.15
	(1.04)	(0.96)	(1.00)	(1.12)	(1.15)
breastfeeding intiated	0.43	0.36	0.44	0.41	0.41
weeks breastfed	8.27	6.95	8.69	7.67	7.72
	(17.11)	(15.33)	(17.31)	(17.41)	(16.76)
preterm birth	0.12	0.17	0.11	0.11	0.10
low birth weight	0.08	0.13	0.08	0.07	0.05
macro	0.02	0.02	0.01	0.03	0.02
Mom's yrs of education	12.62	12.09	12.66	12.68	12.75
	(2.38)	(2.32)	(2.35)	(2.50)	(2.26)
Mother is married	0.62	0.60	0.62	0.63	0.59
Mother is sep., div. or wid.	0.24	0.24	0.24	0.22	0.25
Low Income	0.25	0.28	0.25	0.24	0.26
Middle Income	0.27	0.29	0.26	0.28	0.27
Lives in urban area	0.73	0.76	0.73	0.73	0.69
Month of first prenatal visit	2.62	2.55	2.64	2.54	2.71
	(1.61)	(1.45)	(1.60)	(1.65)	(1.86)
Took prenatal vitamins	0.82	0.76	0.82	0.85	0.88
used alc. in preg. <1 per month	0.23	0.23	0.24	0.21	0.19
used alc. monthly during preg.	0.04	0.04	0.04	0.04	0.03
used alc. weekly during preg.	0.04	0.04	0.05	0.03	0.04
did not smoke cigarettes while preg.	0.997	0.999	0.996	0.997	0.999
Age of child at assessment (months)	122.57	124.47	122.69	121.87	120.85
	(30.50)	(31.66)	(30.76)	(29.44)	(29.02)
Observations	20878	2031	13589	3607	1651

Standard errors for continuous variables in parentheses

Table 7: PIAT Reading Comprehension. Sample means and proportions by pre-pregnancy BMI for PIAT Reading Comprehension outcomes and control variables.

Variable	All Children	Pre-pregnancy BMI <18.5	18.5-24.9	25.0-29.9	>30
BPI	600.10	640.66	595.93	593.56	601.02
	(276.31)	(266.06)	(275.59)	(280.80)	(279.99)
Mom is Hispanic	0.20	0.18	0.19	0.23	0.16
Mom is Black	0.31	0.29	0.29	0.33	0.39
Child is male	0.51	0.53	0.51	0.52	0.48
Mom's age at first birth	21.68	20.16	21.62	22.13	22.93
	(4.74)	(4.02)	(4.73)	(4.71)	(5.11)
Mom's age at birth of this child	24.62	22.29	24.29	25.87	27.25
	(5.17)	(4.80)	(5.09)	(5.01)	(4.89)
Birth order of child	1.88	1.68	1.82	2.09	2.16
	(1.06)	(0.99)	(1.01)	(1.15)	(1.14)
breastfeeding initiated	0.44	0.39	0.46	0.42	0.41
weeks breastfed	8.42	7.46	8.87	7.88	7.15
	(17.12)	(16.21)	(17.34)	(17.37)	(15.64)
preterm birth	0.12	0.18	0.11	0.11	0.11
low birth weight	0.08	0.13	0.08	0.07	0.06
	(0.28)	(0.34)	(0.28)	(0.25)	(0.23)
Macrosomic	0.02	0.02	0.02	0.02	0.02
Mom's yrs of education	12.61	12.12	12.67	12.64	12.65
	(2.39)	(2.33)	(2.36)	(2.53)	(2.27)
Mother is married	0.63	0.60	0.63	0.65	0.60
Mother is sep., div. or wid.	0.23	0.24	0.23	0.21	0.24
Low Income	0.25	0.29	0.24	0.24	0.26
	(0.43)	(0.45)	(0.43)	(0.43)	(0.44)
Middle Income	0.27	0.28	0.27	0.28	0.29
	(0.44)	(0.45)	(0.44)	(0.45)	(0.45)
Lives in urban area	0.73	0.75	0.74	0.73	0.70
	(0.44)	(0.43)	(0.44)	(0.44)	(0.46)
Month of first prenatal visit	2.60	2.54	2.61	2.56	2.67
	(1.63)	(1.46)	(1.61)	(1.70)	(1.82)
Took prenatal vitamins	0.86	0.80	0.85	0.88	0.89
used alc. in preg. <1 per month	0.23	0.24	0.24	0.20	0.19
used alc. monthly during preg.	0.04	0.04	0.04	0.04	0.04
used alc. weekly during preg.	0.04	0.04	0.05	0.03	0.04
did not smoke during preg.	0.997	0.998	0.996	0.997	0.999
Age child in months	110.40	113.85	110.91	108.60	106.31
	(37.09)	(38.17)	(37.18)	(36.32)	(36.23)
Observations	31246	20275	5479	2583	

Standard errors for continuous variables in parentheses

Table 8: BPI. Sample means and proportions by pre-pregnancy BMI for BPI sample outcomes and control variables.

VARIABLES	(1) Macrosomia	(2) Gestation	(3) Low birth weight	(4) Preterm	(5) LGA	(6) SGA
Weight before Pregnancy and Weight Gain						
Mom BMI<18.5	-0.003	-0.456***	0.053***	0.060***	-0.038***	0.071***
	(0.005)	(0.101)	(0.015)	(0.016)	(0.009)	(0.019)
Mom 25<BMI<29.9	0.004	0.043	-0.018**	-0.009	0.026***	-0.037***
	(0.004)	(0.069)	(0.009)	(0.011)	(0.010)	(0.012)
Mom BMI>30	0.014*	0.195**	-0.029**	-0.018	0.075***	-0.064***
	(0.007)	(0.092)	(0.011)	(0.014)	(0.015)	(0.017)
Lbs. gained preg.	0.001***	0.017***	-0.002***	-0.002***	0.002***	-0.003***
	(0.000)	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	0.000	38.107***	0.151***	0.176***	-0.000	0.269***
	(0.004)	(0.081)	(0.011)	(0.011)	(0.008)	(0.013)
Observations	7,496	7,462	7,496	7,487	7,496	7,496
R-squared	0.004	0.017	0.015	0.009	0.022	0.019
Excess Gestational Weight Gain						
wt gain >IOM	0.013***	0.185***	-0.010	-0.020**	0.054***	-0.039***
	(0.004)	(0.055)	(0.007)	(0.009)	(0.008)	(0.010)
wt gain <IOM	-0.005	-0.456***	0.083***	0.059***	-0.033***	0.078***
	(0.003)	(0.072)	(0.010)	(0.011)	(0.007)	(0.013)
Constant	0.014***	38.658***	0.068***	0.115***	0.073***	0.163***
	(0.002)	(0.040)	(0.005)	(0.007)	(0.005)	(0.008)
Observations	7,496	7,462	7,496	7,487	7,496	7,496
R-squared	0.003	0.014	0.019	0.009	0.016	0.015

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
macro=1 if baby born <9.92 lbs., SGA=1 if <10th percentile, LGA==1 if > 90th percentile,
Low birth weight=1 if less than 5.5 lbs at birth, Early birth=1 if born before 40 weeks

Table 9: Unconditional OLS results on key variables of interest. Variables of interest include pre-pregnancy BMI category, gestational weight gain, and whether gestational weight gain was in excess of IOM recommendations

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	C-section	Num Dr. Visits	Mom days hosp.	Breastfed	Weeks Breastfed	Kid Days Hosp
			Weight before Pregnancy and Weight Gain			
Mom BMI<18.5	-0.052***	-0.026	0.234	-0.075***	0.017	1.355*
	(0.017)	(0.164)	(0.172)	(0.024)	(1.661)	(0.706)
Mom 25<BMI<29.9	0.070***	0.189	0.030	-0.049***	-0.873	-0.293
	(0.016)	(0.162)	(0.124)	(0.019)	(1.067)	(0.212)
Mom BMI>30	0.151***	0.308*	0.122	-0.057**	-2.693*	-0.204
	(0.024)	(0.170)	(0.158)	(0.027)	(1.447)	(0.326)
Lbs. gained preg.	0.003***	0.004	0.004	0.001***	-0.085***	-0.031***
	(0.000)	(0.003)	(0.004)	(0.000)	(0.027)	(0.009)
Constant	0.121***	1.571***	3.280***	0.444***	21.904***	5.367***
	(0.014)	(0.120)	(0.170)	(0.018)	(1.032)	(0.355)
Observations	7,484	7,433	7,004	7,285	3,422	7,040
R-squared	0.020	0.001	0.001	0.005	0.004	0.005
			Excess Gestational Weight Gain			
Wt. gain >IOM	0.016**	0.111	0.316***	-0.009	-2.676***	0.022
	(0.008)	(0.108)	(0.093)	(0.015)	(0.842)	(0.176)
Wt. gain <IOM	-0.017**	-0.005	0.281**	-0.087***	-1.314	1.376***
	(0.008)	(0.123)	(0.134)	(0.017)	(1.009)	(0.360)
Prev. c-sec	0.895***					
	(0.005)					
Weeks of gestation	-0.008***					
	(0.002)					
Constant	0.396***	1.715***	3.252***	0.497***	20.216***	4.099***
	(0.059)	(0.084)	(0.064)	(0.012)	(0.629)	(0.143)
Observations	7,425	7,433	7,004	7,285	3,422	7,040
R-squared	0.568	0.000	0.002	0.005	0.003	0.005

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 10: Unconditional OLS results on key variables of interest. Variables include pre-pregnancy BMI category, gestational weight gain, and whether gestational weight gain was in excess of IOM recommendations

VARIABLES	(1) Macrosomia	(2) Gestation	(3) Low birth weight	(4) Preterm	(5) LGA	(6) SGA
Weight before Pregnancy and Weight Gain						
Mom BMI<18.5	-0.002	-0.523***	0.051***	0.060***	-0.032***	0.065***
	(0.005)	(0.102)	(0.015)	(0.016)	(0.009)	(0.019)
Mom 25<BMI<29.9	0.003	0.108	-0.023***	-0.011	0.025**	-0.043***
	(0.004)	(0.069)	(0.009)	(0.011)	(0.010)	(0.012)
Mom BMI>30	0.014*	0.326***	-0.041***	-0.026*	0.076***	-0.075***
	(0.007)	(0.095)	(0.012)	(0.015)	(0.015)	(0.017)
Lbs. gained preg.	0.001***	0.017***	-0.002***	-0.002***	0.003***	-0.003***
	(0.000)	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	-0.803	134.980***	-6.329*	-12.693***	4.261	3.419
	(1.560)	(24.741)	(3.303)	(3.993)	(3.403)	(4.384)
Observations	7,496	7,462	7,496	7,487	7,496	7,496
R-squared	0.013	0.035	0.034	0.019	0.035	0.047
Excess Gestational Weight Gain						
Wt. gain >IOM	0.014***	0.187***	-0.011	-0.021**	0.057***	-0.042***
	(0.004)	(0.055)	(0.007)	(0.009)	(0.008)	(0.010)
Wt. gain <IOM	-0.003	-0.483***	0.077***	0.061***	-0.027***	0.062***
	(0.003)	(0.072)	(0.010)	(0.011)	(0.007)	(0.012)
Constant	-0.938	133.785***	-6.275*	-12.908***	3.391	4.435
	(1.578)	(24.560)	(3.261)	(3.943)	(3.407)	(4.393)
Observations	7,496	7,462	7,496	7,487	7,496	7,496
R-squared	0.013	0.032	0.036	0.019	0.029	0.041

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
macro=1 if baby born <9.92 lbs., SGA=1 if <10th percentile, LGA==1 if > 90th percentile,
Low birth weight=1 if less than 5.5 lbs at birth, Early birth=1 if born before 40 weeks

Table 11: Top Panel: OLS Results for pre-pregnancy BMI and gestational weight gain conditional on control variables. Bottom Panel: OLS Results for pregnancy weight gain in excess of IOM recommendations, conditional on control variables.

VARIABLES	(1) C-section	(2) Num Dr. Visits	(3) Mom days hosp.	(4) Breastfed	(5) Weeks Breastfed	(6) Kid Days Hosp
			Weight before Pregnancy and Weight Gain			
Mom BMI<18.5	-0.019*	-0.023	0.093	-0.017	1.653	1.163*
	(0.010)	(0.161)	(0.174)	(0.022)	(1.586)	(0.693)
Mom 25<BMI<29.9	0.030***	0.249	0.126	-0.045***	-1.582	-0.248
	(0.011)	(0.164)	(0.123)	(0.017)	(1.049)	(0.210)
Mom BMI>30	0.082***	0.373**	0.296*	-0.033	-3.844***	-0.143
	(0.018)	(0.167)	(0.157)	(0.025)	(1.390)	(0.344)
Lbs. gained preg.	0.001***	0.002	0.006	0.000	-0.079***	-0.027***
	(0.000)	(0.004)	(0.004)	(0.000)	(0.027)	(0.008)
Constant	-1.568	40.375	181.173***	-1.032	-244.034	83.632
	(3.502)	(43.044)	(42.261)	(6.276)	(381.164)	(86.087)
Observations	7,425	7,433	7,004	7,285	3,422	7,040
R-squared	0.582	0.014	0.022	0.175	0.066	0.015
			Excess Gestational Weight Gain			
Wt. gain >IOM	0.017**	0.115	0.314***	0.000	-2.100**	0.005
	(0.008)	(0.108)	(0.091)	(0.014)	(0.835)	(0.180)
Wt. gain <IOM	-0.014*	0.081	0.171	-0.020	-0.275	1.185***
	(0.009)	(0.121)	(0.128)	(0.015)	(0.996)	(0.339)
Constant	-2.918	32.407	176.148***	0.066	-166.132	78.951
	(3.526)	(43.331)	(42.252)	(6.279)	(379.822)	(85.503)
Observations	7,425	7,433	7,004	7,285	3,422	7,040
R-squared	0.579	0.013	0.022	0.174	0.063	0.015

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
macro=1 if baby born <9.92 lbs., SGA=1 if <10th percentile, LGA==1 if > 90th percentile,
Low birth weight=1 if less than 5.5 lbs at birth, Early birth=1 if born before 40 weeks

Table 12: Top Panel: OLS Results for pre-pregnancy BMI and gestational weight gain conditional on control variables. Bottom Panel: OLS Results for pregnancy weight gain in excess of IOM recommendations, conditional on control variables.

VARIABLES	(1) PPVTZ	(2) MATHZ	(3) RECOGZ	(4) COMPZ	(5) BPI
		Weight before Pregnancy and Weight Gain			
Mom BMI<18.5	-0.663	-0.255	-0.307	0.139	20.556**
	(0.959)	(0.433)	(0.552)	(0.472)	(10.462)
Mom 25<BMI<29.9	-3.362***	-1.087***	-0.929**	-0.747**	13.878*
	(0.775)	(0.365)	(0.412)	(0.353)	(8.324)
Mom BMI>30	-3.385***	-2.170***	-2.474***	-1.929***	31.072**
	(0.981)	(0.561)	(0.656)	(0.590)	(12.070)
lbs gained while preg.	0.021	-0.014	-0.019*	-0.016*	-0.006
	(0.019)	(0.009)	(0.011)	(0.009)	(0.202)
Age at evaluation	-0.191***	0.001	-0.030***	-0.114***	0.673***
	(0.039)	(0.006)	(0.007)	(0.006)	(0.129)
Observations	4,519	27,764	27,651	20,855	31,215
R-squared	0.349	0.203	0.175	0.250	0.077
		Excess Gestational Weight Gain			
Wt. gain >IOM	-0.719	-0.811***	-0.738**	-0.562*	11.334*
	(0.619)	(0.301)	(0.343)	(0.302)	(6.742)
Wt. gain <IOM	-1.002	-0.598*	-0.366	-0.185	10.646
	(0.682)	(0.337)	(0.377)	(0.333)	(7.314)
Age at evaluation	-0.189***	0.003	-0.029***	-0.113***	0.650***
	(0.039)	(0.006)	(0.007)	(0.006)	(0.129)
Observations	4,519	27,764	27,651	20,855	31,215
R-squared	0.344	0.202	0.173	0.249	0.076

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 13: Top Panel: Cognitive outcomes. OLS Results for pre-pregnancy BMI and gestational weight gain conditional on control variables. Bottom Panel: OLS Results for pregnancy weight gain in excess of IOM recommendations, conditional on control variables.

VARIABLES	(1) Macrosomia	(2) Gestation	(3) Low birth weight	(4) Preterm	(5) LGA	(6) SGA
	Weight before Pregnancy and Weight Gain					
Mom BMI<18.5	0.016	-0.920***	0.058**	0.109***	-0.002	-0.068**
	(0.010)	(0.191)	(0.024)	(0.028)	(0.014)	(0.031)
Mom 25<BMI<29.9	-0.002	0.165	-0.045***	-0.030	0.003	-0.038*
	(0.008)	(0.127)	(0.016)	(0.019)	(0.017)	(0.020)
Mom BMI>30	0.016	0.494**	-0.069***	-0.075**	0.036	-0.094***
	(0.017)	(0.216)	(0.025)	(0.034)	(0.035)	(0.033)
Lbs. gained preg.	0.000	0.023***	-0.002***	-0.003***	0.002***	-0.002***
	(0.000)	(0.004)	(0.000)	(0.000)	(0.000)	(0.001)
Constant	21.341*	43.835	-5.488	10.473	39.177*	-31.214
	(11.237)	(159.098)	(21.937)	(25.500)	(20.795)	(26.151)
R-squared	0.023	0.035	0.022	0.025	0.024	0.016
Number of CASEID	3,987	3,981	3,987	3,984	3,987	3,987
	Excess Gestational Weight Gain					
Wt. gain >IOM	0.004	0.209**	-0.019*	-0.034**	0.027**	-0.046***
	(0.006)	(0.093)	(0.011)	(0.014)	(0.012)	(0.015)
Wt. gain <IOM	-0.003	-0.466***	0.064***	0.047***	-0.014	0.006
	(0.006)	(0.107)	(0.014)	(0.015)	(0.011)	(0.017)
Constant	21.105*	53.879	-7.311	9.955	38.094*	-27.663
	(11.199)	(160.925)	(21.923)	(25.772)	(20.822)	(26.227)
R-squared	0.021	0.024	0.021	0.018	0.020	0.010
Number of CASEID	3,987	3,981	3,987	3,984	3,987	3,987

Robust standard errors in parentheses. Full set of controls in these models are listed in table 3

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

macro=1 if baby born <9.92 lbs., SGA=1 if <10th percentile, LGA==1 if > 90th percentile,

Low birth weight=1 if less than 5.5 lbs at birth, Early birth=1 if born before 40 weeks

Table 14: Top Panel: For immediate birth outcomes, fixed Effect Results for pre-pregnancy BMI and gestational weight gain conditional on control variables. Bottom Panel: Fixed Effects Results for pregnancy weight gain in excess of IOM recommendations, conditional on control variables.

VARIABLES	(1) C-section	(2) Num Dr. Visits	(3) Mom days hosp.	(4) Breastfed	(5) Weeks Breastfed	(6) Kid Days Hosp
Weight before Pregnancy and Weight Gain						
Mom BMI<18.5	0.008	0.329	0.177	-0.007	1.902	2.577*
	(0.015)	(0.297)	(0.268)	(0.026)	(2.992)	(1.541)
Mom 25<BMI<29.9	-0.019	-0.395	-0.509**	0.025	2.295	-1.359***
	(0.013)	(0.325)	(0.234)	(0.022)	(1.839)	(0.390)
Mom BMI>30	0.030	-0.546	-0.341	0.013	0.548	-1.539**
	(0.021)	(0.391)	(0.323)	(0.038)	(3.065)	(0.742)
Lbs. gained preg.	-0.001**	-0.009	-0.003	0.001	-0.042	-0.060**
	(0.000)	(0.006)	(0.006)	(0.001)	(0.051)	(0.024)
Prev. c-sec	0.479***					
	(0.018)					
Weeks of gestation	-0.007***					
	(0.002)					
R-squared	0.446	0.014	0.016	0.013	0.027	0.018
Number of CASEID	3,978	3,974	3,852	3,910	2,084	3,858
Excess Gestational Weight Gain						
Wt. gain >IOM	-0.008	-0.064	0.217	0.039***	1.369	-0.173
	(0.009)	(0.177)	(0.160)	(0.015)	(1.455)	(0.421)
Wt. gain <IOM	0.005	0.199	0.287	0.003	1.693	1.838***
	(0.008)	(0.191)	(0.237)	(0.015)	(1.558)	(0.559)
Prev. c-sec	0.478***					
	(0.018)					
Weeks of gestation	-0.008***					
	(0.002)					
R-squared	0.443	0.013	0.015	0.015	0.027	0.015
Number of CASEID	3,978	3,974	3,852	3,910	2,084	3,858

Robust standard errors in parentheses. Full set of controls in these models are listed in table 3.
*** p<0.01, ** p<0.05, * p<0.1

Table 15: Top Panel: for second group of birth outcomes, fixed Effect Results for pre-pregnancy BMI and gestational weight gain conditional on control variables. Bottom Panel: Fixed Effects Results for pregnancy weight gain in excess of IOM recommendations, conditional on control variables. Constants not shown for space reasons.

Appendix I: OLS with full controls

VARIABLES	(1) PPVTZ	(2) MATHZ	(3) RECOGZ	(4) COMPZ	(5) BPI
		Weight before Pregnancy and Weight Gain			
Mom BMI<18.5	-1.853	-0.276	0.412	0.041	18.177
	(2.804)	(0.698)	(0.769)	(0.747)	(13.248)
Mom 25<BMI<29.9	0.096	0.045	-0.514	-0.060	13.068
	(2.795)	(0.567)	(0.625)	(0.599)	(9.106)
Mom BMI>30	-2.093	2.126**	-0.138	0.031	5.376
	(4.333)	(0.988)	(1.079)	(1.000)	(15.724)
lbs gained while preg.	0.030	0.029**	0.008	0.024	-0.138
	(0.063)	(0.015)	(0.016)	(0.015)	(0.231)
Age at evaluation	0.070	-0.050	-0.105**	-0.131***	0.554
	(0.213)	(0.039)	(0.045)	(0.043)	(0.633)
Observations	4,519	27,764	27,651	20,855	31,215
R-squared	0.839	0.531	0.561	0.577	0.551
		Excess Gestational Weight Gain			
Wt. gain >IOM	0.165	0.720*	0.607	0.586	-4.236
	(1.764)	(0.429)	(0.474)	(0.465)	(6.923)
Wt. gain <IOM	-0.880	-0.379	0.152	-0.190	-4.072
	(1.906)	(0.453)	(0.489)	(0.470)	(7.086)
Age at evaluation	0.074	-0.051	-0.106**	-0.131***	0.603
	(0.214)	(0.039)	(0.045)	(0.043)	(0.633)
Observations	4,519	27,764	27,651	20,855	31,215
R-squared	0.839	0.531	0.561	0.577	0.551

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 16: Top Panel: for cognitive and behavioral outcomes, fixed Effect Results for pre-pregnancy BMI and gestational weight gain conditional on control variables. Bottom Panel: Fixed Effects Results for pregnancy weight gain in excess of IOM recommendations, conditional on control variables. Constants not shown for space reasons.

Appendix II: OLS with Fixed Effect Samples

VARIABLES	(1) Macrosomia	(2) Gestation	(3) birth weight	(4) Preterm	(5) LGA	(6) SGA
BMI<18.5	-0.002	-0.523***	0.051***	0.060***	-0.032***	0.065***
	(0.005)	(0.102)	(0.015)	(0.016)	(0.009)	(0.019)
25<BMI<29.9	0.003	0.108	-0.023***	-0.011	0.025**	-0.043***
	(0.004)	(0.069)	(0.009)	(0.011)	(0.010)	(0.012)
BMI>30	0.014*	0.326***	-0.041***	-0.026*	0.076***	-0.075***
	(0.007)	(0.095)	(0.012)	(0.015)	(0.015)	(0.017)
lbs gained preg.	0.001***	0.017***	-0.002***	-0.002***	0.003***	-0.003***
	(0.000)	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)
Hispanic	-0.008*	-0.068	-0.001	-0.011	-0.011	0.003
	(0.004)	(0.075)	(0.009)	(0.012)	(0.010)	(0.013)
Black	-0.014***	-0.104	0.038***	-0.005	-0.042***	0.099***
	(0.005)	(0.080)	(0.010)	(0.012)	(0.009)	(0.014)
Child is male	0.014***	-0.074	-0.014**	0.007	0.008	0.013
	(0.003)	(0.050)	(0.006)	(0.008)	(0.006)	(0.008)
Birth order	0.007**	-0.052	0.010*	0.004	0.016***	0.007
	(0.003)	(0.044)	(0.006)	(0.007)	(0.005)	(0.008)
child birth year	0.000	-0.048***	0.003*	0.006***	-0.002	-0.002
	(0.001)	(0.013)	(0.002)	(0.002)	(0.002)	(0.002)
age, first birth	-0.001	-0.021	0.005***	0.005**	-0.001	0.005**
	(0.001)	(0.013)	(0.002)	(0.002)	(0.002)	(0.002)
age, birth of child	-0.000	0.006	-0.003	-0.005**	0.002	0.000
	(0.001)	(0.016)	(0.002)	(0.003)	(0.002)	(0.003)
yrs of education	0.002*	-0.019	-0.003	0.002	0.003	-0.009***
	(0.001)	(0.014)	(0.002)	(0.002)	(0.002)	(0.003)
married	-0.004	0.284***	-0.044***	-0.034***	0.004	-0.040***
	(0.005)	(0.086)	(0.011)	(0.012)	(0.010)	(0.014)
sep./div./wid.	-0.007	0.308***	-0.028*	-0.024	-0.030**	-0.007
	(0.007)	(0.119)	(0.016)	(0.018)	(0.013)	(0.020)
Low Income	0.000	-0.163**	0.027**	0.034***	-0.013	0.014
	(0.005)	(0.082)	(0.011)	(0.013)	(0.010)	(0.014)
Middle Income	0.000	-0.049	0.006	0.016	0.004	-0.006
	(0.004)	(0.066)	(0.008)	(0.011)	(0.010)	(0.011)
Constant	-0.803	134.980***	-6.329*	-12.693***	4.261	3.419
	(1.560)	(24.741)	(3.303)	(3.993)	(3.403)	(4.384)
Observations	7,496	7,462	7,496	7,487	7,496	7,496
R-squared	0.013	0.035	0.034	0.019	0.035	0.047

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 17: This table shows the full set of controls and estimated coefficients for the specification in table 11

VARIABLES	(1) C-section	(2) Num Dr. Visits	(3) Mom days hospital	(4) Breastfed	(5) Weeks Breastfed	(6) Kid days hospital
BMI<18.5	-0.019*	-0.023	0.093	-0.017	1.653	1.163*
	(0.010)	(0.161)	(0.174)	(0.022)	(1.586)	(0.693)
25<BMI<29.9	0.030***	0.249	0.126	-0.045***	-1.582	-0.248
	(0.011)	(0.164)	(0.123)	(0.017)	(1.049)	(0.210)
BMI>30	0.082***	0.373**	0.296*	-0.033	-3.844***	-0.143
	(0.018)	(0.167)	(0.157)	(0.025)	(1.390)	(0.344)
lbs gained preg.	0.001***	0.002	0.006	0.000	-0.079***	-0.027***
	(0.000)	(0.004)	(0.004)	(0.000)	(0.027)	(0.008)
Hispanic	0.016	-0.267*	-0.172	0.017	-3.357***	0.028
	(0.012)	(0.140)	(0.108)	(0.021)	(1.113)	(0.287)
Black	0.002	-0.736***	0.520***	-0.225***	-4.396***	0.807**
	(0.010)	(0.129)	(0.171)	(0.018)	(1.230)	(0.329)
Child is male	0.005	0.239***	0.166*	-0.007	0.419	0.140
	(0.006)	(0.082)	(0.095)	(0.011)	(0.700)	(0.218)
Birth order	0.016**	-0.065	-0.002	0.023**	1.770**	0.127
	(0.007)	(0.061)	(0.067)	(0.010)	(0.694)	(0.185)
child birth year	0.001	-0.020	-0.090***	0.000	0.118	-0.039
	(0.002)	(0.022)	(0.021)	(0.003)	(0.194)	(0.044)
age, first birth	-0.003	-0.028	0.044*	0.013***	0.120	0.091
	(0.002)	(0.023)	(0.025)	(0.003)	(0.209)	(0.064)
age, birth of child	0.004*	0.040	-0.025	-0.001	0.393	-0.060
	(0.002)	(0.025)	(0.030)	(0.004)	(0.249)	(0.081)
yrs of education	-0.002	0.026	-0.037	0.039***	1.023***	-0.076
	(0.002)	(0.026)	(0.028)	(0.004)	(0.222)	(0.051)
married	0.026***	-0.156	-0.169	0.090***	1.185	-0.853***
	(0.009)	(0.137)	(0.166)	(0.017)	(1.064)	(0.327)
sep./div./wid.	0.025	0.098	0.005	0.032	-2.876*	-0.138
	(0.017)	(0.209)	(0.264)	(0.026)	(1.679)	(0.540)
Low Income	0.002	0.075	-0.115	-0.042**	2.333*	0.161
	(0.011)	(0.159)	(0.167)	(0.018)	(1.342)	(0.336)
Middle Income	-0.002	0.080	-0.165	-0.011	2.830***	-0.143
	(0.009)	(0.129)	(0.121)	(0.016)	(0.937)	(0.253)
Previous c-section	0.906***					
	(0.005)					
Weeks of gestation	-0.007***					
	(0.001)					
Constant	-1.568	40.375	181.173***	-1.032	-244.034	83.632
	(3.502)	(43.044)	(42.261)	(6.276)	(381.164)	(86.087)
Observations	7,425	7,433	7,004	7,285	3,422	7,040
R-squared	0.582	0.014	0.022	0.175	0.066	0.015

Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

Table 18: This table shows most of the of controls and estimated coefficients for the specification in table 12. Controls suppressed for space include binary indicators for missing income, urban residence, prenatal vitamins, and smoking or drinking during pregnancy.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Macrosomia	Gestation	Low birth weight	Preterm	LGA	SGA
BMI<18.5	-0.000	-0.549***	0.047***	0.062***	-0.034***	0.054**
	(0.006)	(0.119)	(0.017)	(0.018)	(0.010)	(0.022)
25<BMI<29.9	0.004	0.156**	-0.032***	-0.013	0.027**	-0.042***
	(0.005)	(0.079)	(0.010)	(0.012)	(0.012)	(0.014)
BMI>30	0.017**	0.279**	-0.038***	-0.015	0.066***	-0.083***
	(0.009)	(0.109)	(0.014)	(0.017)	(0.017)	(0.019)
lbs gained preg.	0.001***	0.017***	-0.002***	-0.002***	0.003***	-0.003***
	(0.000)	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)
Hispanic	-0.009*	-0.083	0.002	-0.007	-0.013	-0.005
	(0.005)	(0.085)	(0.011)	(0.013)	(0.012)	(0.014)
Black	-0.017***	-0.143	0.039***	-0.005	-0.045***	0.094***
	(0.005)	(0.096)	(0.012)	(0.014)	(0.011)	(0.016)
Child is male	0.016***	-0.110*	-0.013*	0.012	0.006	0.010
	(0.004)	(0.056)	(0.007)	(0.009)	(0.007)	(0.009)
age, first birth	-0.001	-0.022	0.004*	0.004	-0.001	0.003
	(0.001)	(0.016)	(0.002)	(0.003)	(0.002)	(0.003)
age, birth of child	-0.001	0.010	-0.005**	-0.005*	0.002	0.001
	(0.001)	(0.019)	(0.002)	(0.003)	(0.002)	(0.003)
Birth order	0.007**	-0.033	0.010	0.005	0.014**	0.010
	(0.003)	(0.047)	(0.006)	(0.007)	(0.006)	(0.008)
child birth year	0.001	-0.054***	0.005**	0.006***	-0.001	-0.003
	(0.001)	(0.015)	(0.002)	(0.002)	(0.002)	(0.003)
yrs of education	0.002*	-0.022	-0.002	0.003	0.003	-0.009***
	(0.001)	(0.016)	(0.002)	(0.003)	(0.002)	(0.003)
married	-0.005	0.301***	-0.047***	-0.037**	0.001	-0.033**
	(0.005)	(0.102)	(0.012)	(0.014)	(0.011)	(0.016)
sep./div./wid.	-0.012*	0.253*	-0.025	-0.019	-0.035**	-0.010
	(0.007)	(0.138)	(0.018)	(0.020)	(0.014)	(0.023)
Low Income	-0.003	-0.100	0.011	0.028*	-0.013	0.003
	(0.005)	(0.094)	(0.012)	(0.015)	(0.011)	(0.016)
Middle Income	-0.002	-0.019	-0.000	0.017	0.006	-0.012
	(0.005)	(0.075)	(0.010)	(0.012)	(0.011)	(0.013)
Constant	-1.270	145.869***	-9.710**	-12.634***	2.505	5.857
	(1.797)	(29.105)	(3.863)	(4.801)	(4.033)	(5.271)
Observations	5,892	5,864	5,892	5,886	5,892	5,892
R-squared	0.015	0.037	0.034	0.018	0.038	0.047

Robust standard errors in parentheses. Full set of controls in these models are listed in table 3.
*** p<0.01, ** p<0.05, * p<0.1

Table 19: This table shows most of the set of controls and estimated coefficients for the specification in table 11, but using the smaller sample as in the fixed effects specifications. The results are qualitatively the same.

VARIABLES	(1) C-section	(2) Num Dr. Visits	(3) Mom days hospital	(4) Breastfed	(5) Weeks Breastfed	(6) Kid days hospital
BMI<18.5	-0.017	-0.074	0.050	-0.019	1.752	1.339
	(0.012)	(0.191)	(0.171)	(0.026)	(1.909)	(0.846)
25<BMI<29.9	0.032**	0.191	0.077	-0.052***	-0.872	-0.409*
	(0.013)	(0.200)	(0.149)	(0.019)	(1.236)	(0.244)
BMI>30	0.088***	0.333*	0.312*	-0.018	-3.308**	-0.015
	(0.022)	(0.193)	(0.187)	(0.029)	(1.607)	(0.422)
lbs gained preg.	0.001*	-0.001	0.005	0.001	-0.077**	-0.030***
	(0.000)	(0.004)	(0.005)	(0.001)	(0.031)	(0.010)
Hispanic	0.013	-0.249	-0.205*	0.013	-3.538***	0.028
	(0.014)	(0.165)	(0.121)	(0.024)	(1.294)	(0.335)
Black	0.004	-0.796***	0.634***	-0.223***	-4.473***	1.044**
	(0.013)	(0.155)	(0.209)	(0.022)	(1.471)	(0.406)
Child is male	0.007	0.236**	0.172	-0.003	1.030	0.216
	(0.007)	(0.095)	(0.111)	(0.012)	(0.787)	(0.263)
age, first birth	-0.000	-0.027	0.049	0.014***	-0.032	0.084
	(0.002)	(0.028)	(0.033)	(0.004)	(0.237)	(0.082)
age, birth of child	0.004	0.047*	-0.025	-0.001	0.523*	-0.079
	(0.003)	(0.029)	(0.035)	(0.005)	(0.289)	(0.099)
Birth order	0.009	-0.082	0.005	0.022**	1.172	0.108
	(0.007)	(0.065)	(0.072)	(0.010)	(0.760)	(0.209)
child birth year	0.002	-0.019	-0.091***	-0.000	0.125	-0.021
	(0.002)	(0.026)	(0.025)	(0.004)	(0.232)	(0.054)
yrs of education	-0.003	0.012	-0.034	0.038***	0.956***	-0.105*
	(0.003)	(0.033)	(0.029)	(0.005)	(0.255)	(0.062)
married	0.026**	-0.269	-0.141	0.104***	0.706	-0.799**
	(0.012)	(0.170)	(0.194)	(0.020)	(1.291)	(0.386)
sep./div./wid.	0.032	-0.014	0.171	0.046	-2.512	0.163
	(0.021)	(0.249)	(0.318)	(0.030)	(1.957)	(0.646)
Low Income	0.010	0.064	-0.221	-0.035*	0.925	-0.186
	(0.013)	(0.188)	(0.194)	(0.021)	(1.556)	(0.398)
Middle Income	0.001	0.033	-0.140	-0.001	2.606**	-0.302
	(0.011)	(0.146)	(0.146)	(0.018)	(1.083)	(0.303)
prev. c-sec	0.891***					
	(0.006)					
weeks of gestation	-0.008***					
	(0.002)					
Constant	-3.882	39.928	183.424***	0.091	-248.770	48.337
	(4.465)	(50.477)	(48.688)	(7.607)	(455.553)	(105.321)
Observations	5,830	5,842	5,525	5,756	2,701	5,556
R-squared	0.501	0.014	0.022	0.177	0.066	0.016

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 20: This table shows the full set of controls and estimated coefficients for the specification in table 12, but using the smaller sample as in the fixed effects specifications. The results are qualitatively the same.