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Abstract

This study explores the impact of mother's smoking during pregnancy on child bodyweight outcomes, from birth through age five. Prior literature suggests that while maternal smoking during pregnancy leads to a decline in birthweight, the same is linked with higher risk of obesity during early childhood years. To examine the causal interpretation of this health phenomenon, we use a nationally representative sample of children and mothers from the National Longitudinal Surveys and exploit exogenous variation in smoking behavior of mothers prompted by changes in federal and state-level tobacco tax rates at the time of conception. Consistent with prior literature, our instrumental variable estimates suggest that children of smokers weigh significantly less at birth than children of non-smokers (represented by an estimated decline of 0.53 kilograms). However, we do not find any evidence that these children are more likely to be overweight during early childhood. In fact, we find some evidence that negative effects of smoking on children's body weight may linger through preschool years.

Keywords: Maternal smoking; pregnancy; birthweight; overweight; instrumental variable; fixed effect.

JEL codes: I10, I12, I18

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1. INTRODUCTION

The effects of maternal smoking during pregnancy on children's bodyweight outcomes, at birth and at later ages, have been widely explored across several academic disciplines, ranging from epidemiology to economics, medicine, and sociology. Broadly, two main conclusions emerge from the literature. First, there is credible evidence of the negative impact of maternal smoking during pregnancy on children's birthweight (Rosenzweig & Wolpin, 1991; Evans & Ringel, 1999; Bharadwaj et al., 2014). Secondly, the weight disadvantage observed at birth disappears at later childhood ages and smokers' children are, in fact, found to be more likely to be overweight compared to non-smokers' children (e.g. Wideroe et al., 2003).

In our context, it is worth noting that existing evidence on the latter (i.e. the link between maternal smoking and childhood obesity) lacks causal interpretation, given the nature of empirical specifications that have been employed in the related literature. To our understanding, this is broadly due to two reasons. First, the empirical specifications commonly adopted in past literature often fail to account for relevant unobserved confounders that can affect maternal behavior and child well-being. This has rendered a majority of studies descriptive in nature, providing correlational rather than causal evidence (more specifics provided in Section 2). Second, the estimates of the effect of smoking on birthweight and at later ages often comes from cross-sectional samples. To combat both concerns raised in prior evidence, this study exploits instrumental variable (IV) estimation strategy and uses a sample of children born to a nationally representative group of American women. The IV strategy in particular aims to provide causal evidence regarding the relationship between maternal smoking during pregnancy and children's bodyweight from birth through age five.

By utilizing matched mother-child data from the National Longitudinal Survey of Youth (NLSY79) and Child and Young Adult Survey (NLS-CYA), our study presents US-based evidence on the evolutionary impact of maternal smoking during pregnancy on children's bodyweight outcomes from birth through pre-school years. Our empirical strategy is to model children's bodyweight outcomes as a function of their own characteristics, mother's characteristics (including mother's smoking behavior), and family information. One econometric concern in estimating the effect of mothers' smoking on child weight in this framework is the potential endogeneity of mothers' smoking behavior. To address this concern and to estimate the causal relationship of interest, we rely on exogenous variation in maternal smoking participation during pregnancy triggered by Federal and state-level variation in tobacco taxes at the time of conception. In particular, we instrument our key regressor (smoking during pregnancy) with the sum of Federal and State excise tax rates on cigarette consumption (Evans & Ringel, 1999; 2001; Simon, 2016). Our instrument passes the standard tests for strength and validity.

Our contribution is two-fold. First, we confirm the negative effects of maternal smoking during pregnancy on child birthweight documented in prior literature (Rosenzweig & Wolpin, 1991; Evans & Ringel, 1999; Bharadwaj et al., 2014). Second, and more importantly, using the same child-mother sample, we study the evolution of the effects of maternal smoking on children's bodyweight through the pre-school years. In exploring the longer-term effects of maternal smoking during pregnancy, we test the so-called 'catch-up' hypothesis, which postulates that there is an increase in obesity risk among pre-school children who are exposed to prenatal maternal smoking (see Ong et al., 2000; Von Kries et al., 2002).[1]

In line with the findings in the previous literature, our estimates suggest a significant reduction in children's birthweight because of maternal smoking during pregnancy. Specifically, we find

[1] These studies suggest that children of mothers who smoked during pregnancy rapidly grow during early childhood to catch-up with the children of nonsmokers and are in fact more likely to be overweight or obese in later childhood. Ong et al. (2000) focus on likelihood of obesity at the age five whereas Von Kries et al. (2002) focus on the likelihood of being overweight or obese during the age of five to seven years.

that, on average, children of mothers who smoked during pregnancy weigh 0.53 kilogram less than children of mothers who did not smoke while pregnant. However, contrary to what is suggested in the literature, we do not find evidence showing children of smokers are more likely to be overweight in their early childhood years. Instead, in our 2-SLS regression models, we find some evidence for lingering negative effects of maternal smoking during pregnancy on body weight during the pre-school ages.

Our findings, supported by alternative specifications for robustness purposes, have important implications for public health policy. Specifically, our results support and encourage public policies targeted at curbing smoking among expecting mothers and question the causal nature of prior empirical evidence that found a positive relationship between maternal smoking during pregnancy and risk of being overweight or obese in early childhood years. Consequently, it is clear that this is an area with substantial scope for future empirical research.

The remainder of this paper is organized as follows: Section 2 discusses the relevant literature, Section 3 describes the data and variables used in the empirical analysis; Section 4 explains the key elements of the identification strategy; while Section 5 discusses results; and Section 6 presents concluding remarks.

2. RELATED LITERATURE

This paper is related to an extensive literature on the impact of mother's smoking on child health outcomes. Existing studies have linked maternal smoking during pregnancy with a wide array of both short-term and long-term child health consequences. Examples of short-term consequences include premature childbirth, fetal growth restriction, lower birthweight, and infant mortality (Comstock et al., 1971; Meyer & Tonascia, 1977; Cnattingius, 2004). The longer-term health implications for children include higher blood pressure levels, and respiratory and pulmonary disorders (Hanrahan et al., 1992; Stick et al., 1996; Blake et al., 2000; Li et al., 2016); psychological and behavioral problems - such as attention deficit hyperactivity disorder, neurological problems, and poor cognitive functioning (Weitzman, Gortmaker, & Sobol, 1992; Milberger et al., 1996; Wakschlag et al., 1997; Thapar et al., 2003; Huizink & Mulder, 2006; Key et al., 2007; Gilman, Gardener, & Buka, 2008); and increased risks of childhood obesity (Vik et al.,1996; Fried, Watkinson, & Gray, 1999; Von Kries et al., 2002; Oken, Levitan, & Gillman, 2008).

More closely related to our paper are the studies that specifically evaluate the effect of mothers' smoking during pregnancy on child weight outcomes. Among this set of studies, there are two strands of work to draw on.

The first is well established and implies a strong inverse relationship between children's in-utero exposure to maternal smoking and birthweight (Sexton & Hebel, 1984; Permutt & Hebel, 1989; Rosenzweig & Wolpin, 1991; Evans & Ringel, 1999; Harris et al., 2015). A majority of studies in this space exploit exogenous variation in maternal smoking behavior during pregnancy resulting from natural experiments such as smoking regulations (e.g. bans or excise tax on cigarette prices) or controlled trials in an experimental setting where pregnant smokers are randomly assigned to treatment (smoking cessation interventions such as counselling) and control groups.

The second strand of relevant literature is focused on child weight outcomes post-birth and argues that the risk of obesity during childhood, mainly during the pre-school period, is much higher among children whose mothers smoke during pregnancy.[2] The existing evidence in this space is mostly descriptive and thus the associations cannot be interpreted as causal. Our contribution in this literature space is to provide an empirically robust estimate of the causal

[2] See Oken et al. (2008) and Ino (2010) for a comprehensive review of international studies exploring the association between maternal smoking and child obesity.

impact of mothers' smoking during pregnancy on child weight during pre-school ages (two through five). In following two sub-sections, we discuss the two sets of studies, the methods used, and the key findings in greater detail.

2.1 Causal link between maternal smoking during pregnancy and birthweight

For causal interpretation of the estimated relationship between maternal smoking during pregnancy and children's birthweight, the empirical literature has primarily relied on exogenous variation in smoking behavior prompted by natural experiments such as macro-level regulations implemented to reduce smoking (Evans & Ringel, 1999;2001; Lien & Evans, 2005; Kabir et al., 2009; Bharadwaj et al., 2014). For instance, Kabir et al. (2009; Irish evidence) and Bharadwaj et al. (2014; Norwegian evidence) estimate differences in birthweights before and after implementation of smoking bans in the workplace. Both these studies find that smoking bans were effective in improving (increasing) children's birthweight. With respect to U.S. evidence on this front, Lien & Evans (2005) focus on four states (Arizona, Illinois, Michigan, and Massachusetts) that have experienced large excise tax hikes. Importantly, and of relevance to our study, the authors use state-level regulations as the instrumental variable for smoking participation of mothers during pregnancy. Using two-stage least squares (2-SLS) regressions, the Lien & Evans (2005) find that exogenous variation in maternal smoking during pregnancy has an inverse relationship with children's birthweight. In particular, the authors found that smoking during pregnancy leads to a substantial increase in the likelihood of infants having low birthweight (defined as less than 2500 grams or 5.5 pounds approximately).

The use of variation in excise tax regulation on cigarettes was motivated by earlier work of Evans & Ringel (1999; 2001). More specifically, the authors' 1999 study uses federal and state-level excise tax rates on cigarette consumption to perform 2-SLS regressions to estimate the impact of maternal smoking during pregnancy on children's birthweight. Of note is that the authors find their IV regression estimate (of a 0.36 kilogram drop in birthweight when there was maternal smoking during pregnancy) to be closely comparable to the results obtained from a clinical trial where pregnant smokers were randomly assigned to an intervention designed to reduce smoking prior to childbirth. Of further note, the 2-SLS estimates increase in magnitude with inclusion of additional socio-demographic characteristics (see Models 1-3 in Table 3 of Evans & Ringel, 1999) and the absolute values are larger than that of the coefficients obtained from single equation models.

The negative correlation between individuals' smoking behavior and cigarette prices (usually increased through taxation) has been widely examined in the previous literature (Wasserman, 1991; Chaloupka & Werner, 2000; Carpenter & Cook, 2008). In majority of empirical studies on the link between smoking and cigarette prices, the estimated price elasticity of demand for cigarettes is found to be in the range between -0.3 to -0.5 (Chaloupka & Werner, 2000). However, these estimates vary by data sources and estimation methods (Evans & Ringel, 1999).

The large evidence on the negative price elasticity of demand for cigarettes prompts us to expect that women are likely to face substantial health as well as economic cost for smoking when pregnant. Therefore, increase in cigarette prices induced through adoption of higher tax rates can provide added impetus to pregnant smokers to reduce smoking behavior in response.

The validity of using governmental smoking regulations as the instrumental variable in this setting is based on the assumption that exogenously determined macro-level policies are uncorrelated with individual-level unobserved heterogeneities that affect maternal behavior and children's well-being at birth. If this is true, then the policy-induced natural experiments can also be utilized to study the effects of maternal smoking during pregnancy on later childhood outcomes as well. Further motivation for using state-level variation in tobacco tax rates as IV for evaluating the effects of prenatal smoking among mothers on children's long-term outcomes is provided by a recent study by Simon (2016). The study finds that exogenous increase in the state-level cigarette tax rates during pregnancy improves children's long-term health measured in terms of sick leaves from school and incidence of asthma, doctor visits, and hospitalizations.

To conclude this strand of literature review, it is worth mentioning that some studies in this space have also employed alternative empirical strategies such as Fixed Effects (FE) regressions and have found similar results. For example, Rosenzweig & Wolpin (1991), exploit within-mother (across childbirths) variation in prenatal smoking behavior to control for confounding influences arising from mothers' time-invariant characteristics that may affect their prenatal behavior (including smoking) as well as their children's well-being. The authors' findings support the negative relationship between maternal smoking during pregnancy and children's birthweight.

2.2 <u>Association between maternal smoking during pregnancy and early childhood weight</u>

Upon close examination of the extant literature, while there's an overwhelming evidence that prenatal exposure to maternal smoking results in fetal growth retardation (Miller et al., 1976; Cnattingius, 2004; Ward et al., 2007), the same is associated with stunted growth (in terms of height), higher risk of adiposity (skin thickness), and obesogenic growth during later childhood (Oken et al., 2008; Ino, 2010; Suzuki et al., 2011; Howe et al., 2012; Li et al., 2016). Taken together, the literature on maternal smoking during pregnancy indicates that the evolving effects likely prompt smokers' children to experience a greater risk of being overweight (or obese) as they grow up.

Focusing on existing US-based evidence, Whitaker (2004) and Salsberry & Reagan (2007) present the earliest evidence on the positive association between maternal smoking during pregnancy and an increased risk of being overweight among children. While Whitaker's (2004) study focused at children aged 2-4, Salsberry & Reagan's (2007) population of interest included children aged 2-8. In both studies, the indicator for whether a mother smoked during pregnancy was treated as one of the prenatal determinants of children's bodyweight outcomes rather than the regressor of interest. Similar to our study, Salsberry & Reagan (2007) use linked matched mother-child information from the National Longitudinal Surveys (up to the survey year 2002) to explore the prenatal determinants of risks of having excess weight among children. Estimating multivariate logistic regressions, the authors find smoking during pregnancy (among a range of other prenatal and demographic characteristics) to have a positive and statistically significant association with the likelihood of child being overweight.

Subsequent analysis that have confirmed Salsberry & Reagan's (2007) findings for the U.S., include Chen et al. (2005) and Oken et al. (2005). In these studies, the relevant odds ratio estimated, which represents the risk of being overweight for children whose mothers smoked during pregnancy (compared to non-smokers' children), ranges between 1.21 and 2.20 (Ino, 2010).

With respect to the international evidence, the majority of relevant studies present evidence from developed economies in Europe (e.g. Germany, Sweden, Norway, and Spain) and Australia. Table 1 summarizes some of the empirical findings from selected key studies in the extant literature.

Table 1

Summary of findings from international literature on the association between maternal smoking during pregnancy and risk of being overweight during childhood

Authors	Country (Data period)	Population of interest	Estimation strategy	Estimated risk of overweight (Smokers Vs Non-smokers)
Maessen et al. (2019)	Sweden (children born in 1991-2009)	Adult daughters aged 18-26.	Generalized linear model regression	ARR:1.48
Wideroe et al. (2003)	Sweden; Norway (pregnancies in 1986-1992)	Children aged 5	Logistic regression	RR: 2.5
Von Kries et al. (2002)	Germany (school entry data in 1999-2000)	Children aged 5-7	Logistic regression	AOR: 1.43 for overweight; 2.06 for obesity
Mendez et al. (2008)	Spain (children born in 1997-1998)	Children aged 5-7	Logistic regression	AOR (smoking in first trimester): 2.65 AOR (smoking later in pregnancy): 1.88
Al Mamun et. al (2006)	Australia (children born in 1981-1984)	Children aged 14	Logistic regression	OR: 1.31 OR for obesity: 1.42

Notes: OR: Odds ratio; AOR: Adjusted odds ratio; RR: Relative risk ratio; ARR: Adjusted relative risk ratio

It is important to note, that most of the studies discussed thus far attempt to control for ‘confounding’ factors by including a wide range of observed family-level characteristics as covariates in their regression models such as mother’s prenatal attributes and family’s socio-economic status. However, the estimated relationships between smoking during pregnancy and children’s likelihood of being overweight may still suffer potential endogeneity bias for not accounting for unobserved heterogeneities that can be related to both maternal behavior and child outcomes. For instance in a recent paper, Bharadwaj et al. (2018) conceptualize how parents respond to children’s birth outcomes. The authors demonstrate the possibility that parents may engage in ‘compensating behavior’ by reallocating parental investments to children born with poorer birth outcomes (such as low birth weight) to mitigate potential long-term differences in siblings’ outcomes. Alternatively, parents may choose to direct more resources to children with higher endowment at birth ('reinforcing behavior'). Consequently, this can amplify the differences between offspring born with different birth endowments. To this end, using administrative data from Chile, the authors find empirical evidence in support of a compensatory framework. Further, using the National Longitudinal Survey data, Restrepo (2016) adds to the existing empirical evidence on parental response to children's birth endowment. The author finds that parents' compensating behavior can vary by their socio-economic characteristics such as mothers' education. These empirical findings hold relevance to our research objective. This is because, with respect to children's bodyweight during preschool years, the evidence of 'catching-up' by smokers' children (who are born with lower birthweight) with children of non-smoker mothers can potentially be attributed to parents' compensating behavior which can further be explained by unobserved attributes such as innate characteristics or attitudes. If this argument holds true, the literature evidence linking maternal smoking during pregnancy with child risk of being overweight can be argued to be associational rather than causal.

In general, it appears clear that compared to the strong causal evidence with regard to children's birthweight, the empirical findings in terms of impact of maternal smoking during pregnancy on body weight during childhood years are mostly descriptive in nature. We therefore contribute to the current knowledge base by combining the two aforementioned strands of the literature and exploring the validity of the catch-up phenomenon using a panel of children born to a nationally representative sample of American mothers. We employ established empirical techniques to exploit exogenous variation in maternal smoking behavior to test if there is a causal influence of prenatal exposure to maternal smoking on the risk of being overweight during pre-school ages.

3. DATA: THE NATIONAL LONGITUDINAL SURVEYS

We link mothers' information from the original cohort of the NLSY79 with information on their biological children from the NLS-CYA. Administered by the Bureau of Labor Statistics, the National Longitudinal Surveys are widely utilized for social and policy-relevant empirical research. The surveys incorporate a wide range of socio-economic and demographic information on a nationally representative sample of 12,686 individuals, who were born between 1957 and 1964. Commencing in 1979, the surveys were administered annually until 1994, and biennially thereafter. The NLS-CYA commenced in 1986 and are conducted biennially. These surveys document health, schooling, behavioral, as well as family-specific information of biological children born to women in the original NLSY79 cohort.

Upon linking the two surveys and conducting a list wise deletion based on all relevant variables, our total matched sample includes 7,174 children born to 3,881 mothers. However, depending on the availability of the data required to test the relationship of interest, we apply further restrictions to this sample.

Our main analysis has two elements: (i) impact of mothers' smoking during pregnancy on children's birthweight, and (ii) impact of mothers' smoking during pregnancy on bodyweight of pre-school children aged two to five.[3] For the first part of our analysis, we limit our sample to children who were born between 1979 and 2011 (the last year in which a childbirth was recorded in the NLS-CYA). This is done in order to maximize our sample size and simultaneously control for important mother- and family-level covariates derived from the NLSY79 (which commenced in the year 1979). Further, since the NLSY79 were conducted biennially since the 1994 survey, for children born during odd-numbered years post-1994 i.e.

[3] By the standard approach in child health literature, especially with respect to US-based studies, early childhood obesity is usually evaluated from the age of two (Ogden et al. 2008; 2010; 2012). To maintain consistency with approach in the related literature, we exclude children aged one from our main analysis.

from 1995 onwards until 2011, the covariates derived from the NLSY79 are based on information from survey years immediately succeeding the birth years. At this point, it is important to note that excluding children with odd-numbered birth year post-1994 survey does not affect our key findings in the birthweight analysis. Moreover, these children account for marginally less than 5 percent of the birthweight regression sample.

For the second part of our empirical exercise, investigating the impact on pre-school age bodyweight, we begin by including the same set of children included in the birthweight analysis. However, not all children included in the birthweight analysis were surveyed at every age from two through five, due to the biennial nature of NLS-CYA. Therefore, depending on a child's birth year, their later childhood information are either documented at odd numbered or even numbered ages. As a result, for post-birth years, we have one set of children who have been surveyed at the ages of two and four, and another set of children surveyed at ages three and five. As indicated earlier, we do not include children aged one. The study period for the preschool analysis spans across the biennial survey years between 1986 and 2012.

For our preferred specification (i.e. 2-SLS), in conducting the preschool weight analysis, we pool all children aged two to five together and treat each survey unit as a distinct observation such that the data resembles a cross-sectional sample. However, we also take advantage of the panel aspect of the data to verify whether our key findings our supported by alternative empirical specifications that account for mothers' fixed effects by exploiting 'within-mother across child birth' variation in smoking behavior (Rosenzweig & Wolpin, 1991).

The main outcome variable in our analysis is children's bodyweight reported in NLS-CYA's pre- and post-natal information (expressed in kilograms). The key explanatory variable is a binary indicator that incorporates mother's smoking behavior during pregnancy. In our most parsimonious model for the birthweight analysis, we additionally control for a wide range of mother and child demographic, social and health-specific contemporaneous characteristics. The mother and family-specific information are captured by indicator of mothers' prenatal substance use (alcohol or other illicit drugs including marijuana, cocaine, etc.), mother's age, height, marital status, employment status, and family's poverty status at childbirth. The child-specific characteristics include child's sex, race, birth order, and birth length. We later test the robustness of our 2-SLS estimates in a more saturated version of the above specification by incorporating additional controls in our regressions.

Similar controls are incorporated in the preschool age bodyweight analysis. More importantly with respect to preschoolers' analysis, since our objective is to test the effect of in-utero exposure of maternal smoking on children's likelihood of being overweight during the early childhood years, we create two dichotomous indicators of being overweight using World Health Organization's (WHO) body mass index-for-age (BMI-for-age) and weight-for-age distributions. In addition to continuous measure of children's weight during preschool years (ages 2-5), we consider these two binary overweight indicators as our dependent variables of interest in the preschool analysis.

To construct the overweight indicators using standard definitions, we assign a value one when child's BMI and weight lie at or above 85^{th} percentile in relevant distributions and zero otherwise. One of the empirical advantages of using these binary bodyweight indicators is that the construction of the variables is performed using age- and sex-specific distributions. This mitigates comparability concerns with respect to children's health outcomes due to differences across children's sex and age, and therefore allows us to maximize our analysis sample in the preschool analysis. Pursuant to our earlier discussion (in Section 2), the majority of studies that evaluate the association between prenatal smoking and the risk of child being overweight use similar bodyweight measures (additional example includes Wang & Lim, 2012).[4] Using WHO's BMI and weight-for-age distributions, we further create two binary indicators of being underweight that are assigned a value of one when child's BMI or weight lies below the 5th percentile of the two corresponding distributions.

Additionally, our access to restricted NLSY data permits control for state-level time-invariant characteristics through state fixed effects in both sets of analyses. Tables 2 and 3 provide descriptive information on all relevant variables used in our analysis. For ease of comparison, we present the summary statistics for samples separated by mothers' smoking behavior during pregnancy. We discuss the main takeaways from these tables later in Section 5.

4. IDENTIFICATION STRATEGY

4.1 Cross-sectional analysis

Our cross-sectional regression analyses employ 2-SLS regressions to evaluate causal effects of maternal smoking during pregnancy on child health outcomes of our interest. With respect to the birthweight analysis, our IV regression model is-

$$Y_{is} = \alpha_1 + \delta . \widehat{Mother's\ Smoking}_{is} + \alpha_2 . X_{is} + \epsilon_{is} \qquad (1)$$

$$Mother's\ Smoking_{is} = \beta_1 + \gamma . tax_s + \beta_2 . X_{is} + \upsilon_{is} \qquad (2)$$

where Y_{is} represents weight of child *i* from state *s* at birth. $Mother\ Smoking_{is}$ is an indicator of prenatal smoking participation of mother of child *i*. X_{is} is a vector of child- and mother-specific characteristics including state fixed effects.

To study the association between maternal smoking and children's birth weight, we first

[4] The formula utilized in calculating BMI (in kg/m^2): BMI = Weight / (Height in inches)^2; See https://www.bcbst.com/providers/MPMTools/BMICalculator.shtm.; Accessed on July 17, 2018.

estimate ordinary least squares (OLS) regression represented by equation (1). Next, to account for potential biases in the OLS estimates resulting from exclusion of unobserved heterogeneities, we estimate 2-SLS regressions whose first-stage is represented by equation (2).

In our analysis, to be treated as an instrument, variable tax_s should be correlated with mothers' smoking behavior (during pregnancy) but uncorrelated with unobserved heterogeneities that can influence children's health outcomes. Based on previous studies, we expect that a variable that captures exogenous variation in state and federal tobacco tax rates over the years meets these requirements (Evans & Ringel, 1999; 2001; Lien & Evans, 2005; Simon, 2016). To construct our IV, we consider the sum of state and federal tobacco tax rates during the year a mother likely conceived her child. The conception year was calculated by using information on children's reported gestation length (originally reported in weeks) and birth date (in month and year) in NLS-CYA. The state-level variation in the sum of the two tax rates across pregnancy years allows us to estimate the effect of the governmental tobacco regulations on mothers' smoking participation during pregnancy (Evans & Ringel, 1999).

For the later childhood bodyweight analysis (ages 2-5 years), we adopt a similar empirical approach that resembles the birthweight specifications given by equations (1) and (2).

4.2 Within mother across childbirth regressions

An improvement over the OLS model discussed in 4.1 would be to account for mother-specific time-invariant unobserved factors and estimate a mother fixed effects regression as below:

$$Y_{cm} = \rho_1 + \lambda . Mother\ Smoking_{cm} + \rho_2 . X_{cm} + \mu_m + u_{cm} \qquad (3)$$

where Y_{cm} represents birthweight (in kilogram) of child c born to mother m. $Mother\ Smoking_{cm}$ is the binary indicator of whether a mother m smoked during pregnancy before birth of child c. X_{cm} is a vector of child- and family-specific characteristics that vary within each cluster of mothers including variables that vary either by birth year or just across sibling (such as child's birth order). μ_m represents mother-specific time-invariant effects that are likely to be correlated with their smoking behavior and may affect child health outcomes. It is further important to note that μ_m can also be treated as family or sibling fixed effects given the nature of the survey design. Because we control for mothers' FE, our identification strategy relies on within mother and across pregnancies variation in smoking behavior (Rosenzweig & Wolpin 1991). Finally, u_{cm} is the error term. In case the source of bias in the OLS estimate is generated only from unobserved time-invariant mother and family-specific heterogeneities, the estimated parameter λ in equation (3) would represent an unbiased measure of the impact of maternal smoking on children's birthweight. However, the FE estimates may be biased if there are time-variant unobserved characteristics that are correlated with both smoking behavior and children's health outcomes. While, this particular empirical concern is likely to be addressed by instrumental variable strategy described in the previous subsection, estimation of mother FE regressions provides additional evidence to check the robustness of our 2-SLS regression findings. However, it is important to note that the treatment effects evaluated by the 2-SLS models and mother FE regressions differ in the way that the former looks at between differences in mothers' smoking behavior during pregnancy and the latter estimates the within-mother variation in prenatal smoking. Further, since identification of FE estimate relies on within mother across pregnancies variation in smoking behavior, we restrict our FE analysis to mothers with two or more children only.

5. RESULTS

5.1 <u>Summary statistics of variables</u>

We begin by discussing the descriptive statistics of the two main samples we use in our analysis. Table 2 presents summary statistics for the child sample at birth. We also present statistics for the overall child sample, and its subsamples separated by gender and smoking participation of mothers during pregnancy. Average birth weight of children is found to be 3.32 kg, which lies in the range of birthweight estimates reported in other studies (see Table III in Butler et al., 1972). In the overall child sample, we find that 28 percent of mothers reported to have smoked during pregnancy and further 32.5 percent reported to have used some substance during pregnancy including alcohol, marijuana, cocaine or other illicit drugs. Demographically, approximately 57 percent of women identify as White, 25 percent as Black, and 18 percent are Hispanic. Female children make up about 49 percent of the full sample.

With respect to socio-economic and health-related conditions, we present descriptive information of variables including mothers' employment status, marital status, highest academic qualification, and family's poverty status at the time of childbirth. Based on these variables, we find that 73 percent of mothers report being employed at the time of birth and 68 percent mothers are married at the time birth (this excludes women who were previously married but do not currently have a partner). Further, while 44 percent have a high school degree and 34 percent reported to have went to college. Focusing of family's economic condition, we see 23 percent of our sample fall below the Federal poverty threshold. These statistics are similar across samples of boys and girls (reported in columns 4 and 7 respectively).

To provide further understanding of socio-economic and demographic differences between smokers and non-smokers, we present descriptive information of all relevant variables in Table 2 classified by mothers' smoking behavior during pregnancy. Consistent with our expectation based on previous literature we find that children's average birth weight in smoking sample is less than that in nonsmoking sample (columns 2 and 3). In particular, the difference in children's average birthweight in the two samples is equivalent to 240 grams. This finding further holds in the separate samples of boys (columns 5 and 6) and girls (columns 8 and 9).

Demographically, while the share of Whites appears to be substantially larger in the smokers' sample (66 percent of smokers versus 53 percent of non-smokers), the proportion of Hispanics appear to be comparatively higher in the non-smokers' sample (10 percent of smokers versus 22 percent of non-smokers). In addition, mothers who smoke during pregnancy are less likely to be employed or have gone to college, and more likely to be under federally defined poverty line. Mothers who smoked during pregnancy are also found to be more likely to have engaged in prenatal consumption of alcohol or other illicit substance.

Regarding our instrumental variable, the average federal and state-level tax rates during pregnancy years are US$ 0.32 and 0.25 per pack of 20 cigarettes respectively. These tax rates are converted in 2005 dollars to account for the effects of price inflation.[5]

[5] The tax rate data have been accessed from 'Tax Burden on Tobacco' (Orzechowski & Walker, 2017). Also see https://healthdata.gov/dataset/tax-burden-tobacco-1970-2018 for state and federal tax rates in terms of US$ per pack of 20 cigarettes; Accessed on April 30, 2018.

Table 2

Mean/proportions of variables used in birthweight regressions

	All children			Boys only			Girls only		
	Total	Smoker	Non-smoker	Total	Smoker	Non-smoker	Total	Smoker	Non-smoker
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Birth weight (in kg)	3.32	3.15	3.39	3.38	3.22	3.44	3.26	3.09	3.33
Prenatal smoking (fraction)	0.28	-	-	0.28	-	-	0.28	-	-
Prenatal substance use	0.33	0.48	0.27	0.33	0.49	0.27	0.32	0.47	0.26
Birth length (in inches)	20.02	19.76	20.12	20.18	19.86	20.30	19.86	19.66	19.93
Birth order	1.99	2.11	1.95	1.98	2.09	1.94	2.00	2.13	1.95
White	0.57	0.66	0.53	0.57	0.66	0.53	0.57	0.66	0.53
African-American	0.25	0.24	0.25	0.24	0.23	0.25	0.25	0.25	0.26
Hispanic	0.19	0.10	0.22	0.19	0.11	0.22	0.18	0.09	0.22
Female child	0.49	0.49	0.49	-	-	-	-	-	-
Mother’s age	26.40	25.35	26.81	26.40	25.29	26.83	26.40	25.42	26.78
Employed	0.73	0.69	0.75	0.73	0.67	0.74	0.75	0.71	0.76
Married	0.68	0.54	0.73	0.69	0.54	0.74	0.67	0.54	0.73
High-school	0.44	0.49	0.42	0.44	0.47	0.42	0.44	0.50	0.42
College	0.34	0.16	0.41	0.34	0.16	0.41	0.34	0.15	0.41
Poverty status	0.23	0.33	0.20	0.23	0.33	0.19	0.24	0.33	0.20
Mother's height (in meters)	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.64	1.63
Tobacco Tax	0.58	0.56	0.58	0.58	0.56	0.58	0.58	0.56	0.58
Federal cigarette tax	0.25	0.24	0.25	0.25	0.24	0.25	0.25	0.24	0.25
State cigarette tax	0.32	0.31	0.33	0.32	0.31	0.33	0.32	0.31	0.33
Observations	7174	2009	5165	3670	1030	2640	3504	979	2525

Notes: The above table presents the sample proportions/ averages of all variables used in our birthweight regression analysis. The Federal and state-level cigarette tax rates are in terms of 2005 dollars/ per pack of 20 cigarettes (Tax burden on tobacco (Orzechowski & Walker, 2017)).

Table 3 presents summary statistics for our preschoolers' sample (related to children aged 2 to 5). Focusing on child characteristics, in the overall sample of preschoolers (see column 1), the average body weight is approximately 15.6 kg and average height is 0.98 meters. Further, based on weight-for-age measures, we find that 19 percent of children lie above 85th percentile of their relevant distribution. However, with the respect to BMI-for-age, 30 percent of children appear to be above 85th percentile of their corresponding distribution. Of particular relevance to our study is the finding that the proportion of children in the smokers' group who are found to be in the BMI-based overweight category (32 percent) is marginally higher than the relevant proportion in the non-smokers' group (29 percent). This aligns with the literature evidence on the positive association between prenatal smoking and likelihood of children being overweight.

In addition, the average proportions of children having bodyweight measures lying below 5th percentile of weight-for-age and BMI-for-age distributions are 6 and 8 percent respectively. Interestingly, in contrast to the birthweight analysis sample, we do not observe any noteworthy differences in the mean proportions of being overweight when the preschoolers' overall sample is classified by children's sex (columns 4 and 7) and mothers' prenatal smoking behavior (columns 2-3; 5-6; and 8-9).

The preschoolers' sample estimates of socio-economic and demographic characteristics of mothers do not differ much from those observed in the childbirth sample. Among the mothers in the preschoolers' sample 53 percent identify themselves as White, 26 percent are African-Americans, and 20 percent are Hispanic. Additionally, about 70 percent of mothers report being employed when at the time of survey, and approximately 69 percent are married. We do not see any major differences in the sample means of the mothers and family level variables in boys and girls only subsamples (see columns 4 and 5 respectively).

Table 3

Mean/proportions of variables used in preschool weight regressions (2-5 years)

	All children			Boys only			Girls only		
	Total	Smoker	Non-smoker	Total	Smoker	Non-smoker	Total	Smoker	Non-smoker
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Child weight (in kg)	15.59	15.67	15.56	15.84	15.90	15.82	15.33	15.43	15.29
Overweight (BMI)	0.30	0.32	0.29	0.33	0.35	0.32	0.27	0.28	0.26
Underweight (BMI)	0.08	0.08	0.09	0.08	0.07	0.08	0.09	0.09	0.09
Overweight (WFA)	0.19	0.19	0.19	0.20	0.19	0.20	0.17	0.18	0.17
Underweight (WFA)	0.06	0.07	0.06	0.06	0.07	0.05	0.06	0.07	0.06
Prenatal smoking (fraction)	0.28	-	-	0.28	-	-	0.28	-	-
Prenatal substance use	0.34	0.49	0.29	0.36	0.49	0.30	0.33	0.48	0.27
Child height (in meter)	0.98	0.97	0.98	0.98	0.97	0.98	0.97	0.98	0.97
Birth order	2.02	2.10	1.99	2.02	2.11	1.99	2.01	2.09	1.98
Child age	3.52	3.58	3.49	3.52	3.57	3.50	3.52	3.60	3.49
White	0.53	0.65	0.49	0.53	0.64	0.49	0.54	0.66	0.49
African-American	0.26	0.25	0.27	0.26	0.25	0.26	0.27	0.26	0.28
Hispanic	0.21	0.10	0.25	0.22	0.11	0.26	0.19	0.09	0.24
Female child	0.49	0.49	0.49	-	-	-	-	-	-
Mother’s age	28.69	28.06	28.94	28.75	28.12	29.00	28.63	28.00	28.88
Employed	0.68	0.65	0.69	0.67	0.63	0.69	0.69	0.67	0.70
Married	0.69	0.57	0.73	0.69	0.57	0.74	0.68	0.57	0.72
High-school	0.49	0.52	0.48	0.50	0.51	0.49	0.49	0.54	0.47
College	0.31	0.17	0.37	0.31	0.17	0.36	0.32	0.18	0.37
Poverty status	0.28	0.38	0.24	0.28	0.39	0.24	0.28	0.37	0.24
Household size	4.39	4.28	4.43	4.39	4.29	4.43	4.38	4.27	4.42
Mother's height (in meters)	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.64	1.63
Tobacco Tax	0.56	0.54	0.56	0.56	0.55	0.56	0.56	0.54	0.57
Federal cigarette tax	0.25	0.25	0.26	0.25	0.25	0.26	0.25	0.25	0.26
State cigarette tax	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.31
Observations	4991	1391	3600	2548	713	1835	2443	678	1765

Notes: The above table presents the sample proportions/ averages of all variables used in our pre-schoolers’ regression analysis. The Federal and cigarette tax rates are in terms of 2005 dollars/ per 20 cigarettes (Tax burden on tobacco (Orzechowski & Walker, 2017)). The age and sex-specific binary indicators are constructed using World Health Organization’s standard thresholds of body mass index and weight-for-age distributions of boys and girls. The information has been accessed from https://www.who.int/childgrowth/standards/en/. Accessed on April 23, 2017.

5.2 Birthweight analysis

Table 4 presents estimates of effects of maternal smoking during pregnancy on children's birthweight, as estimated by the baseline OLS as well as 2-SLS and mother FE regression models.

With respect to OLS regression estimates, for the overall sample that controls for child's sex in addition to other relevant covariates (column 1), we find that on average, birthweight of children whose mothers smoked during pregnancy falls short of birthweight of children whose mothers did not by 0.18 kilograms (kg). We also see that the OLS regression estimate is statistically significant at the one percent level. We find comparable reductions in birth weight when comparisons are made across same child gender. Specifically, we observe that mothers' smoking during pregnancy is associated with a reduction of 0.15 kg in birthweight when comparisons are made among boys only (column 4) and 0.19 kg in the girls' sample (column 5).

As indicated earlier, the main empirical concern regarding OLS regressions is failure to account for all observed and unobserved individual, family-level and socio-economic characteristics that may be simultaneously associated with mothers' smoking and child's well-being. To address these endogeneity concerns, we use an IV strategy illustrated in Section 4. For empirical validity of our instrument, the cigarette tax-based instrument should meet two basic requirements. First, the instrument must be strongly correlated with mother's smoking behavior (the relevance criteria), and second, the instrument must be uncorrelated with unobserved heterogeneities that affect the child's body weight except through the channel of mother's smoking, conditional on all controls included in model (the excludability requirement).

We argue that the federal and state taxes levied on cigarettes over years meet the above two requirements. However, while the empirical evidence in support of the first assumption is presented in Table 4 itself, where we present our first stage estimate of 2-SLS regressions, the exclusion restriction criteria cannot be directly tested.

One of the concerns regarding the validity of the excludability assumption is that state-level tobacco tax policy may be correlated with implementation of other health-promoting welfare programs, which may have impact on children's weight. For example, states with high tobacco tax rates may also be more likely to have high soda tax (e.g. New York). Because such possibilities cannot be ignored, in all our regression models, we control for state fixed effects (mothers' state of residence at the time of survey) that account for any time-invariant differences across states. In addition, ex ante, another possibility is that tobacco taxes might be large enough to influence other health-related behaviors that we do not control for in our main regression models. Therefore, in a supplemental robustness exercise (presented in Appendix Table A.1), we estimate our IV model controlling for additional prenatal controls such as prenatal visits and vitamin intake.

With respect to the first stage results of our 2-SLS regressions with children's birthweight as dependent variable, we find that pregnant women respond strongly to tax increases. In particular, a dollar increase in real tobacco tax rate results in a decline in mothers' probability of smoking during pregnancy by 26 percentage points (column 3). These results are qualitatively consistent with findings in prior studies that evaluates the effect of tobacco taxes on maternal smoking during pregnancy (Evans & Ringel, 1999; 2001; Lien & Evans, 2005). Further, in the gender-specific samples, the decline in the probability of smoking during pregnancy as a result of state and federal tobacco taxes is found to be larger in case of boys sample relative to that of girls (0.29 versus 0.21 percentage points; columns 5 and 8). In all three samples, we find that the instrumental variables are strong predictors of maternal smoking during pregnancy, as indicated by the statistically significant (at the one percent level) first-stage regression coefficient values. Moreover, for the overall child sample and for the sample of boys, the partial F-statistics are 30.04 and 21.34, which are above the recommended value of 10 (Stock, Wright, and Yogo, 2002).

Focusing on the second-stage results, we find that prenatal smoking leads to a decline in children's birthweight by 0.53 kg (531 grams; column 2). The estimated coefficient is statistically significant at the 5 percent level. While the 2-SLS estimate is larger than our OLS estimate, it is important to note that IV estimates represent Local Average Treatment Effect (LATE) rather than Average Treatment Effect (ATE). More specifically, in our case, the 2-SLS regression generates estimates of the effect of maternal smoking on children born to mothers who are at the margin of adjusting their smoking behavior based on variation in tobacco taxes. Nonetheless, our 2-SLS estimate of the effect of maternal smoking during pregnancy on children's birthweight lies within the range of IV-based point estimates obtained by Evans & Ringel (1999) who utilize the Natality Data Files (1989-1992) for their analysis. In particular, Evans & Ringel's (1999) 2-SLS estimate of the effect of mothers' smoking participation birthweight varies from 0.36 to 0.59 kg depending on a step-by-step inclusion of additional covariates ranging from a less saturated specification to a more highly saturated model. In the gender-specific sample, we find comparing birthweight among boys only, maternal smoking during pregnancy leads to 0.63 kg decline in birthweight. However, the regression coefficient is statistically significant at the 10 percent level. On the other hand, in the girls only sample, the second stage regression coefficient is not statistically indistinguishable from zero although the coefficient is negative.

In our final empirical specification, we control for mother fixed effects by estimating equation (3). The FE estimate of birth effect as seen in column 3 of Table 4 suggests that mothers' prenatal smoking leads to a reduction in children's birthweight by 0.15 kilogram. Once again, our FE estimate of the impact of maternal smoking during pregnancy on children's birthweight lies in the range of the FE estimates presented in Rosenzweig & Wolpin's (1991) study. To illustrate, Rosenzweig & Wolpin's (1991) FE estimate represented a decline in children's birthweight by 2.92 ounce (≈0.08 kg) for prenatal smoking amounting to less than a pack and 5.62 ounce (≈0.16 kg; for prenatal smoking amounting to a pack or more). With respect to our FE regressions using gender-specific samples, we find qualitatively similar results as that of our 2-SLS analysis. In other words, we find statistically significant and relatively larger effects for boys (represented by a decline in birthweight by 0.26 kg) compared to that of girls (see columns 6 and 9).

Table 4

Estimates of the effect of maternal smoking during pregnancy on birthweight

	All			Boys only			Girls only		
	OLS	2-SLS	FE	OLS	2-SLS	FE	OLS	2-SLS	FE
Sample mean	3.32		3.33	3.38		3.38	3.26		3.27
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Prenatal smoking	-0.176***	-0.531**	-0.147***	-0.157***	-0.632*	-0.263***	-0.190***	-0.281	-0.052
	(0.016)	(0.247)	(0.035)	(0.023)	(0.301)	(0.068)	(0.021)	(0.428)	(0.055)
First stage (*Dependent variable: Indicator of smoking during pregnancy*)									
Sample proportion		0.28			0.28			0.28	
Tobacco tax		-0.258***			-0.294***			-0.207***	
		(0.047)			(0.062)			(0.067)	
Partial F	-	30.03	-	-	21.34	-	-	9.36	-
Observations	7174	7174	5543	3670	3670	2842	3504	3504	2701

Notes: The above table presents regression estimates obtained from ordinary least squares (OLS), two-stage least squares (including the first stage estimates), mother fixed effects (FE) regressions for all children (1-3), boys only (4-6), and girls only (7-9) samples. All models control for child characteristics, mother characteristics, and state fixed effects. Robust standard errors are corrected for clustering on the mothers and are presented in parenthesis. ***, **, * denote the coefficients are significantly different from zero at the 10%, 5%, and 1% level respectively.

5.3 Bodyweight outcomes of preschoolers

For children aged between 2 and 5, we begin by analyzing children's weight (expressed in kg) as our dependent variable. It is however important to note, that continuous measure of children's weight may lack comparability owing to potential physiological differences between genders and across ages. Nonetheless, prior to focusing on the binary health measures of being overweight, analyzing children's weight shall allow us to examine whether on average, preschoolers' weight continues differs during early childhood years, as observed in the birthweight analysis. Table 5 presents our regression estimates obtained from all three empirical specifications - OLS, 2-SLS and mother FE models.

In all our child samples (columns 1, 4, and 7), the OLS estimates suggest that there is no statistically significant association between maternal smoking during pregnancy and children's weight during preschool years. However, in the 2-SLS regressions, we observe that weight of children of non-smokers continue to exceed weight of smokers' children. For instance, in the overall sample, the second-stage regression estimate indicates a gap of 4.40 kg between the two groups of interest. This effect is statistically significant at the 1 percent level. Further for boys, the negative effect of maternal smoking on children's weight (during preschool years) remains larger than that of girls, as indicated by a difference of 5.79 kg (for boys) versus a difference of 2.97 kg (for girls). Finally, the first stage coefficients are largely similar to the first-stage results obtained in the birthweight IV analysis.

In relation with mother fixed effects regressions for preschoolers, it is first important to discuss the empirical adjustments we applied to the preschoolers' sample used in the OLS and 2-SLS analyses. By construction, OLS and 2-SLS estimation allow the preschooler's sample to be treated as cross-sectional data. To put it more succinctly, despite the possibility that a child-mother pair can be observed repeatedly given the longitudinal nature of the biennial NLS-CYA data, information recorded for a particular child-mother pair at each survey year can be treated as a unique observation. However, in case of mother fixed effects regression where we try to exploit variation in mothers' prenatal smoking (across multiple childbirths), observing a child-mother pair multiple times in a longitudinal data format may lead to misspecification due to lack of variation in our key time-invariant regressor i.e. mothers' smoking participation during pregnancy. Therefore, to avoid double counting of a child-mother pair, we compress our OLS (or 2-SLS) sample by each child so that the data format resembles the format used in the birthweight analysis where we have a unique observation for each mother-child pair. The data compression is performed in a way such that in the resultant sample, all the time-variant variables used in the mother fixed effects regressions can be interpreted as an average value of the respective indicators over the children's preschool years (2-5 years) under evaluation.

Based on Table 5 estimates, our mother's fixed effects regression using the resultant overall child sample indicates that maternal smoking does not have any significant impact on preschoolers' weight (see column 3).

Table 5

Estimates of the effect of maternal smoking during pregnancy on pre-schoolers' weight

	All			Boys only			Girls only		
	OLS	2-SLS	FE	OLS	2-SLS	FE	OLS	2-SLS	FE
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Sample mean	15.52		15.50	15.82		15.78	15.22		15.21
Prenatal smoking	0.063	-4.400***	0.341	0.078	-5.792**	0.871*	0.060	-2.969*	-0.054
	(0.101)	(1.588)	(0.225)	(0.152)	(2.927)	(0.474)	(0.132)	(1.722)	(0.415)
First stage (*Dependent variable: Indicator of smoking during pregnancy*)									
Sample proportion		0.28			0.28			0.28	
Tobacco tax		-0.300***			-0.265**			-0.329***	
		(0.055)			(0.088)			(0.067)	
Partial F	-	29.26	-	-	8.88	-	-	24.01	-
Observations	4553	4553	2533	2548	2548	1274	2239	2239	1259

Notes: The above table presents regression estimates obtained from ordinary least squares (OLS), two-stage least squares (including the first stage estimates), mother fixed effects (FE) regressions for all children (1-3), boys only (4-6), and girls only (7-9) samples. All models control for child characteristics, mother characteristics, and state fixed effects. Robust standard errors are corrected for clustering on the mothers and are presented in parenthesis. For the FE regression samples, we collapse all the variables at their respective means such that each observation relates to a unique mother-child pair to avoid lack of variation in maternal smoking during pregnancy. ***, **, * denote the coefficients are significantly different from zero at the 10%, 5%, and 1% level respectively.

Next, we focus on the binary indicators of being overweight. While bodyweight status of being overweight or obese is usually evaluated using BMI measures, we use a second overweight indicator (based on weight-for-age distribution) for additional evidence. Further, since the dichotomous indicators are evaluated by accounting for child age- and sex-specific distributions of respective weight measures, we perform our analysis only on the overall child sample used in Table 5 regressions. However, we do control for children' sex and age in our regressions in addition to other relevant covariates.

In Table 6, consistent with the evidence in prior health literature discussed earlier (see Section 2), in our linear probability analysis of BMI-based overweight indicator (column 1), we find that maternal smoking during pregnancy is associated with a 3 percentage points increase in the probability of being overweight. However, considering exogenously determined smoking participation during pregnancy, our 2-SLS estimates indicate prenatal smoking does not have any statistically significant influence on the risk of children being overweight (column 2). This result holds when we consider our second overweight indicator (column 5). However, based on our IV analysis, we also do not find any statistically significant effect of prenatal smoking on the likelihood of being underweight among preschoolers (columns 8 and 11). [6]

Finally, using the compressed child sample used in the FE analysis reported in Table 5, we find that once we account for mothers' unobserved time-invariant fixed effects, maternal smoking during pregnancy is negatively associated with both BMI-based indicators of being overweight and underweight, and weight-for-age indicator of being underweight. It should be noted that in

[6] To further test the 'catch-up' growth phenomenon discussed in the prior literature, we estimate OLS and mother FE specifications using children's weight as dependent variable on child samples for each preschool age (from 2 to 5 years). Although we do not intend to overstate the importance of the age-specific findings due to small sample size at each age, we present these results in Appendix Table A.2. Our FE estimates indicate no statistically significant differences in children's weight between the smoking and non-smoking group at any of the preschool ages. We further refrain from estimating 2-SLS regressions as the second-stage regression coefficients are imprecisely estimated owing to the lack of the IV's predictive power in the small age-specific child samples.

the compressed sample, the dependent variable could be interpreted as proportion of times a child is observed in the survey to be overweight or underweight (bounded by a 0-1 interval) during the preschool ages under evaluation. Owing to the fractional form of our dependent variable, the reliability of linear FE estimates may be restricted due to possible non-linearity in the effects of our regressor (Papke & Wooldridge, 2008).[7] Further, lack of continued availability of relevant information for all children in NLS-CYA in consecutive surveys may also misrepresent the actual proportion of times a child is observed to be in a particular bodyweight category.

Overall, our analysis using the national longitudinal surveys indicates that once confounding influences of unobserved heterogeneities are accounted for, maternal smoking does not have any causal impact on the risk of being overweight among preschool aged children. This is contrary to the discussions presented in the prior literature based on descriptive empirical evidence that guide us to conjecture that maternal smoking during pregnancy leads to childhood obesity. As such our findings introduce a wide scope for future research to explore potential mechanisms and socio-economic factors or individual characteristics (including lifestyle choices and decisions made by parents) that may underlie the observed positive association between maternal smoking during pregnancy and risk of having excess weight during early childhood (Simon 2016).

[7] We do test our FE estimates using generalized linear models, following Papke & Woolridge's (2008) recommendation on panel data treatment of fractional response variables (also see Wooldridge's (2011) Stata conference discussion). Findings are qualitatively similar to the FE results. Since, this additional empirical test is not directly pertinent to our analysis results from generalized linear model we do not present our findings but results are available upon request.

Table 6

Estimates of the effect of maternal smoking during pregnancy on pre-schoolers' bodyweight indicators

	Overweight (BMI)			Overweight (Weight-for-age)			Underweight (BMI)			Underweight (Weight-for-age)		
	LPM	2-SLS	FE	LPM	2-SLS	FE	LPM	2-SLS	FE	LPM	2-SLS	FE
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Sample proportion	0.30		0.28	0.18		0.17	0.08		0.08	0.06		0.05
Prenatal smoking	0.029*	-0.157	-0.063**	0.004	-0.056	0.033	-0.008	-0.055	-0.062**	0.010	-0.209	-0.037*
	(0.017)	(0.287)	(0.027)	(0.014)	(0.171)	0.041	(0.010)	(0.134)	(0.027)	(0.008)	(0.164)	(0.020)
Partial F stat	-	14.51	-	-	29.26	-	-	41.60	-	-	29.26	-
Observations	4553	4553	2533	4553	4553	2533	4553	4553	2533	4553	4553	2533

Notes: The above table presents regression estimates obtained from linear probability model (LPM), two-stage least squares (including the first stage estimates), mother fixed effects (FE) regressions for indicators of overweight and underweight based on BMI and weight-for-age distributions. All models control for child characteristics, mother characteristics, and state fixed effects. Robust standard errors are corrected for clustering on the mothers and are presented in parenthesis. For the FE regression samples, we collapse all the variables at their respective means such that each observation relates to a unique mother-child pair to avoid lack of variation in maternal smoking during pregnancy. Consequently, the dependent variable for FE regressions represent the proportion of times a child is observed to be overweight or underweight. ***, **, * denote the coefficients are significantly different from zero at the 10%, 5%, and 1% level respectively.

6. CONCLUSION

The numerous health hazards associated with smoking demonstrate its severity on the public health front. In fact, cigarette smoking is known to harm almost every organ of the human body, cause several diseases, and reduce the health of smokers in general, making it the leading preventable cause of death in the United States (Centers for Disease Control and Prevention, 2013). Moreover, the health effects of cigarette smoking reach far beyond the smokers themselves. This study provides new and policy-relevant evidence on the child health impacts of maternal smoking during pregnancy. Our contribution to the literature in this space is a focus on the causal link between prenatal exposure to maternal smoking and future child weight outcomes.

In summary, while maternal smoking is found to have a significant negative impact on children's birth weight, the same does not cause a higher risk of obesity during preschool ages. Our analysis indicates that the associational evidence on the positive link between maternal smoking and child obesity may be mediated by poor socio-economic, health, and behavioral characteristics that can commonly be attributed to mothers who smoke during pregnancy. Assuming that these characteristics are driven by mothers' unobserved characteristics, our instrumental variable strategy corrects for the potential confounders and produces plausibly more reliable estimates.

This study provides enhanced motivation for implementing policies to effectively address smoking behavior among pregnant mothers. In addition to continuing with traditional ways to curb smoking such as through information campaigns, smoke-free policies, age restrictions, etc., there is a need to implement broader and more effective methods to motivate quitting. For example, a recent paper by Islam, Folland & Kaarbøe (2017) provides evidence on how investing in social capital variables such as community trust and participation in organization activities could lower the incidence of smoking.[8] Finally, our results underscore the role of socioeconomic causes of childhood obesity and indicate the need for effective intervention in this area of public health.

[8] There has been some evidence that quitting smoking may be associated with increased risk of obesity (see Chou et al, 2004 and Liu et al, 2010). However, recent evidence by Pieroni & Salmasi (2016) maintain the importance of policies aimed at reducing smoking, as they find limited consequences in terms of a rise in obesity risk among adults.

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Appendix

Table A.1

Two-stage least square estimates of relationship between maternal smoking during pregnancy and child bodyweight outcomes with additional set of covariates

	Birthweight	Overweight (BMI)	Overweight (WFA)	Underweight (BMI)	Underweight (WFA)
	(1)	(2)	(3)	(4)	(5)
Prenatal smoking	-0.493**	-0.369*	-0.366	-0.055	-0.216
	(0.232)	(0.199)	(0.165)	(0.131)	(0.159)
First stage (*Dependent variable: Indicator of prenatal smoking*)					
Tobacco tax	-0.275***	-0.377***	-0.312***	-0.377***	-0.312***
	(0.047)	(0.056)	(0.055)	(0.056)	(0.055)
Partial F-stat	10.24	44.48	31.47	44.48	31.47
Observation	6024	4478	4478	4478	4478

Notes: All models control for child characteristics, mother characteristics, and state fixed effects. All models control for child characteristics, mother characteristics, and state fixed effects. Additional characteristics include prenatal doctor visits and vitamin intake during pregnancy. Robust standard errors are clustered at the mother level and are reported in parentheses. ***,**,* = statistically different from zero at the 1%, 5%, 10% level.

Table A.2

OLS and Mother Fixed Effects estimates of relationship between maternal smoking during pregnancy and child weight

Child age	2 years		3 years		4 years		5 years	
	OLS	FE	OLS	FE	OLS	FE	OLS	FE
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Prenatal smoking	0.002	-2.565	0.439**	0.756	-0.173	0.136	-0.048	0.620
	(0.199)	(3.103)	(0.173)	(1.429)	(0.152)	(1.927)	(0.210)	(2.529)
Observations	683		1571		1459		840	

Notes: All models control for child characteristics, mother characteristics, and state fixed effects. All models control for child characteristics, mother characteristics, and state fixed effects. Robust standard errors are clustered at the mother level and are reported in parentheses. ***,**,* = statistically different from zero at the 1%, 5%, 10% level. We do not estimate 2-SLS models for age-specific effects of maternal smoking during pregnancy as small sample size at each age likely reduces the precision of IV estimates.