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The Earlier and the More, the Healthier? The Effects of Prenatal Care Utilization on Maternal Health and Health Behaviors

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The Earlier and the More, the Healthier? The Effects of Prenatal Care Utilization on Maternal Health and Health Behaviors[1]

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SUMMARY

While many economic studies have explored the role of prenatal care in infant health production, the literature is quite sporadic about the effects of prenatal care on the mother. This research contributes to this understudied but important area using a unique large dataset of sibling newborns. We apply empirical models with mother fixed effects to find robust evidence that poor prenatal care utilization due to late onset of care, low frequency of care visits, or combinations of the two significantly increases the risks of maternal inadequate gestational weight gain, prenatal smoking, premature rupture of membranes, precipitous labor, no breastfeeding, postnatal underweight, and postpartum smoking. The magnitude of the estimates relative to the respective sample means of the outcome variables ranges from 3 to 33 percent. The results highlight the importance of receiving timely and sufficient prenatal care in improving maternal health and health behaviors during pregnancy as well as after childbirth. Moreover, we also find there is a high prevalence of underuse of prenatal care among pregnant women, which suggests potentially large scope for subsequent policy intervention.

Keywords: Prenatal Care; Maternal Health; Gestational Weight Gain; Smoking; Breastfeeding; Unhealthy Body Weight

JEL classification: I12; I18

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1. INTRODUCTION

One important public health objective in Health People 2020 is improving the well-being and health of mothers in the United State (USDHHS, 2012). Over the last four decades, legislators and policymakers have substantially improved access to affordable coverage and care for American mothers, in the belief that more health care will translate into better maternal health. A specific medical care which mothers have significantly increased their usage of through health care reform is prenatal care (Currie and Gruber, 1996; Epstein and Newhouse, 1998; Blumenthal and Collins, 2014; USDHHS, 2015). Contemporary prenatal care allows health professionals to instruct mothers on proper nutritional diet, smoking cessation, illness prevention, and benefits of breastfeeding throughout the course of pregnancy. During regular check-ups, physicians assess changes to mothers' weight and uterus size, as well as monitor and treat various maternal health problems while promoting healthy lifestyles that benefit mothers and infants (ACOG, 2012). Therefore, it is reasonable to expect that by connecting mothers with the health care system, prenatal care will make a difference on maternal health and health behaviors during pregnancy, childbirth, and the postpartum period.

To date, much of the large literature on the efficacy of prenatal care has focused on infant outcomes such as birth weight. Recent economic research on newborn birth weight has reported inconsistent results which vary significantly by research design (e.g., Conway and Deb, 2005; Evans and Lien, 2005; Abrevaya and Dahl, 2008; Reichman *et al*., 2009). In contrast, very little is known about how mothers benefit from receipt of adequate prenatal care themselves (see Conway and Kutinova (2006) for a review). A few early works look at women in developing countries and provide descriptive evidence that prenatal care reduces maternal morbidity and mortality (Acharya 1995; McDonagh 1996). A recent study by Nizalova and Vyshnya (2010)

demonstrates that a maternal health program in Ukraine reduces the rates of several pregnancy and delivery complications, by enhancing labor and delivery services plus prenatal care.

To the best of our knowledge, only three economic studies have examined the relation of prenatal care and maternal health outcomes in the context of the United States. Conway and Kutinova (2006) shows receiving adequate prenatal care lessens the chances of maternal excessive hospitalization after the newborn delivery and becoming underweight postpartum. Reichman *et al*. (2010) presents evidence about the lasting beneficial effects of early prenatal care initiation on maternal postnatal smoking, well-baby visits, and breastfeeding. However, the findings of the two cross sectional analyses are suggestive and somewhat sensitive to model specifications, in part because it is hard to sufficiently deal with the unobservable mother heterogeneity correlated with prenatal care utilization. In addition, Kutinova and Conway (2008) reports the Medicaid expansions lower the incidences of maternal anemia and pregnancy-induced hypertension, while this effect appears not to operate mainly through improved prenatal care. On the whole, the existing evidence is sparse and inconclusive about the influences of prenatal care on mothers, thereby leaving plenty of room for new research.

Exploring the efficacy of prenatal care in enhancing maternal well-being will significantly increase our understanding of maternal health production, which goes beyond the usual framework of newborn health production. The revealed beneficial effects on mothers also add new insights on the cost-benefit analysis of interventions to promote prenatal care. A well-known challenge in this arena, however, is the difficulty of measuring maternal health especially the outcomes during pregnancy. It is tempting to consider maternal pregnancy complications, a lot of which are developed in the mid-pregnancy. Nevertheless, standard health surveys usually focus on detection of such complications in mid-pregnancy (e.g., onset of gestational

hypertension studied in prior research) but rarely report successful treatment on any detected health problem in the subsequent visits. Therefore, this incomplete reporting makes prenatal care appear less effective than actually is in reducing such maternal complications, biasing the impact estimate to zero. Moreover, Conway and Kutinova (2006) points out it will be promising to study 'subtle' maternal outcomes in new research, since this attempt reveals how prenatal care affects women's lifestyle habit during and after pregnancy. One subtle outcome of interest not explored before is gestational weight gain which can be modified by prenatal counselling on diet, nutrition, and exercise. Lastly, prenatal care can affect mother's postnatal outcomes both directly by health education or intervention and indirectly by influencing infant health and the associated maternal responsive investments. When the main interest is the direct impact, we can isolate it by controlling newborn birth weight.

This study sheds new light on the role of prenatal care in improving maternal health and health behaviors, using a very large data of 0.35 million sibling births linked to 0.17 million mothers. This data, constructed from the universe birth in two states, contains rich information on prenatal care utilization and maternal health plus health behaviors across consecutive pregnancies.[3] As such, it provides a unique opportunity to apply empirical models with mother fixed effects to compare various maternal outcomes by the timing of care onset, frequency of care visits, and combinations of the two. This within-family design removes the bias on the estimated effects of prenatal care due to the unobserved mother heterogeneity. The specifications we use also control for quite a few observed characteristics of infants, mothers, and families. Moreover, the large size of our data yields more precise estimates, relative to those in the previous studies.

[3] The maternal outcomes coded in the data include maternal gestational weight gain, smoking prior to pregnancy and by trimester, risk factors in pregnancy, onset of labor, breastfeeding, etc.

In this research, we explore two sets of adverse and preventable health outcomes of the mother during pregnancy, in a spirit similar to Conway and Kutinova (2006). The first set, closely related to the maternal lifestyle, consists of inadequate gestational weight gain, excessive gestational weight gain, and prenatal smoking. Inappropriate weight gain during pregnancy due to either nutritional deficiency or over-nutrition is an important risk factor for maternal morbidity.[4] Prenatal smoking significantly increases the incidences of a wide range of maternal complications (CDC, 2001; Roelands *et al*., 2009). In light of the above concern on incomplete reporting, the baseline analysis focuses on the total weight gain and smoking beyond the first trimester. The reason is when early onset of care detects inappropriate weight change or smoking but subsequent visits provide successful treatments later in pregnancy, using the two outcomes will capture this effect as part of the 'effectiveness' of timely care initiation. The second set includes premature rupture of membranes (PROM) and onset of precipitous labor. Both reflect severe health conditions close to childbirth and can result in significant maternal morbidity.[5] PROM leads to higher rates of infections and several complications (Duff, 1991; Cararach *et al*., 1993; Poma, 1996). Precipitous labor, in which intense contractions make the mother very painful, is associated with elevated risks of lacerations of the cervix, placental abruption, and uterine rupture (Mahon *et al*., 1994; Cunningham *et al*., 2001; Sheiner *et al*., 2004).

We also investigate the following poor postnatal outcomes: no breastfeeding, unhealthy body weight, and postpartum smoking. Compared with breastfeeding mothers, mothers who do not

[4] Women with low weight gain and deficient nutrition intake during pregnancy are at elevated risks of hyperemesis, anemia, preterm rupture of membranes, and other complications (Gosselink *et al*., 1992; Villar *et al*., 2003; Dodds *et al*., 2006; Viswanathan *et al*., 2008). Excessive weight gain is associated with pregnancy-induced hypertension, impaired glucose tolerance, and gestational diabetes (IOM, 2009; Hedderson *et al*., 2010; De la Torre *et al*., 2011).

[5] Recall the concern on incomplete reporting only applies to health problems detected in mid-pregnancy. So it does not affect the results on such two maternal outcomes at the end of pregnancy.

breastfeed infants are more likely to develop breast cancer, ovarian cancer, depression as well as less protected against infections (Furberg *et al*., 1999; Labbok, 2001; Ip *et al*., 2007; Luan *et al*., 2013). Unhealthy body weight is a serious health threat for women.[6] Furthermore, postpartum smoking negatively impacts women's health in many ways (Seltzer, 2000; McAfee and Burnette, 2014). Applying empirical models controlling for mother fixed effects, we find robust evidence that late care onset and low frequency of visits (or combinations of the two) increase the risks of most of the adverse outcomes above. The results underscore the importance of having early care onset and sufficient care visits in promoting maternal health.

2. DATA

The data source for this study is the natality record of all the annual live births in the states of Pennsylvania (year 2003 to 2010) and Washington (year 2003 to 2006). In 2003, both states started adopting the new U.S. Standard Certificates of Live Birth (2003 revision). In addition to utilization of prenatal care, the revised certificate codes rich information maternal health and health behaviors during pregnancy, childbirth, and the postpartum period. Under access permission to the restricted birth files by the two state departments of public health, consecutive singleton births are linked to the same mother by mother's name, date of birth, race, and newborn parity. We also drop a few women who had more than three births in the sampling period or were non-residents of either state.

With the exclusions above, two final samples are constructed: one on maternal prenatal health and health behaviors plus breastfeeding, the other on postpartum maternal body weight and smoking. The first sample has 147,157 mothers with two births and 19,207 mothers with three

[6] Previous studies report a U- or J-shape association between BMI and quite a few health problems including respiratory disease, cardiovascular disease, physical and mental disorders, and cancers (Ford *et al*., 2001; Hu, 2003; Kelly *et al*., 2010).

births, totally 351,935 observations (mother-infant pairs). Since the original birth files do not report postpartum maternal body weight or smoking, we use the panel of the 19,207 three-birth mothers to work out proxy variables. Specifically, maternal weight and smoking three month before the current conception are used as proxies for postpartum weight and smoking after the last birth. This method gives postpartum proxy outcomes after the first two births (in the sampling period) for the three-birth mothers, yielding the second sample of 38,414 observations.[7]

This study applies four sets of measures on poor prenatal care utilization. All of them are expected to increase the risks of the adverse maternal outcomes mentioned in the last section. The first includes two dummy variables on care initiation (the base is timely onset of care in the first trimester): second-trimester care onset and third-trimester care onset.[8] Clearly, using the two indicators allows us to compare the mothers with 'late care initiation' to those with 'very late care initiation'. The second one reflects low frequency of care visits. This indicator variable equals 1 (having an insufficient number of visits), if the ratio of a woman's total care visits to the recommended care visits given gestation (ACOG, 2012) is less than 1. The third measure, built upon the Kessner index (Kessner *et al*., 1973), assesses care adequacy by integration of the timing of care onset and number of visits. This measure ('inadequate care by the Kessner index') is coded as 1 for the women receiving 'inadequate' or 'intermediate' care by the Kessner index, otherwise 0. The last one is based on the recently proposed Adequacy of Prenatal Care Utilization Index (Kotelchuck, 1994). We call this measure 'inadequate care by the APNCU

[7] In this sample, the average time between the last childbirth and three month before the current pregnancy is about 15 months. It is close to the period between the last birth and the time point when postpartum outcomes after the last newborn delivery were surveyed in other datasets (Conway and Kutinova, 2006; Reichman *et al*., 2010). As such, the above proxy variables are arguably similar to the ideal postpartum counterparts.

[8] Here the group of third-trimester care onset is broadly defined, which includes a very small number of mothers who reported receiving no care (the extreme case of 'very late onset of care'). Dropping these observations yields very similar results.

Index' which equals 1 for the women with 'inadequate' or 'intermediate' care by this index (the reference group receives 'adequate' or 'adequate plus' care).[9] In general, women with both late care initiation and low frequency of visits are rated to almost the same degree as 'having inadequate care' by the last two measures on poor utilization of prenatal care.

The methods by which we construct the maternal outcomes merit further discussion. First, a newly issued guideline by the Institute of Medicine provides the recommended gestational weight gain ranges which vary by pre-pregnancy BMI category (IOM, 2009). By this guideline, we define two types of unhealthy gestational weight gain: 'inadequate' (weight gain below the ranges) and 'excessive' (weight gain above the ranges). Second, since onset of prenatal care in the first trimester will promote smoking cessation later in pregnancy, we code the women smoking in the second or third trimester as 'prenatal smokers' in the baseline analysis and hypothesize a positive association between late care initiation and this outcome variable. Additional sensitivity analysis considers the women smoking in any trimester as 'prenatal smokers'.[10] Third, as to maternal postnatal weight, we regroup the standard BMI categories into 'underweight' (<18.5 kg/m^2), 'normal weight' (reference, 18.5-25 kg/m^2), and 'overweight or obesity' (>25 kg/m^2), since both overweight and obesity are considered having more body fat than is optimally healthy. Fourth, we use simple indicator variables on all the other adverse

[9] Compared to the Kessner index, the APNCU index is less weighted toward care initiation (e.g., the cutoff for timely onset of care is the fourth month instead of the third month during pregnancy) while placing a higher standard on the expected visits in defining adequate prenatal care.

[10] Early care onset is supposed to promote smoking cessation right after care initiation (even during the first trimester). To precisely examine this effect, ideally we should classify the women who quit smoking within the first trimester right after the care onset as nonsmokers ('type 1 quitters' with smoking cessation due to prenatal care) and the women who ceased smoking before the care onset within the first trimester as smokers ('type 2 quitters' who ceased smoking without prenatal care). However, we are unable to distinguish the two types of quitters who stopped smoking in the first trimester, since the exact time of smoking cessation is not reported. In this sense, neither measure above of 'prenatal smokers' is perfect. The first measure (smoking beyond the first trimester) correctly codes the 'type 1 quitters' as nonsmokers but miscodes the 'type 2 quitters' as nonsmokers. In contrast, the second one (smoking in any trimester) miscodes the 'type 1 quitters' as smokers yet correctly codes the 'type 2 quitters' as smokers.

prenatal and postnatal outcomes (PROM, onset of precipitous labor, no breastfeeding, and postpartum smoking).

3. METHOD

To assess the relation between prenatal care and maternal prenatal health plus health behaviors, we apply the following baseline specification

$$Y_{ij} = \alpha_0 + \alpha_1 Prenatal\ Care_{ij} + \alpha_2 X_{ij} + \alpha_3 W_{ij} + \mu_i + \varepsilon_{ij} \quad (1)$$

where Y_{ij} is one of the five adverse prenatal outcomes for mother i with infant j and $prenatal\ care$ is one measure on poor utilization of prenatal care mentioned above for the same mother and infant. X is a rich set of birth-variant characteristics of the mother (age, education, marital status, WIC enrollment, infant delivery payment types, year and month indicators),[11] the father (age, education, race, ethnicity), and the infant (gender, birth order). W is a vector of the mother's health and behavior prior to pregnancy (pre-pregnancy BMI and smoking). And μ_i is the fixed effect of mother i, which captures the unobserved characteristics of the mother and her family across pregnancies. Since this unobserved hetergoneity is very likely to correlate with both prenatal care utilization and maternal outcomes, it is important to control for μ_i to yield unbiased estimates on α (the effects of prenatal care). Because having bad health outcomes in the last pregnancy can lead women to change body weight or quit smoking before the current conception, this 'feedback' effect suggests pre-pregnancy BMI and smoking (the vector W) in

[11] Maternal race and ethnicity are birth invariant and not used in models with mother fixed effects. Still, we report their statistics for the descriptive analysis below. In addition, the time dummies vary by the maternal dependent variable: for the prenatal outcomes we use the year and month of conception, while for the postnatal outcomes we apply indicators of the year and month when such outcomes were measured.

equation (1) may not be strictly exogenous. Nevertheless, this will not bias the results on the key parameter α_1, if strict exogeneity holds for prenatal care (Wooldridge, 2002).[12]

When studying the postnatal outcomes, we begin with equation (1) and then consider several variants of this specification. First, the postpartum outcomes examined in this study also capture some features of maternal investment on infants. It opens a potential way connecting prenatal care with postnatal health and health behaviors: through modifying the effects of prenatal shocks on infants, prenatal care utilization may influence mother's investment (e.g., breastfeeding, smoking) in response to newborn health endowment.[13]This indirect mechanism, while interesting, does not reflect the direct lasting effect of prenatal care on mother's own postnatal health (via prenatal health education or intervention). If the main interest lies in the direct effect, we can isolate it by controlling infant birth weight (BW):

$$Postnatal\ Outcome_{ij} = \alpha_0 + \alpha_1 Prenatal\ Care_{ij} + \alpha_2 X_{ij} + \alpha_3 W_{ij} + \alpha_4 BW_{ij} + \mu_i + \varepsilon_{ij} \quad (2)$$

where the dependent variable is no breastfeeding, postnatal unhealthy body weight, or postpartum smoking. Below we also try adding other birth outcomes in this specification.

Second, recall in sample construction, we use maternal weight and smoking before the current pregnancy as the proxies for postpartum weight and smoking after the last childbirth. So when the dependent variable is specifically postpartum weight or smoking in equation (1) or (2), one element in the W vector is essentially a lagged dependent variable and not strictly exogenous.[14] In particular, as we apply equation (2), a similar 'feedback effect' story suggests

[12] Indeed, we find none of the adverse prenatal outcomes during the last pregnancy significantly affect prenatal care utilization in the current pregnancy.

[13] Two recent studies (Currie and Almond, 2011; Almond and Mazumder, 2013) review the literature on responsive investments with regard to newborn health endowment.

[14] As mentioned above, here we examine two types of postnatal unhealthy body weight ('underweight', 'overweight or obesity'). So the W vector accordingly consists of two pre-pregnancy body weight indicators plus one indicator of pre-pregnancy smoking.

neither the other elements in W nor newborn birth weight is strictly exogenous. Although this implies biased coefficient estimates on $W(\hat{\alpha}_3)$ and $BW\ (\hat{\alpha}_4)$, again it won't bias the key coefficient estimate on prenatal care. As a further robustness check, we remove such unimportant biasness to see if the results are different. Specifically, we difference the fixed effects μ_i in equation (2), assume W and BW sequentially exogenous, and use their lagged values as instruments for ΔW and ΔBW(Wooldridge, 2002; Cameron and Trivedi, 2005).

4. RESULTS

Table I displays the descriptive statistics of the maternal prenatal outcomes plus breastfeeding, the prenatal care measures, and the maternal and infant characteristics. Column (1) shows 22% of the mothers of all the newborns had inadequate gestational weight gain and 50% of them gained excessive weight. Moreover, 14% of the mothers smoked during pregnancy and one-third of them did not breastfeed their babies. In contrast, both PROM and precipitous labor are less prevalent among the pregnant women. As to prenatal care utilization, while about 30% of the mothers initiated care beyond the first trimester, two-thirds had low frequency of visits and about 30-40% of them had inadequate care by the APNCU/Kessner Index. The other columns break down the sample by trimester of care onset. Compared to the women with early care initiation (column 2), the women who started care visits beyond the first trimester were more likely to take an insufficient number of visits or receive inadequate care by either index, have inadequate gestational weight gain, smoke during pregnancy, experience PROM or precipitous labor but less likely to breastfeed the infant after delivery (columns 3 and 4). Such women with late care onset were younger, less educated, as well as more likely to be Black/Hispanic, unmarried, and enroll in WIC/Medicaid.

[Insert Table I Here]

Table AI (in the appendix) reports the summary statistics of the smaller sample on postpartum body weight and smoking. After childbirth, about 4% of the mothers were underweight; 45% of them were overweight or obese; and about one-fifth smoked cigarettes. The mothers with care initiation beyond the first trimester were more likely to be underweight or smoke after giving birth. Similar to Table I, late onset of care is positively correlated with low frequency of care visits and low socioeconomic status of the mother. Further subsample analysis (not shown) indicates sufficiency on the number of care visits also appears to make a difference in the maternal prenatal and postnatal health outcomes.

Table II represents the baseline estimates on the effects of prenatal care on the five prenatal outcomes by specification (1). Column (1) shows second-trimester and third-trimester care onset increase the risk of inadequate gestational weight gain by 0.8 and 2.8 percentage points (on the base of 0.22), respectively. The results on low frequency of visits and inadequate care by either index suggest an increase of 1.1 to 2.2 percentage points on inadequate weight gain (panels 2 to 4, column 1). In contrast, the association between prenatal care and excessive weight gain is weak and insignificant (column 2). Column (3) demonstrates that the women who initiate care beyond the first trimester are more likely to smoke in the second or third trimester by 0.6-1.4 percentage points, a 4 to 10 percent increase relative to the sample mean of smoking. Again, the effects are stronger for the women who delay obtaining care until the third trimester or have no care. Likewise, late onset of prenatal care significantly increases the risks of PROM and precipitous labor by 13%-27% of the sample means (columns 4 and 5). With respect to the other prenatal care measures, panels 2 to 4 show low frequency of visits and inadequate care are associated with a 6 to 27 percent increase in the incidences of prenatal smoking, PROM, and precipitous labor. We have also alternatively defined the women smoking in any trimester as

prenatal smokers, with the results (suppressed) close to column (5) across all the prenatal care measures.

[Insert Table II Here]

Table III explores two subsamples by number of sibling births. For both the two-birth mothers and three-birth mothers, poor prenatal care utilization is significantly associated with higher risks of inadequate weight gain, prenatal smoking, PROM, and precipitous labor, regardless of which care measure we use. Table IV reports the estimates by state. They are also consistent with the baseline results in Table II. Furthermore, the estimated impacts of poor prenatal care utilization on the four prenatal outcomes (relative to respective sample means) are larger for women in the state of Washington than Pennsylvania. The heterogeneous effects may be attributed to the cross-state difference in the quality of prenatal care or other supply side factors (not coded in the data). Additional subsample analysis as above reveals a weak and insignificant relation between prenatal care and excessive weight gain (not shown). Overall, the robust findings on gestational weight gain suggest receipt of timely and sufficient prenatal care is more effective in reducing deficient nutrient intake than curbing over-nutrition during pregnancy.

[Insert Table III Here]

[Insert Table IV Here]

Table V reports the association between prenatal care and postnatal breastfeeding. Column (1) indicates care onset beyond the first trimester increases the risk of no breastfeeding by 0.8 to 3.1 percentage points, or by 3 to 11 percent. The women with low frequency of care visits and inadequate care by either index are also 0.9 to 1.7 percentage points less likely to breastfeed the newborn. Column (2) adds newborn birth weight to control for responsive investments by specification (2), with the results close to column (1). The new estimates on care initiation and

inadequacy (by the Kessner index) are slightly smaller. Moreover, the findings are similar when we include alternative birth outcomes such as low birth weight and preterm birth (not shown for brevity). Overall, the isolated direct effect of prenatal care (e.g., the lasting educational effect of prenatal health education) is the main driving force of the estimated total effect (column 1). The other columns report the results by state and by number of birth. All of them are consistent with the case using the full sample. Interestingly, the effects of poor prenatal care are again stronger for the Washington women relative to the Pennsylvania women.

[Insert Table V Here]

Table VI investigates the other postnatal maternal outcomes. Column (1) shows both late initiation of prenatal care and low frequency of care visits raise the likelihood of postnatal underweight by about 1 to 1.3 percentage points (25 to 33 percent on the base of 0.04). Similar results hold for the two measures on care inadequacy.[15] Column (3) displays little effect of prenatal care on postnatal overweight or obesity. Column (5) suggests poor prenatal care utilization due to late onset or low frequency of visits (or combinations of the two) increases the risk of maternal smoking postpartum by about 3 to 10 percent. Controlling for newborn birth weight in the even-numbered columns yields very similar results, suggesting again the primary contributor to the baseline estimates above is the direct effect of prenatal care on women's own health. We also perform two additional robustness checks, with the full results available upon request. One, findings by state are generally consistent with the baseline results, although the estimates of the Washington subsample (with a small sample size) are insignificant. Two, all the

[15] We also find suggestive evidence that the women who were underweight before pregnancy but received inadequate prenatal care are less likely to maintain a healthy weight postpartum and the normal weight women with inadequate care are at an elevated risk of becoming underweight after childbirth.

results in the even-numbered columns are robust, when we use the lagged values of the two postnatal body weight indicators and newborn birth weight as instruments after taking the first difference of equation (2).

[Insert Table VI Here]

Table VII summarizes the results when both the onset and frequency of care simultaneously are controlled in the regressions. Columns (1) to (5) examine the prenatal outcomes. Compared with the women with both timely and sufficient visits, the women having late onset of care but a sufficient number of visits still have significantly higher risks of inadequate gestational weight gain, prenatal smoking, PROM and precipitous labor. The point estimates on late care onset are slightly smaller than their counterparts in panel 1 and 2 of Table II. In addition, the magnitude of the estimates ranges from 3 to 23 percent (relative to the means of the outcome variables). Conditioning on early care onset, low frequency of care visits still moderately increases the probabilities of the above four adverse prenatal outcomes by 4 to 10 percent. Similar patterns emerge for the postnatal measures. Column (6) suggests poor prenatal care utilization in only one dimension drives up the likelihood of no breastfeeding by 2 to 10 percent. By column (7), the corresponding adverse effects on postnatal underweight are found to be more sizable, ranging from 20 to 28 percent. Again, the association between prenatal care and excessive weight gain or high BMI postpartum is weak and insignificant (columns 2 and 8). Finally, column (9) displays while delayed care initiation still significantly increases maternal postpartum smoking conditioning on sufficient visits, the effect of low frequency of care visits on postnatal smoking is insignificant for the women with early onset of prenatal care.

[Insert Table VII Here]

5. CONCLUSION

While many economic studies have explored the role of prenatal care in infant health production, the literature is meager and equivocal about the effects of prenatal care on the mother. This research contributes to this understudied but important arena using a rich and large data of sibling newborns delivered by 0.17 million mothers. We find, first, about 30% of the mothers initiated care beyond the first trimester, two-thirds had low frequency of care visits, and about 30-40% of them had inadequate care by the two care utilization indexes. Second, the baseline estimation with mother fixed effects shows poor utilization of prenatal care due to late care onset or low frequency of visits significantly increases the risks of inadequate gestational weight gain, prenatal smoking, PROM, precipitous labor, no breastfeeding, postnatal underweight, and postpartum smoking. The magnitude of the estimates (relative to the corresponding bases) is meaningful, which varies from 3 to 33 percent.

We find the benchmark results are robust in various sensitivity checks, which include integrating the timing and quantity of care visits in different ways, stratifying the sample by state or number of sibling births, controlling for maternal responsive investments, applying alternative specifications, etc. In particular, poor prenatal care utilization in only one element (either late onset or low frequency of visits) still in general negatively affects maternal health and health behaviors to a nontrivial degree. Such new evidence on maternal health production suggests both early onset of care and having a sufficient number of care visits matter for improving health of the mother. Moreover, the empirical method used in this study can be readily applied to investigate the other elements of prenatal care (e.g., quality), additional maternal pregnancy complications (with detection and treatment fully reported), and health outcomes of the mothers in other states.

Finally, the high prevalence of poor prenatal care utilization among mothers reported above is certainly an important public health concern. It will be interesting to explore the causes of such variation (both within and across markets) by subsequent research (Skinner, 2012). If the demand-side factors such as income and access are important in explaining underuse of prenatal care, then, further expanding insurance coverage can be an effective intervention. However, inadequate care utilization and the associated welfare loss may mainly come from incomplete information on maternal health production which has led some physicians to underestimate the incremental benefits of better prenatal care to expectant mothers (Phelps, 2000). In this case, policies which increase diffusion of the true productivity of timely and sufficient care plus promote the latest practice guideline for prenatal care (Alexander and Kotelchuck, 2001; ACOG, 2012) among health professionals may significantly reduce the efficiency loss due to under-provision of prenatal care.

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Table I. Descriptive statistics: adverse maternal health outcomes and health behaviors in pregnancy or right after childbirth

	(1) Full sample (Num of mothers=166,364)		(2) Care onset in the first trimester		(3) Care onset in the second trimester		(4) Care onset in the third trimester	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Inadequate weight gain	0.22	(0.41)	0.21	(0.40)	0.25	(0.43)	0.29	(0.46)
Excessive weight gain	0.50	(0.50)	0.51	(0.50)	0.48	(0.50)	0.46	(0.50)
Prenatal smoking	0.14	(0.35)	0.12	(0.32)	0.19	(0.39)	0.25	(0.43)
Premature rupture of membranes	0.03	(0.18)	0.03	(0.17)	0.04	(0.19)	0.04	(0.19)
Precipitous labor	0.04	(0.19)	0.03	(0.18)	0.05	(0.21)	0.06	(0.23)
No breastfeeding	0.28	(0.45)	0.26	(0.44)	0.34	(0.47)	0.42	(0.49)
Care onset in the second trimester	0.22	(0.42)	0.00	(0.00)	1.00	(0.00)	0.00	(0.00)
Care onset in the third trimester	0.06	(0.23)	0.00	(0.00)	0.00	(0.00)	1.00	(0.00)
Low frequency of care visits	0.66	(0.47)	0.59	(0.49)	0.82	(0.38)	0.97	(0.18)
Inadequate care by the APNCU Index	0.33	(0.47)	0.21	(0.41)	0.55	(0.50)	1.00	(0.00)
Inadequate care by the Kessner Index	0.41	(0.49)	0.18	(0.39)	1.00	(0.00)	1.00	(0.00)
Mother's age	27.61	(5.59)	28.20	(5.38)	26.19	(5.82)	25.51	(5.80)
Mother non-Hispanic White	0.83	(0.38)	0.86	(0.35)	0.75	(0.43)	0.68	(0.47)
Mother non-Hispanic Black	0.08	(0.27)	0.05	(0.22)	0.13	(0.34)	0.20	(0.40)
Mother Hispanic	0.04	(0.21)	0.04	(0.18)	0.07	(0.25)	0.07	(0.26)
Mother Asian	0.03	(0.16)	0.03	(0.16)	0.03	(0.16)	0.02	(0.15)
Mother education=12 years	0.25	(0.43)	0.23	(0.42)	0.31	(0.46)	0.32	(0.47)
Mother education=13-15 years	0.26	(0.44)	0.28	(0.45)	0.24	(0.42)	0.21	(0.41)
Mother education ≥16 years	0.34	(0.47)	0.40	(0.49)	0.19	(0.39)	0.13	(0.33)
Mother married	0.70	(0.46)	0.76	(0.42)	0.56	(0.50)	0.46	(0.50)
Mother in WIC	0.33	(0.47)	0.29	(0.45)	0.44	(0.50)	0.42	(0.49)
Mother in Medicaid	0.26	(0.44)	0.22	(0.41)	0.38	(0.49)	0.44	(0.50)
Maternal pre-pregnancy obese	0.19	(0.39)	0.19	(0.39)	0.19	(0.40)	0.20	(0.40)
Maternal pre-pregnancy overweight	0.23	(0.42)	0.23	(0.42)	0.23	(0.42)	0.24	(0.43)
Maternal pre-pregnancy underweight	0.05	(0.21)	0.04	(0.21)	0.06	(0.23)	0.06	(0.24)
Maternal smoking before pregnancy	0.21	(0.41)	0.19	(0.39)	0.25	(0.43)	0.30	(0.46)
Infant male	0.51	(0.50)	0.51	(0.50)	0.52	(0.50)	0.51	(0.50)
Infant birth order	2.14	(1.22)	2.03	(1.05)	2.35	(1.45)	2.66	(1.79)
Number of sibling births	351,935		254,314		78,191		19,430	

Notes: The full sample, constructed from natality birth records, consists of all the mothers with two or three live births in the state of Pennsylvania in 2003-2010 and in the state of Washington in 2003-2006. Additional birth variant control variables (not shown) include father's age, race, ethnicity, and education.

Table II. Effects of prenatal care on prenatal health and health behaviors

	(1) Inadequate weight gain	(2) Excessive weight gain	(3) Prenatal Smoking	(4) PROM	(5) Precipitous Labor
Panel 1: care onset					
Care onset in the second trimester	0.008***	0.002	0.006***	0.004***	0.005***
	(0.002)	(0.003)	(0.001)	(0.001)	(0.001)
Care onset in the third trimester	0.028***	-0.004	0.014***	0.008***	0.010***
	(0.004)	(0.005)	(0.002)	(0.002)	(0.002)
Panel 2: number of visits					
Low frequency of care visits	0.011***	-0.003	0.009***	0.004***	0.005***
(Insufficient number of care visits)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
Panel 3: care adequacy 1					
Inadequate care	0.022***	0.001	0.010***	0.003***	0.005***
(by the APNCU index)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
Panel 4: care adequacy 2					
Inadequate care	0.019***	-0.002	0.009***	0.008***	0.004***
(by the Kessner index)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)
Maternal and paternal control variables	Y	Y	Y	Y	Y
Infant gender and birth order	Y	Y	Y	Y	Y
Mother fixed effects	Y	Y	Y	Y	Y
Sample mean (prenatal outcomes)	0.22	0.50	0.14	0.03	0.04
Number of mothers	166,364	166,364	166,364	166,364	166,364
Number of sibling births	351,935	351,935	351,935	351,935	351,935

Notes: All the regressions use the full sample of mothers with two or three births. The maternal control variables include mother's age, education, marital status, WIC enrollment, delivery payment types, pre-pregnancy BMI and smoking, year and month of conception; the paternal control variables are father's age, race, ethnicity, and education. Robust standard errors clustered at the mother's level are reported in parentheses. *Significant at 10% level. ** Significant at 5% level. *** Significant at 1% level.

Table III. Effects of prenatal care on prenatal health and health behaviors: by number of births

	Mothers with two births				Mothers with three births			
	(1) Inadequate weight gain	(2) Prenatal smoking	(3) PROM	(4) Precipitous labor	(5) Inadequate weight gain	(6) Prenatal smoking	(7) PROM	(8) Precipitous labor
Panel 1: care onset								
Care onset in the second trimester	0.007***	0.006***	0.004***	0.003**	0.010*	0.005*	0.004*	0.009***
	(0.003)	(0.001)	(0.001)	(0.001)	(0.005)	(0.003)	(0.002)	(0.003)
Care onset in the third trimester	0.028***	0.015***	0.006**	0.011***	0.032***	0.010**	0.012**	0.010**
	(0.005)	(0.003)	(0.002)	(0.003)	(0.009)	(0.005)	(0.006)	(0.005)
Panel 2: number of visits								
Low frequency of care visits	0.009***	0.010***	0.004***	0.004***	0.017***	0.004**	0.004*	0.007***
(Insufficient number of visits)	(0.002)	(0.001)	(0.001)	(0.001)	(0.004)	(0.002)	(0.002)	(0.002)
Panel 3: care adequacy 1								
Inadequate care	0.022***	0.011***	0.003**	0.004***	0.022***	0.006***	0.004**	0.010***
(by the APNCU index)	(0.002)	(0.001)	(0.001)	(0.001)	(0.004)	(0.002)	(0.002)	(0.002)
Panel 4: care adequacy 2								
Inadequate care	0.018***	0.010***	0.008***	0.004***	0.021***	0.006***	0.008***	0.007***
(by the Kessner index)	(0.002)	(0.001)	(0.001)	(0.001)	(0.004)	(0.002)	(0.002)	(0.002)
Maternal and paternal control variables	Y	Y	Y	Y	Y	Y	Y	Y
Infant gender and birth order	Y	Y	Y	Y	Y	Y	Y	Y
Mother fixed effects	Y	Y	Y	Y	Y	Y	Y	Y
Sample mean (prenatal outcomes)	0.22	0.15	0.03	0.04	0.23	0.08	0.04	0.04
Number of mothers	147,157	147,157	147,157	147,157	19,207	19,207	19,207	19,207
Number of sibling births	294,314	294,314	294,314	294,314	57,621	57,621	57,621	57,621

Notes: Columns (1)-(4) study the mothers with two births; and columns (5)-(8) examine the mothers with three births. The maternal control variables include mother's age, education, marital status, WIC enrollment, delivery payment types, pre-pregnancy BMI and smoking, year and month of conception; the paternal control variables are father's age, race, ethnicity, and education. Robust standard errors clustered at the mother's level are reported in parentheses. *Significant at 10% level. ** Significant at 5% level. *** Significant at 1% level.

Table IV. Effects of prenatal care on adverse prenatal health and health behavior: by state

	Mothers in PA				Mothers in WA			
	(1) Inadequate weight gain	(2) Prenatal smoking	(3) PROM	(4) Precipitous labor	(5) Inadequate weight gain	(6) Prenatal smoking	(7) PROM	(8) Precipitous labor
Panel 1: care onset								
Care onset in the second trimester	0.006**	0.006***	0.003***	0.004***	0.025***	0.008***	0.011***	0.012***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.007)	(0.003)	(0.003)	(0.004)
Care onset in the third trimester	0.024***	0.014***	0.009***	0.009***	0.063***	0.017***	0.014*	0.015**
	(0.005)	(0.003)	(0.002)	(0.002)	(0.015)	(0.006)	(0.008)	(0.008)
Panel 2: number of visits								
Low frequency of care visits	0.011***	0.009***	0.003***	0.005***	0.009*	0.007***	0.006**	0.005*
(Insufficient number of visits)	(0.002)	(0.001)	(0.001)	(0.001)	(0.005)	(0.002)	(0.003)	(0.003)
Panel 3: care adequacy 1								
Inadequate care	0.020***	0.011***	0.002**	0.005***	0.032***	0.007***	0.007**	0.007**
(by the APNCU index)	(0.002)	(0.001)	(0.001)	(0.001)	(0.005)	(0.002)	(0.003)	(0.003)
Panel 4: care adequacy 2								
Inadequate care	0.017***	0.010***	0.007***	0.003***	0.032***	0.007***	0.012***	0.008***
(by the Kessner index)	(0.002)	(0.001)	(0.001)	(0.001)	(0.006)	(0.002)	(0.003)	(0.003)
Maternal and paternal control variables	Y	Y	Y	Y	Y	Y	Y	Y
Infant gender and birth order	Y	Y	Y	Y	Y	Y	Y	Y
Mother fixed effects	Y	Y	Y	Y	Y	Y	Y	Y
Sample mean (prenatal outcomes)	0.22	0.15	0.03	0.04	0.23	0.08	0.04	0.04
Number of mothers	141,426	141,426	141,426	141,426	24,938	24,938	24,938	24,938
Number of sibling births	301,234	301,234	301,234	301,234	50,701	50,701	50,701	50,701

Notes: Columns (1)-(4) focus on the mothers in the state of Pennsylvania; and columns (5)-(8) examine the mothers in the state of Washington. The maternal control variables include mother's age, education, marital status, WIC enrollment, delivery payment types, pre-pregnancy BMI and smoking, year and month of conception; the paternal control variables are father's age, race, ethnicity, and education. Robust standard errors clustered at the mother's level are reported in parentheses. *Significant at 10% level. ** Significant at 5% level. *** Significant at 1% level.

Table V. Effects of prenatal care on breastfeeding

	Dependent variable: no breastfeeding					
	(1) Full sample	(2) Full sample	(3) Mothers in PA	(4) Mothers in WA	(5) Mothers with two births	(6) Mothers with three births
Panel 1: care onset						
Care onset in the second trimester	0.008***	0.007***	0.006***	0.017***	0.008***	0.008*
	(0.002)	(0.002)	(0.002)	(0.005)	(0.002)	(0.004)
Care onset in the third trimester	0.031***	0.030***	0.029***	0.041***	0.032***	0.026***
	(0.004)	(0.004)	(0.004)	(0.011)	(0.005)	(0.008)
Panel 2: number of visits						
Low frequency of care visits	0.009***	0.009***	0.008***	0.017***	0.010***	0.007*
(Insufficient number of visits)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.004)
Panel 3: care adequacy 1						
Inadequate care	0.017***	0.017***	0.014***	0.032***	0.019***	0.010***
(by the APNCU index)	(0.002)	(0.002)	(0.002)	(0.004)	(0.002)	(0.004)
Panel 4: care adequacy 2						
Inadequate care	0.013***	0.012***	0.011***	0.026***	0.014***	0.011***
(by the Kessner index)	(0.002)	(0.002)	(0.002)	(0.004)	(0.002)	(0.004)
Maternal and paternal control variables	Y	Y	Y	Y	Y	Y
Infant gender and birth order	Y	Y	Y	Y	Y	Y
Infant birth weight	N	Y	N	N	N	N
Mother fixed effects	Y	Y	Y	Y	Y	Y
Sample mean (no breastfeeding)	0.28	0.28	0.31	0.10	0.28	0.30
Number of mothers	166,364	166,364	141,426	24,938	147,157	19,207
Number of sibling births	351,935	351,935	301,234	50,701	294,314	57,621

Notes: Columns (1)-(2) use the full sample of mothers; columns (3)-(4) stratify the sample by state; columns (5)-(6) stratify the sample by number of births. The maternal control variables include mother's age, education, marital status, WIC enrollment, delivery payment types, pre-pregnancy BMI and smoking, year and month of conception; the paternal control variables are father's age, race, ethnicity, and education. Robust standard errors clustered at the mother's level are reported in parentheses. *Significant at 10% level. ** Significant at 5% level. *** Significant at 1% level.

Table VI. Effects of prenatal care on postpartum body weight and smoking

	Postnatal underweight		Postnatal overweight or obese		Postnatal smoking	
	(1)	(2)	(3)	(4)	(5)	(6)
Panel 1: care onset						
Care onset in the second trimester	0.010***	0.010***	0.002	0.002	0.008**	0.008**
	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)
Care onset in the third trimester	0.012***	0.012***	-0.007	-0.007	0.020***	0.020***
	(0.004)	(0.004)	(0.008)	(0.008)	(0.007)	(0.007)
Panel 2: number of visits						
Low frequency of care visits	0.013***	0.013***	0.001	0.001	0.006*	0.006*
(Insufficient number of visits)	(0.002)	(0.002)	(0.004)	(0.004)	(0.003)	(0.003)
Panel 3: care adequacy 1						
Inadequate care	0.009***	0.009***	0.001	0.001	0.009***	0.009***
(by the APNCU index)	(0.002)	(0.002)	(0.004)	(0.004)	(0.003)	(0.003)
Panel 4: care adequacy 2						
Inadequate care	0.009***	0.009***	0.001	0.001	0.013***	0.013***
(by the Kessner index)	(0.002)	(0.002)	(0.004)	(0.004)	(0.003)	(0.003)
Maternal and paternal control variables	Y	Y	Y	Y	Y	Y
Infant gender and birth order	Y	Y	Y	Y	Y	Y
Infant birth weight	N	Y	N	Y	N	Y
Mother fixed effects	Y	Y	Y	Y	Y	Y
Sample mean	0.04	0.04	0.45	0.45	0.21	0.21
(postpartum body weight and smoking)						
Number of mothers	19,207	19,207	19,207	19,207	19,207	19,207
Number of sibling births	38,414	38,414	38,414	38,414	38,414	38,414

Notes: All the regressions use the sample of the three-birth mothers and their first two births delivered in the sampling period. The maternal control variables include mother's age, education, marital status, WIC enrollment, delivery payment types, pre-pregnancy BMI and smoking, indicators of the year and month when the postnatal outcomes were measured; the paternal control variables are father's age, race, ethnicity, and education. Robust standard errors clustered at the mother's level are reported in parentheses. *Significant at 10% level. ** Significant at 5% level. *** Significant at 1% level.

Table VII. Effects of prenatal care on maternal health outcomes: controlling both the onset and frequency of care visits

	(1) Inadequate weight gain	(2) Excessive weight gain	(3) Prenatal smoking	(4) PROM	(5) Precipitous labor	(6) No breastfeeding	(7) Postnatal underweight	(8) Postnatal overweight or obese	(9) Postnatal smoking
Care onset in trimester two	0.006***	0.002	0.004***	0.004***	0.004***	0.006***	0.008***	0.001	0.007*
	(0.002)	(0.003)	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	(0.004)	(0.004)
Care onset in trimester three	0.026***	-0.003	0.012***	0.007***	0.009***	0.029***	0.009**	-0.010	0.019***
	(0.004)	(0.005)	(0.002)	(0.002)	(0.002)	(0.004)	(0.004)	(0.008)	(0.007)
Low frequency of visits	0.009***	-0.003	0.008***	0.003***	0.004***	0.007***	0.011***	0.001	0.003
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.004)	(0.003)
Maternal and paternal control variables	Y	Y	Y	Y	Y	Y	Y	Y	Y
Infant gender and birth order	Y	Y	Y	Y	Y	Y	Y	Y	Y
Mother fixed effects	Y	Y	Y	Y	Y	Y	Y	Y	Y
Sample mean (outcomes)	0.22	0.50	0.14	0.03	0.04	0.28	0.04	0.45	0.21
Number of mothers	166,364	166,364	166,364	166,364	166,364	166,364	19,207	19,207	19,207
Number of sibling births	351,935	351,935	351,935	351,935	351,935	351,935	38,414	38,414	38,414

Notes: columns (1) to (6) use the full sample of mothers with two or three births; columns (7) to (9) use the sample (a subset of the full sample) which consists of the three-birth mothers and their first two births delivered in the sampling period. The maternal control variables include mother's age, education, marital status, WIC enrollment, delivery payment types, pre-pregnancy BMI and smoking, year and month of conception (columns 7 to 9 instead control for the year and month when the postnatal outcomes were measured); the paternal control variables are father's age, race, and education. Robust standard errors clustered at the mother's level are reported in parentheses. *Significant at 10% level. ** Significant at 5% level. *** Significant at 1% level.

APPENDIX A

Table AI. Descriptive statistics: maternal postpartum unhealthy body weight and smoking

	(1) Full sample (Num of mothers =19,207)		(2) Care onset in the first trimester		(3) Care onset in the second trimester		(4) Care onset in the third trimester	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Maternal postpartum underweight	0.04	0.20	0.04	0.18	0.05	0.22	0.06	0.24
Maternal postpartum overweight or obese	0.45	0.50	0.45	0.50	0.45	0.50	0.47	0.50
Maternal postpartum smoking	0.21	0.41	0.19	0.39	0.25	0.43	0.30	0.46
Care onset in the second trimester	0.27	0.44	0.00	0.00	1.00	0.00	0.00	0.00
Care onset in the third trimester	0.07	0.26	0.00	0.00	0.00	0.00	1.00	0.00
Low frequency of care visits	0.69	0.46	0.60	0.49	0.84	0.36	0.96	0.19
Inadequate care (by the APNCU Index)	0.37	0.48	0.22	0.41	0.58	0.49	1.00	0.00
Inadequate care (by the Kessner Index)	0.46	0.50	0.18	0.39	1.00	0.00	1.00	0.00
Mother's age	28.12	5.28	28.71	5.13	27.03	5.35	26.74	5.52
Mother non-Hispanic White	0.87	0.34	0.90	0.30	0.82	0.39	0.75	0.43
Mother non-Hispanic Black	0.08	0.27	0.06	0.23	0.12	0.33	0.18	0.38
Mother Hispanic	0.03	0.18	0.03	0.16	0.04	0.20	0.05	0.22
Mother Asian	0.01	0.11	0.01	0.11	0.01	0.10	0.01	0.11
Mother education=12 years	0.26	0.44	0.25	0.43	0.30	0.46	0.29	0.45
Mother education=13-15 years	0.24	0.42	0.26	0.44	0.19	0.39	0.20	0.40
Mother education ≥16 years	0.30	0.46	0.38	0.49	0.15	0.36	0.10	0.30
Mother married	0.73	0.44	0.79	0.41	0.65	0.48	0.54	0.50
Mother in WIC	0.34	0.47	0.32	0.47	0.39	0.49	0.39	0.49
Mother in Medicaid	0.29	0.46	0.25	0.43	0.36	0.48	0.42	0.49
Infant male	0.52	0.50	0.52	0.50	0.51	0.50	0.51	0.50
Infant birth order	2.09	1.27	1.91	1.01	2.35	1.52	2.79	1.91
Number of sibling births	38,414		25,454		10,202		2,758	

Notes: The sample consists of the three-birth mothers and their first two births delivered in the state of Pennsylvania in 2003-2010 and in the state of Washington in 2003-2006. Additional birth variant control variables (not shown) include father's age, race, ethnicity, education and maternal pre-pregnancy BMI and smoking.