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Rahi Abouk
Scott Adams
Bo Feng
Johanna Catherine Maclean
Michael F. Pesko

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Authors listed in alphabetical order. All authors contributed equally to the manuscript. Corresponding author is Michael F. Pesko. Research reported in this publication was supported by the National Institute on Drug Abuse of the National Institutes of Health under Award Number R01DA045016 (PI: Michael Pesko). The views expressed herein are those of the authors and do not necessarily reflect the views of the National Bureau of Economic Research.

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ABSTRACT

We use the universe of birth records in the United States from 2013 to 2017 to examine the effect of e-cigarette taxes on pre-pregnancy smoking, prenatal smoking, and birth outcomes (birth weight, gestational length, and Apgar 5 score). We apply a differences-in-differences model to study these questions. We have two principle findings. First, e-cigarette tax adoption increases pre-pregnancy and prenatal smoking, implying that e-cigarettes and traditional cigarettes are substitutes among pregnant women. Second, in line with clinical literature suggesting that both e-cigarettes and traditional cigarettes are harmful to developing fetuses, birth outcomes are largely unchanged following adoption of an e-cigarette tax. In sum, our results suggest that e-cigarettes reduce prenatal smoking, but have no observable benefit towards the goal of promoting fetal development.

Rahi Abouk
William Paterson University
Department of Economics, Finance,
and Global Business
300 Pompton Road
Wayne, NJ 07470
aboukr@wpunj.edu

Scott Adams
Department of Economics
University of Wisconsin-Milwaukee
Milwaukee, WI 53201
sjadams@uwm.edu

Bo Feng
Andrew Young School of Policy Studies
Department of Public Management and Policy
14 Marietta Street, NW, 3rd Floor
Atlanta, GA 30303
Georgia
bfeng1@gsu.edu

Johanna Catherine Maclean
Department of Economics
Temple University
Ritter Annex 869
Philadelphia, PA 19122
and NBER
catherine.maclean@temple.edu

Michael F. Pesko
Department of Economics
Andrew Young School of Policy Studies
PO Box 3992
Atlanta, GA 30302-3992
Georgia
mpesko@gsu.edu

1. Introduction

Electronic cigarettes ('e-cigarettes')[1] were developed in China in 2003 (Riker et al. 2012) and have become increasingly popular over the past decade in the United States (Bao et al. 2018) and the European Union (Filippidis et al. 2017). In the U.S, the focus of our study, the adult e-cigarette regular use rate was 4.7% in 2016 (5.6% for men and 3.8% for women), which implies nearly 11 million Americans used these products (Hu et al. 2019).

There is debate within the medical community as to whether e-cigarette use ('vaping') improves or harms population health (Ribisl, Seidenberg, and Orlan 2016, Kenkel 2016, Royal College of Physicians 2016, NHS Health Scotland 2017). One potential benefit of e-cigarettes is that these products may represent a healthier alternative for consuming nicotine -- the addictive ingredient in tobacco products -- to traditional cigarettes for smokers who are unable to quit. For example, the Surgeon General of the U.S. has concluded that while e-cigarettes are not harmless, these products generally contain fewer toxicants than traditional cigarettes (U.S. Department of Health and Human Services 2016). This benefit offered by e-cigarettes could be potentially important as 68% of current smokers want to quit but cannot (Babb 2017).

Pregnant women who smoke may place elevated value on e-cigarettes as an alternative to traditional cigarettes, at least during pregnancy, as such women are highly motivated to quit smoking. The health harms of maternal smoking are well known, and smoking while pregnant is highly stigmatized and strongly discouraged by healthcare professionals. However, government data show that 45% of women smoking three months before their pregnancy are unable to quit

[1] Other names for these products include: e-cigs, vapes, e-hookahs, vape pens, electronic nicotine delivery systems, and ENDS. The e-cigarette market contains disposable and rechargeable devices that are available in a wide variety of forms. We follow the U.S. Surgeon General's convention in referring to all of these products as e-cigarettes. While their names differ, all of these devices have the same functional purpose: to allow inhalation of an aerosol typically containing nicotine, flavorings, and other additives (U.S. Department of Health and Human Services 2016).

smoking for the duration of pregnancy (Centers for Disease Control and Prevention 2016). Pregnant women who cannot quit smoking may therefore disproportionately look to e-cigarettes for help in quitting, or at least consider transitioning to a product that is perceived as less harmful for the duration of the pregnancy. E-cigarettes may be especially attractive to pregnant women who smoke because of reluctance on the part of healthcare professionals to recommend other forms of nicotine replacement therapy (NRT), products that are efficacious for most other smoking populations (Kapaya, Tong, and Ding 2015). NRTs have not been proven efficacious for pregnant women (Coleman et al. 2015), which likely prevents healthcare professionals from recommending these products.[2] Many pregnant women perceive e-cigarettes as less harmful than traditional cigarettes for the fetus and helpful in smoking cessation (Wagner, Camerota, and Propper 2017, Mark et al. 2015, Oncken et al. 2017), and a recent clinical trial suggests that e-cigarettes are *more* effective for cessation than NRTs for adults generally (Hajek et al. 2019).

Descriptive evidence on vaping prevalence among pregnant women provides additional confirmation of such women's potential interest in e-cigarettes. Data from two states in the Pregnancy Risk Assessment System (PRAMS) show that in 2015 -- roughly the mid-point of our study period -- 10.8% of the sample used e-cigarettes in the three months prior to the pregnancy while 7.0%, 5.8%, and 1.4% used these products at the time of the pregnancy, in the first trimester, and at birth (Kapaya et al. 2019). According to National Health Interview Survey (NHIS) data from 2014 to 2017, 38.9% of pregnant smokers used e-cigarettes compared to only 13.5% of non-pregnant, reproductive age women smokers (Liu et al. 2019). The high rates of e-

[2] The Centers for Disease Control and Prevention recommend that healthcare professionals discuss costs and benefits of NRT use only among women who are unable to quit using other methods such as behavioral interventions (Centers for Disease Control and Prevention 2016).

cigarette use among pregnant women that smoke could be due to these women attempting to quit traditional cigarette smoking with e-cigarettes.

Further, dual use of e-cigarettes and traditional cigarettes is common among pregnant women, which may reflect attempts to reduce smoking (perceived as more harmful to the fetus) by partially substituting toward e-cigarettes (perceived as less harmful to the fetus). Among pregnant women, 4.9% reported current use of e-cigarettes in the 2013 to 2014 Population Assessment of Tobacco and Health and 28.5% of currently smoking pregnant women also used e-cigarettes (Kurti et al. 2017). Liu et al. (2019) document similar patterns using the 2014 to 2017 NHIS: 38.9% of pregnant women who smoked also used e-cigarettes. Given the prevalence of e-cigarette use among pregnant women, state and local laws designed to regulate these products may affect consumption of e-cigarettes and traditional cigarettes among such women, potentially leading to changes in birth outcomes.

In this paper, using comprehensive records on the universe of births from the U.S., we provide the first evidence on the effect of e-cigarette taxes on pre-pregnancy and prenatal smoking. The birth record data contain information on traditional cigarette smoking, mother's demographics, and place of birth. We match the birth record data to state and county e-cigarette taxes levied over the period 2013 to 2017. We also estimate the effect of e-cigarette taxes on birth outcomes. This latter question allows us to provide evidence on the extent to which any substitution from traditional cigarettes to e-cigarettes during pregnancy improves or harms fetal development. A large literature documents that prenatal smoking adversely affects fetal development (Bernstein et al. 2005, Blatt et al. 2015, Ko et al. 2014, Lumley et al. 2009), and that, among other adverse childhood outcomes, this prenatal behavior is linked with asthma (Jaakkola and Gissler 2004) and obesity (Rayfield and Plugge 2017).

However, the extent to which substituting e-cigarettes for traditional cigarettes affects fetal health is *a-priori* less obvious than the effect of full abstinence from smoking. This ambiguity is due to the fact that vaping itself may adversely affect birth outcomes. While e-cigarettes do not contain carcinogens found in traditional cigarettes, these products generally contain nicotine. Nicotine is an important source of adverse fetal development (Holbrook 2016, Committee on Obstetric Practice 2017). Therefore, any improvements to birth outcomes from reduced traditional cigarette use may be offset by harm imposed on the fetus from vaping. As *prima facie* evidence that pregnant women who transition from traditional cigarettes to e-cigarettes do not improve the development of the fetus, a recent meta-analysis of available clinical studies suggests that e-cigarette use may cause similar harms to the fetus as do traditional cigarettes (Whittington et al. 2018). In sum, the relationship between e-cigarette taxes and birth outcomes is difficult to predict using theory alone, and we provide credible quasi-experimental empirical evidence on this important question.

We have two primary findings. First, the levying of an e-cigarette tax leads to increased traditional cigarette smoking among pregnant women, with the substantial share of the increased smoking occurring in the pre-pregnancy period and carrying through to the prenatal period. This result implies that e-cigarettes and traditional cigarettes are substitutes for pregnant women. Second, we find no evidence that e-cigarette taxes influence birth outcomes. This result suggests that pregnant women who use nicotine products, either e-cigarette or traditional cigarettes, face worse birth outcomes than women who do not use these products while pregnant.

2. Background

We first discuss e-cigarette taxation in the U.S. Second we review two strands of related literature: (i) the effect of price increases on e-cigarette and traditional cigarette use, and (ii) the effect of e-cigarettes and traditional cigarettes on fetal development.

2.1 Taxation of e-cigarettes in the U.S.

Because e-cigarettes are relatively new products in U.S. tobacco markets, regulation on their production, distribution, marketing, and sale is still in the formative stage. The Food and Drug Administration (FDA), the federal agency with the authority to regulate tobacco products, only gained the power to regulate e-cigarettes in 2016.[3] The FDA, however, does not have the authority to levy e-cigarette taxes; therefore this legislative action must occur at the state or local level. As of March 2017, the end of our study period, 15 states, counties, and cities had levied e-cigarette taxes. Unlike traditional cigarette taxation which is a standard excise tax, localities have levied e-cigarette taxes in varied ways. Kansas, Louisiana, North Carolina, West Virginia, the city of Chicago, and Cook County in Illinois levy consumer taxes per milliliter of e-liquid. The city of Chicago also levies an excise tax per vaping unit. Washington DC, Minnesota, Montgomery County in Maryland, and five counties in Alaska tax a percentage of wholesale value. One state (Pennsylvania) taxes e-cigarettes as a percentage of retail sales value.

Taxes may reduce e-cigarette use by raising the relative price of the product.[4] Increasing the price of a product by the law of demand will decrease the quantity consumed. In addition, levying a tax may send a signal to consumers regarding the health harms of the product, thus reducing demand for e-cigarettes. This phenomenon has been documented for other health

[3] The FDA was granted the authority to regulate a wide range of tobacco products through the Family Smoking Act of 2009. The FDA then 'deemed' e-cigarettes as a tobacco product and thus under its purview. In 2016, this deeming became official policy with the FDA gaining authority to regulate many attributes related to the production and sale of e-cigarettes. The FDA has had the authority to regulate smoking cessation products for a much longer time period, therefore any e-cigarettes marketed explicitly as a cessation product have been under the purview of this agency prior to 2016.

[4] To the best of our knowledge there is no empirical evidence on e-cigarette tax pass through rates.

behaviors, for example, see an excellent discussion in the context of soda taxation by Gostin (2017). Further, a recent paper highlights that traditional cigarette tax changes are often heavily covered in the news media, and this attention have an independent effect on product use (Rees-Jones and Rozema 2019). While we cannot discriminate between these hypotheses in our analysis, at the market level all will act to reduce the quantity of e-cigarettes consumed.

2.2 Studies estimating own- and cross- price elasticities of traditional cigarettes and e-cigarettes

A series of studies combines quasi-experimental methods to study the effects of e-cigarette prices on smoking and vaping. First, several studies use e-cigarette prices created from retail scanner data to show that increasing the price of e-cigarettes leads to a reduction in the quantity demanded (Stoklosa, Drope, and Chaloupka 2016, Huang et al. 2018, Pesko et al. 2018, Pesko and Warman 2017, Zheng et al. 2017). Excluding studies specific to youth (Pesko et al. 2018, Pesko and Warman 2017), the estimated elasticities range from a low of -0.8 (Stoklosa, Drope, and Chaloupka 2016) to a high of -2.1 (Zheng et al. 2017). Discrete choice experiments (DCEs), which present hypothetical purchasing decisions to respondents when product attributes such as prices are varied, provide additional evidence on e-cigarette own-price elasticity. Using DCEs Pesko et al. (2016) and Marti et al. (2019), for example, ask adult smokers to choose between e-cigarettes and traditional cigarettes. The authors document that the probability of choosing an e-cigarette declines as its price rises. Collectively, these studies using scanner data and DCEs provide evidence on the 'first stage' relationship between prices and quantities.

Second, the cross-price elasticity of demand, which captures the extent to which e-cigarettes and traditional cigarettes are substitutes or complements, has been explored in a number of recent studies. Unlike the available literature on the own-price elasticity, which provides strong evidence of a downward sloping demand curve for e-cigarettes, no consensus has yet been reached on the relationship between e-cigarettes and traditional cigarettes. Instead, findings differ across populations and datasets in ways that are difficult to explain as most studies rely on similar arguably credible differences-in-differences style models to estimate treatment effects. While understanding the observed heterogeneity is clearly important for the field, it is beyond the scope of this paper. Instead, we simply summarize the literature to date and discuss our contribution.

Huang et al. (2018), using Neilson household scanner data, provide no statistically significant evidence that increases in traditional cigarette prices lead to changes in e-cigarette purchases. Similarly, Pesko et al. (2018) document limited evidence that increases in e-cigarette prices influence youth traditional cigarette use. On the other hand, several other studies imply that e-cigarettes and traditional cigarettes are substitutes, with cigarette cross-price elasticities ranging from 1.9 to 4.6 (Stoklosa, Drope, and Chaloupka 2016, Pesko and Warman 2017) and one estimate suggesting an e-cigarette cross-price elasticity as low as 0.004 (Zheng et al. 2017).

While not directly estimating a cross-price elasticity of demand, several studies have examined the effect of minimum legal sales ages (MLSA) on youth traditional cigarette use. An MLSA increases the non-pecuniary cost (or hassle) of e-cigarettes as youth below the MLSA are prohibited from legally purchasing the product. Studies in this literature also offer mixed evidence on the relationship between e-cigarettes and traditional cigarettes. Friedman (2015); Pesko, Hughes, and Faisal (2016); and Dave, Feng, and Pesko (2019) show evidence of substitution: following the passage of an MLSA youth traditional cigarette use increases. However, in a sample of 12^{th} grade students, Abouk and Adams (2017) find that MLSA adoption leads to a decrease in youth smoking, suggesting that the two products are complements.

Finally, two studies use variation in taxes, rather than prices, to estimate cigarette own- and cross-tax elasticities. In the study that is arguably closest to our own, Pesko, Courtemanche, and Maclean (2019) combine survey data from the Behavioral Risk Factor Surveillance Survey (BRFSS) and the NHIS over the period 2011 to 2017 to study the effects of e-cigarette and traditional cigarette taxes on vaping and smoking. The authors find that adoption of an e-cigarette tax reduces vaping among adults by as much as 10% (estimates vary to some extent across samples) but is not associated with smoking. Further, a one-dollar increase in the traditional cigarette tax rate leads to a 13% increase in any vaping, suggesting that the products are economic substitutes. Second, Cotti, Nesson, and Tefft (2018) use Neilson household scanner data to show that an increase in the traditional cigarette tax leads to a *reduction* in e-cigarette household purchases, suggesting that the products are complements.

In summary, the literature offers definitive evidence that e-cigarette use declines when the price or tax of this product rises but the extent to which e-cigarettes and traditional cigarettes are related is unclear at this time. Thus, we expect that, among pregnant women, e-cigarette use will decline when localities adopt an e-cigarette tax. However, the extent to which pregnant women will increase smoking following such a tax is not clear because pregnant women are different from youth and the general population. They likely consider the well-being of the fetus when making health-related decisions such as whether to alter their e-cigarette and traditional cigarette use following policy changes. Further, some pregnant women who smoke may be seeking to quit temporarily, i.e. for the duration of the pregnancy, rather than establishing a longer-term change in smoking. Our study seeks to provide evidence on this question.

2.3 Effect of tobacco policies on prenatal smoking and birth outcomes

A series of studies has investigated the extent to which traditional cigarette taxes and indoor use bans, both of which are designed to reduce smoking, influence fetal development. While related, these studies do not include data from the e-cigarette era, thus women do not have the option to substitute e-cigarettes for traditional cigarettes in response to policy changes.

Early studies using birth records document that higher traditional cigarette taxes reduce smoking among pregnant women with implied own-tax elasticities of -0.7 to -1 (Ringel and Evans 2001, Colman, Grossman, and Joyce 2003). More recent studies confirm the negative relationship between traditional cigarette taxes and smoking among pregnant women in birth record data, although the implied tax-elasticities of demand are smaller in magnitude. For example, Adams et al. (2012) estimate an elasticity of -0.09.

The established reductions in smoking among pregnant women attributable to taxes improve fetal development. For example, Evans and Ringel (1999) show that a one-dollar increase in the traditional cigarette tax increases birth weight by 16 grams (0.5%). When this tax is used as an instrumental variable, the authors document much larger effects: prenatal smoking reduces birthweight by 360 grams (11%). Lien and Evans (2005) report similar effects using variation in traditional cigarette tax hikes in four states (Arizona, Illinois, Massachusetts, and Michigan) during the 1990s. The benefits from traditional cigarette tax increases also appear to persist beyond birth outcomes. Simon (2016) investigates a longer-term impact of *in utero* exposure to traditional cigarette tax hikes on outcomes among children two to 17 years. The results of this study indicate a one-dollar increase in the traditional cigarette tax reduces school sick days by 10%, and reduces inpatient and outpatient visits among children by 12% and 4.7%.

Research on the effect of e-cigarette policies on birth outcomes is limited. To the best of our knowledge, only two studies have explored this question. Cooper and Pesko (2017) estimate the effect of e-cigarette indoor bans on prenatal conventional cigarette smoking and birth outcomes in U.S. states and counties using birth records. E-cigarette indoor air laws reduce prenatal smoking cessation, but the laws have no effect on birth outcomes. Pesko and Currie (2019) examine the effect of MLSA laws on teenage prenatal smoking and birth outcomes, and similarly find that MLSA laws reduce prenatal smoking cessation rates for rural youth but have no effect on birth outcomes.[5] These two studies foreshadow our findings that e-cigarette taxes increase smoking among pregnant women but have no discernable effect on birth outcomes.

3. Data

3.1 Data on birth records

We use administrative birth records with geocodes provided by the National Center for Health Statistics (NCHS). In particular, we use the 2003 revised birth record forms rather than the traditional forms which have been in place since 1988. We use the revised records because this format includes self-reported smoking information at four points in time: pre-pregnancy (three months prior to pregnancy) and in each trimester. States transitioned, in a staggered manner, from the traditional form to the revised form over the period 2003 to 2015. Neither revised nor unrevised birth records includes information on prenatal vaping.

As of July 2019, the time of writing, revised birth records are available from the NCHS through the end of 2017. We restrict our analysis sample to mothers giving birth in 2013 or conceive[6] before April 2017 to avoid censoring the data based on gestational length.[7] That is,

[5] Rural youth are the only sub-group for which the data appear to satisfy the parallel trends assumption.
[6] We assume that the infant was born at the mid-point of the month recorded in the birth record. We then use gestational length in weeks, to identify the estimated point of gestation and the start of the three trimesters. The first trimester is defined as the point of ovulation that led to pregnancy. The second trimester is defined as week 14 of pregnancy (14 weeks after last menstrual period). The third trimester is defined as week 28 of pregnancy.
[7] For example, a mother conceiving after March 2017 would only appear in our data in the event of a premature birth. By restricting our sample to conceptions occurring on or before March 2017, we avoid this issue of our sample only containing premature births, which are very different from full term births, beyond March 2017.

mothers who conceive after March 2017, and have a full term pregnancy, would not be observed in all three trimesters if we extended our study period to incorporate more recent data. We begin our study period in 2013 to ensure a representative sample; by this year all but three states (Connecticut, New Jersey, and Rhode Island) had adopted the revised birth record form. Minnesota was the first locality in the U.S. to adopt an e-cigarette tax (August 2010). We exclude Minnesota from the analysis sample as this state is a treated control throughout our study period. In robustness checks reported later in the manuscript we (i) begin our sample in 2011 and exclude 13 states that had not adopted the revised birth record format by that year, and (ii) include Minnesota. Results are not sensitive to these sample changes.

We make several additional exclusions to form our analysis sample. First, we exclude mothers giving birth in Hawaii in 2013 because of a large percentage of missing smoking information in that state and year (98%). Second, we exclude non-singleton births to reduce potential confounding from fertility treatment availability (Kulkarni et al. 2013). Third, we exclude a small number (2.8%) of mothers with missing smoking information pre-pregnancy and in any of the three trimesters. Finally, we exclude mothers with missing gestational length (0.3%) as we cannot determine birth month for these observations. These exclusions leave us with 17,269,246 births in our analysis sample.

We construct three traditional cigarette smoking measures: (i) any smoking during the pregnancy, (ii) the average number of traditional cigarettes smoked per day during the pregnancy, and (iii) any smoking during the three months prior to conception ('pre-pregnancy smoking'). We also construct the following birth outcomes to study the health effects of e-cigarette taxes: gestational length (weeks), premature birth (<37 weeks), birth weight (grams), low birth weight (<2,500 grams), small-for-gestational age ($\leq 25^{th}$ percentile), extra small-for-gestational age (≤10th percentile), and Apgar 5 score. The Apgar 5 is an index used by healthcare professionals to evaluate the condition of a newborn along five dimensions, and this variable ranges from a minimum of zero (very poor health) to a maximum of ten (perfect health). These measures are established markers of fetal development commonly used in economics (Cooper and Pesko 2017, Evans and Ringel 1999, Pesko and Currie 2019).

3.2 Data on e-cigarette taxes and traditional cigarette policies

We identify dates of e-cigarette and traditional cigarette taxes from the Vapor Products Tax Data Center (2018), American Nonsmokers Rights Foundation (proprietary data), and the Tax Foundation (2018). Appendix Table 1 lists the localities levying e-cigarette taxes at different points in time through March 2017. Figure 1 reports the number of new e-cigarette tax adoptions in each year of our study and Figure 2 reports the tax variation graphically. While the majority of localities did not levy a tax by the end of our study period, among adopting localities there is no clear geographic clustering and, given the limited number of adopting localities, we have reasonably good coverage of the U.S.

We also consider whether there is heterogeneity in the effect of e-cigarette taxes that are levied on consumers or on producers. We decompose the any e-cigarette tax variable into separate indicators for any consumer tax and any wholesaler tax (Appendix Table 1). We further explore the importance of the manner in which an e-cigarette tax is levied by replacing the any wholesaler e-cigarette tax indicator with the wholesaler percent ad valorem tax. We are unable to construct a similar continuous measure for consumer taxes as there is no obvious approach to standardize these taxes as they are applied to different units (e.g., sales tax on purchase price, excise tax on milliliters of fluid and/or units).

The producer taxes appear to be larger taxes and so may be anticipated to have a greater impact on prenatal smoking. Of the six localities using excise taxes, five of these range from \$0.05 to \$0.20 per fluid milliliter (mL). For comparison, each JUUL (a leading manufacturer of e-cigarettes in the U.S. at the time of writing) disposable pod contains 0.7 fluid mL of liquid nicotine, implying that these excise taxes are quite small. For ad valorem taxes, the tax rates ranged from 30% in Montgomery County to 95% in Minnesota. Washington, DC has an ad valorem tax of between 65% to 67% during our study period, which is unique in that the tax is pegged to be equal to the traditional cigarette excise tax rate (Tobacco Control Legal Consortium 2018), which is \$2.50 during our study period. In sum, while not a direct comparison, the ad valorem taxes appear substantially larger than the excise taxes.

We adjust for other tobacco control policies in our regression models. Specifically, we control for inflation-adjusted federal, state, and local traditional cigarette taxes (Centers for Disease Control and Prevention 2019), and state and county e-cigarette minimum legal purchase age laws[8] (Pesko and Currie 2019). Finally, we use proprietary data from the American Non-Smokers Rights Foundation to determine whether the county comprehensively bans smoking and vaping in private workplaces, bars, and restaurants. More specifically, we create the indicators of bans for smoking and vaping separately.

4. Methods

We first estimate the effects of e-cigarette taxes on pre-pregnancy and prenatal smoking in a cross-sectional differences-in-differences (DD) specification outlined in Equation (1):

$$(1) \qquad S_{i,c,s,t} = \alpha + \beta Tax_{c,s,t} + TP_{c,s,t}\gamma + X_{i,c,s,t}\theta + \gamma_{c,s} + \omega_t + \varepsilon_{i,c,s,t}$$

[8] We incorporate the adoption of a federal minimum legal purchase age law of 18 in August, 2016. By this point in time only Pennsylvania had not already passed a state law.

i indexes a pregnancy with gestation year-month t, in county c in state s. $S_{i,c,s,t}$ is an indicator for whether the mother smoked at any point during the pregnancy, or the average daily number of traditional cigarettes smoked while pregnant. $X_{i,c,s,t}$ includes mother's race/ethnicity (White, non-Hispanic, Black, non-Hispanic, Hispanic, and other), age (separate indicators for ages 14 through 50), primary payment source information on file at birth (Medicaid, private insurance, uninsured, Indian Health Service, military [CHAPUS/TRICARE], other government sources, other, and unknown), marital status (married, not married, and unknown), education (less than high school, high school, some college, a college degree more, and unknown), and birth count (1, 2, …7, 8 or more, and unknown). $TP_{c,s,t}$ includes tobacco control policies.

β is our primary coefficient of interest and captures the effect of e-cigarette taxes on smoking outcomes. We expect $\hat{\beta}$ to be positive if e-cigarettes are substitutes for traditional cigarettes among pregnant women. However, if instead these products are complements, then $\hat{\beta}$ should be negative. Finally, the two products may be unrelated goods among pregnant women, suggesting that $\hat{\beta}$ will be zero.

We control for county fixed effects ($\gamma_{c,s}$), which mitigate potential bias from time invariant, county-specific factors. Note that county fixed effects incorporate state fixed effects as counties are nested within states. Including these fixed effects allows us to leverage within locality (county or state) variation in e-cigarette taxes for identification of treatment effects.[9]

In our primary specification, we control for month-by-year of gestation fixed effects (ω_t). Including these fixed effects allows us to account for time varying factors affecting the nation as

[9] We use place codes provided in the birth records to divide Cook County into the city of Chicago and the rest of Cook County, given that the city of Chicago passed a city e-cigarette tax prior to the passage of a county-wide tax (see Appendix Table 1 for more details). Both localities are treated as separate counties (and receive separate county fixed effects) in all regression models.

a whole, such as the increase in the popularity of e-cigarettes that occurred over our study period. In an alternative specification, we control for time effects by including state-by-year of gestation fixed effects in addition to month-by-year of gestation fixed effects. Controlling for these additional fixed effects isolates the impact of e-cigarette taxes on smoking outcomes within the gestation year in which the e-cigarette tax is levied for that specific state, rather than across all years of enactment, as is the case when we do not include state-by-year of gestation fixed effects.

A necessary assumption for the DD model to recover causal estimates is that the treatment (i.e., localities adopting an e-cigarette tax) and the comparison (i.e., localities not adopting an e-cigarette tax) groups would have followed the same trend in pre-pregnancy and prenatal smoking outcomes in the post-treatment period, had the treatment localities not been treated. While this assumption is clearly untestable as adopting localities are treated in the post-period and hence we cannot observe counterfactual trends, we provide suggestive evidence on whether the parallel trends assumption is satisfied by modifying Equation (1) to conduct an event study as is standard within the economic literature (Autor 2003).

To implement the event study, we replace the e-cigarette tax indicator variable with a set of mutually exclusive and collectively exhaustive tax leads and lags that divide the study period into the following categories (all relative to the e-cigarette effective date): gestation >18 months before, >15 to 18 months before, >12 to 15 months before, >9 to 12 months before (omitted category), >6 to 9 months before (i.e., the e-cigarette tax plausibly affects pregnant women during their third trimester), >3 to 6 months before (i.e., the e-cigarette tax plausibly affects pregnant women during their second and third trimester), >0 to 3 months before (i.e., the e-cigarette tax plausibly affects pregnant women during all trimesters), 0 to >3 months after gestation, and >3 months after gestation. Apart from including these tax leads and lags instead of the standard DD variable, the event study equation is identical to Equation (1).

In this event study specification, the coefficient estimates on the tax leads can provide evidence of differential pre-trends between the treatment and comparison groups. Differential pre-trends may occur if, for example, localities adopt e-cigarette taxes in response to changes in pre-pregnancy and prenatal smoking outcomes and/or anticipatory behaviors on the part of pregnant smokers. If the coefficient estimates on the tax leads are small in magnitude and statistically indistinguishable from zero, this pattern of null results suggests that the parallel trends assumption is satisfied in the birth record data and that our DD models can recover causal estimates of e-cigarette tax effects. The event lag indicators are informative for assessing any dynamics in tax effects that emerge over time in the post-period. Dynamics may capture the time required for a levied tax to be passed through to consumers (e.g., menu costs, stockpiling among e-cigarette users) or avoidance behaviors among consumers (e.g., purchasing e-cigarettes in localities that do not levy the tax or online). These behaviors suggest that e-cigarette tax effects could increase or decrease over time post-tax.

As a secondary analysis, we explore the effect of e-cigarette tax adoption that occurs *during* a mother's pregnancy on within-pregnancy smoking; we refer to this analysis as the 'panel data analysis.' We create a panel of pregnancies with four observations per pregnancy; that is we rely on the balanced panel in this analysis. In particular, in the panel data analysis our outcome of interest is prenatal smoking. We estimate the model outlined in Equation (2):

$$(2) \qquad S_{i,c,s,p,t} = \rho + \pi Tax_{c,s,t} + TP_{c,s,t}\phi + \delta_i + \kappa_{p,t} + \vartheta_{i,c,s,p,t},$$

where i is a mother in period p (either in the three months prior to pregnancy or in each of the three trimesters) and t indexes year-by-month of the start of each period p. We replace individual mother characteristics with pregnancy fixed effects (δ_i) as these variables do not vary within-mother. We control for period-by-year-by-month fixed effects ($\kappa_{p,t}$). Pregnancy fixed effects incorporate locality fixed effects.

In the panel data analysis, we stratify the sample by pre-pregnancy smoking status. Through this stratification we are able to provide evidence on whether, and to what extent, e-cigarette tax adoption triggers smoking cessation, initiation, and/or relapse during a pregnancy. If the estimate of π generated in a sample of pre-pregnancy smokers is positive, then this finding suggests that e-cigarette taxes reduce prenatal smoking cessation. On the other hand, if the estimate of π generated in a sample of pre-pregnancy non-smokers is positive, then our findings suggest that e-cigarette taxes trigger smoking initiation/relapse. Given the well-known health harms and stigma of smoking during a pregnancy, we expect no effect of e-cigarette taxes within the sample of pre-pregnancy never-smokers.

All models are estimated with linear probability models when the outcome is binary and least squares when the outcome is continuous. We use variation generated by the decisions of counties and states to levy e-cigarette taxes. Thus, the correct level (county or state) at which to cluster standard errors is unclear. We choose to cluster standard errors at the state level to provide conservative estimates of precision. However, as we report in robustness checking, our precision is not markedly different if we instead cluster standard errors at the county level.

5. Results

5.1 Summary statistics

Table 1 reports summary statistics for the full sample, the sample of counties that levy an e-cigarette tax, and the sample of counties that do not levy an e-cigarette tax by the end of our study period (March 2017). 7.8% and 10.1% of the full sample reported any smoking while pregnant and any smoking in the three months prior to conception. In the full sample, the unconditional average number of traditional cigarettes smoked per day before pregnancy is 1.33. Smoking declines monotonically as the birth date approaches: the unconditional average number of traditional cigarettes smoked per day in the 1st, 2nd, and 3rd trimester is 0.81, 0.61, and 0.54. For all smoking variables that we consider, smoking is lower in counties that levy vs. do not levy an e-cigarette tax. For example, average pre-pregnancy daily unconditional traditional cigarette smoking in counties that levy an e-cigarette tax is 0.97 and this average is 1.46 in counties that did not levy such a tax.

The racial/ethnic breakdown of the sample is 52.3% non-Hispanic White, 14.3% non-Hispanic Black, 23.8% Hispanic, and 9.6% other. The average age of mothers at the birth of their child in our sample is just over 28 years. Private insurance finances 47.3% (the plurality) of all births in the sample, with Medicaid, self-pay, and other payment forms (Indian Health Service, military insurance, other government sources, other, and payment source unknown) financing 43.5%, 4.1%, and 5.1% of births, respectively.

Demographics and policies vary somewhat across counties that levy and do not levy an e-cigarette tax. We control for these differences in all regression models.

5.2 Differences-in-differences regression results

Our main DD results are reported in Table 2 (any smoking), Table 3 (average number of traditional cigarettes smoked per day), and Table 4 (pre-pregnancy smoking). We model e-cigarette taxes, measured at the time of conception, three ways: (i) any e-cigarette tax indicator, (ii) separate indicators for a wholesale tax and a consumer tax, and (iii) wholesale tax rate and a consumer tax indicator. For each approach to modelling e-cigarette taxes, we report coefficient estimates generated in specifications that do not and do include state-by-year of gestation fixed effects. Results are robust to the inclusion of these additional fixed effects. A full set of coefficient estimates for the any smoking specification is reported in Appendix Table 2.

The levying of an e-cigarette tax leads to a 0.3 percentage point (ppt) increase in the probability of any smoking during pregnancy (Table 2, column 1). Comparing this point estimate to the prenatal smoking proportion in localities that levy e-cigarettes taxes prior to the tax adoption (all coefficient estimates are compared to this baseline henceforth), the relative effect size is 6.3%. This pattern of results suggests that e-cigarettes and traditional cigarettes are substitute products among pregnant women.

In column 3, we decompose the e-cigarette tax indicator into an indicator for a wholesale tax and a consumer tax. After a wholesale tax is levied, smoking increases among pregnant women by 0.6 ppts (11.3%); the corresponding increase following the levying of a consumer e-cigarette tax is 0.3 ppts (5.9%). Finally, we report results in which we include the wholesale tax rate and an indicator for a consumer tax. A 100 ppt increase in the wholesale tax rate (approximately double the national conditional e-cigarette wholesaler tax rate of 45.4%) leads to a 1.3 ppt (25%) increase in prenatal smoking. The coefficient estimate on the consumer tax indicator is largely unchanged: 0.3 ppt (5.9%) increase in smoking. We note that the point estimate on the wholesale tax rate variable generated in the specification that includes state-by-year of gestation fixed effects is not statistically distinguishable from zero, although the point estimate survives in terms of sign and magnitude.

Results for the average number of traditional cigarettes smoked per day (Table 3) closely mirror our any prenatal smoking findings. The levying of an e-cigarette tax leads to 0.02 (5.9%) (Table 3, column 1) more traditional cigarettes smoked per day among pregnant women. Similarly, the number of traditional cigarettes smoked per day increases by 0.05 (11.3%) (Table

3, column 3) after a wholesale e-cigarette tax is levied and 0.02 (5.5%) following the levying of a consumer e-cigarette tax; we note that the latter point estimate is not statistically different from zero. A 100 ppt increase in the wholesale tax rate increases the average number of traditional cigarettes smoked per day by 0.10 (24%) (Table 3, column 5). The implied cross tax-elasticity of the wholesale tax rate on prenatal smoking is 0.0001 in our preferred specification,[10] which carries the same sign but is smaller in magnitude than the only other e-cigarette cross-price elasticity in the literature: 0.004 (Zheng et al. 2017). This elasticity is for all individuals, not specifically pregnant women. Our positive cross-tax elasticity suggests that pregnant women do not reduce cigarette consumption by as much when there is an e-cigarette tax in place.

In Table 4 we test the effect of e-cigarette taxes on smoking in the three months prior to conception. We observe that the levying of an e-cigarette tax leads to a 0.5 ppt (6.7%) (column 1) increase in the probability of this outcome. This point estimate is similar to the 0.3 ppt (6.3%) increase in the probability of prenatal smoking shown in Table 2; other coefficient estimates in alternative specifications are also comparable across the two tables. Combining these findings suggests that the increase in prenatal smoking attributable to e-cigarette taxes is due to women smoking more *before* becoming pregnant rather than changes that occur *during* the pregnancy. We will explore this hypothesis in the panel data analysis (Section 5.5).

5.3 Internal validity of the research design

Event study point estimates and associated standard errors for our three smoking outcomes are reported in Table 5. We also report these results graphically in Figure 3. In general, the event study results do not provide evidence of differential pre-trends in our

[10] Cross-tax elasticities are calculated as follows: $\hat{\varepsilon} = \frac{\hat{\beta}_{tax} * mean\ of\ e-cigarette\ wholesale\ tax\ rate}{mean\ of\ the\ dependent\ variable} = \frac{0.00098*0.091}{0.653} = 0.0001$. In the regression, we measure e-cigarette wholesaler tax rates on a 0-1 scale. To convert it to the 0 to 100 scale, we divide $\hat{\beta}_{tax}$ by 100.

outcomes between localities that levy and do not levy an e-cigarette tax by March 2017. However, we note that one lead coefficient estimate in the any pre-pregnancy specification is statistically distinguishable from zero at the 10% level and carries a positive sign. While point estimates appear to increase in the post period (i.e., are larger in magnitude in periods more distal rather than proximate to birth, suggesting that e-cigarette tax effects escalate with time), the 95% confidence intervals surrounding the tax lag point estimates overlap, preventing us from drawing firm conclusions on the existence of dynamics.

Additionally, we test the internal validity of the DD model by exploring whether e-cigarette taxes influence birth rates. If e-cigarette taxes affect birth rates through changes in conception or fetal deaths, then our regression coefficients may suffer from conditional-on-positive (COP) bias (Angrist and Pischke 2009). To explore this hypothesis, we estimate a model using county-by-gestation year/month counts as the dependent variable and controlling for number of women 15 to 44 years of age, time-varying controls included in Equation (1), county fixed effects, and year-by-month of gestation fixed effects. The coefficient estimate on the e-cigarette tax variable is not statistically different from zero ($\hat{\beta}$ = 1.61; $\widehat{SE}$= 3.12) and is small in magnitude (1.9% of the pre-tax mean of 83.45 births for a given county/month of conception). Thus, we find no evidence of potential COP bias.

Finally, we test for balance in observable characteristics across treatment and comparison groups following Pei, Pischke, and Schwandt (2018): we regress the probability that a locality levies an e-cigarette tax on tobacco control policies, mothers' demographics from the birth records (aggregated to the county-year level), and various fixed effects reported in Equation (1). Results are reported in Table 6. We find that traditional cigarette taxes are correlated with the probability of levying an e-cigarette tax, but we observe no evidence that any other covariates predict our treatment variable. While achieving full balance across treatment and comparison groups is obviously optimal, given that e-cigarettes and traditional cigarettes are plausibly related products, the observed correlation is perhaps not surprising. For example, this correlation may simply reflect an overall tobacco control policy, which targets both e-cigarettes and traditional cigarettes, adopted by a locality. We control for tobacco policies in all specifications.

Overall, we interpret the findings from our examination of the identification strategy to imply that the birth records data satisfy necessary assumptions. Thus, we focus on results generated in the DD model to estimate the effect of e-cigarette taxes.

5.4 Heterogeneity in e-cigarette tax effects across mother characteristics

We next explore the extent to which e-cigarette tax effects may vary across mother characteristics. More specifically, we estimate separate regressions by mother’s age (less than 25 years vs. 25 years or older), educational attainment (high school education or less vs. some college or more), and primary payer for pregnancy healthcare (Medicaid and private insurance; we lack sufficient sample size to estimate separate regressions for other payment sources). We also separately examine mothers who are having their first-birth or higher order births.

Perceptions about the relative harm of e-cigarettes compared to traditional cigarettes may vary by socio-demographic factors, thereby affecting the degree to which individuals may view e-cigarettes and traditional cigarettes as substitutable products. For example, more educated and younger adults consider e-cigarettes to be less harmful than traditional cigarettes (Viscusi 2016, Pearson et al. 2012, Chivers et al. 2016). Further smoking while pregnant is more common among younger, Medicaid enrolled, and less educated women (Centers for Disease Control and Prevention 2016). These differences in risk perceptions and product use open the door to the possibility of heterogeneous e-cigarette tax effects across demographic groups.

Heterogeneity analysis results are reported in Table 7 for smoking outcomes. Results for any smoking are similar across age, education, and parity groups; while we note that point estimates vary, 95% confidence intervals overlap preventing us from drawing strong conclusions regarding heterogeneous treatment effects. For example, among younger mothers, the probability of smoking increases by 0.4 ppts or 5.6% after an e-cigarette tax is levied while the corresponding increase among older mothers is 0.3 ppts or 5.9%, we note that the former point estimate is not statistically distinguishable from zero however. Among mothers with less than a college degree the probability of smoking increases by 0.5 ppts (6.0%) following implementation of an e-cigarette tax while the corresponding increase among mothers with a college degree or more is 0.3 ppts (8.5%). Among mothers whose delivery was financed by Medicaid, the probability of smoking increases by 0.7 ppts (8.2%) compared to 0.1 ppts (5.0%) for mothers with private insurance, the latter point estimate is imprecise. Results for cigarettes smoked per day and any pre-pregnancy smoking are broadly similar to results for any prenatal smoking.

5.5 Panel data analysis

We next estimate Equation (2) in which we convert the cross-sectional data to panel form. More specifically, we use four observations per pregnancy (one pre-pregnancy and three for each trimester of the pregnancy) rather than one. Results are reported in Table 8.

Overall, we observe no statistically significant evidence that the levying of an e-cigarette tax within a pregnancy leads to changes in smoking. The finding of a null effect on pre-pregnancy smokers in particular suggests that e-cigarette taxes did not alter rates of smoking cessation during pregnancy, and the finding of a null effect on pre-pregnancy non-smokers implies that e-cigarette taxes did not affect the rare event of smoking initiation or relapse during pregnancy. These findings in combination with those reported in Tables 2 to 4 suggest that e-cigarette taxes induce substitution only before the pregnancy begins, and not during pregnancy. Mothers who continue to smoke into their pregnancy do not appear to respond to e-cigarette taxes in terms of the outcomes we study.

We propose two possible explanations for this null effect. First, pregnant women are highly motivated to quit smoking traditional cigarettes and so it is possible that they make decisions about trying to quit smoking with e-cigarettes regardless of the e-cigarette tax rate (e.g., inelastic cross-tax elasticity of demand). In contrast, not all women three months prior to their pregnancy will anticipate their pregnancy, and these women in particular may be less serious about trying to quit smoking than pregnant women who are aware of their pregnancy status. Thus, the former group of women may be more malleable on whether to use e-cigarettes for smoking cessation or not (e.g., greater cross-tax elasticity of demand). Second, the e-cigarette taxes may have had less of an information shock than other e-cigarette policies (e.g., indoor vaping laws and minimum legal purchase age laws) because taxes were mostly levied in 2016 to 2017 after health harms of vaping were better understood, which could help reconcile the null results for e-cigarette taxes in this study with other studies finding that earlier e-cigarette policies decreased prenatal smoking cessation (Cooper and Pesko 2017, Pesko and Currie 2019).

5.6 E-cigarette tax effects on birth outcomes

We now turn to exploring whether the increases in smoking during pregnancy that we document from our cross-sectional DD model lead to changes in birth outcomes. *A-priori*, the effect of e-cigarette taxes on birth outcomes is ambiguous because e-cigarette taxes could improve birth outcomes by reducing e-cigarette use and associated nicotine exposure, but any beneficial gains from a reduction in e-cigarette use could be offset by increased traditional cigarette smoking, which is harmful to developing fetuses. Therefore, the overall effect of e-cigarette taxes on birth outcomes is an empirical question.

We report results for the specification using a single indicator for an e-cigarette tax that does not include state-by-year fixed effects in Table 9. Overall, we observe no statistically significant evidence that the levying of an e-cigarette tax leads to changes in the birth outcomes we study. Taken together, our results suggest little effect of e-cigarette taxes on birth outcomes, which is in line with the available evidence on the effects of e-cigarette indoor vaping restrictions and minimum legal purchase age laws from two recent studies (Cooper and Pesko 2017, Pesko and Currie 2019). We estimate an event study and observe no evidence of differential pre-trends. Further, there is little evidence of dynamics in the post-period.[11] Results are reported in Table 10 and Figure 4.

5.7 Robustness checks

Our results are stable across several alternative specifications. We report results based on specifications that model e-cigarette taxes as a single indicator, separate indicators for a wholesale tax and a consumer tax, and an indicator for a consumer tax and the wholesale tax rate. We also report models without state-by-year of gestation fixed effects.

We first explore the sensitivity of our results to alternative samples. We include Minnesota in our sample (Appendix Table 3). As discussed in Section 3, this state levied an e-cigarette tax in 2010 and is a treated control during our study period. We next begin the sample in 2011 (Appendix Table 4). In this case, standard errors are generally larger than in models using data starting in 2013, potentially because we are adding two years to our analysis (2011

[11] We note that a small number of the tax lag point estimates are statistically distinguishable from zero at conventional levels. However, no clear pattern emerges and thus we are not able to draw firm conclusions on the extent to which birth outcomes may change as time passes following the levying of an e-cigarette tax.

and 2012) in which e-cigarettes were not as widely used and we exclude 13 states that had not adopted revised birth records by 2011. The range of the coefficients for the effect of any e-cigarette is between 0.002 to 0.004 (for models with and without state-by-year of gestation fixed effects), which is wider but similar to the range of 0.002 to 0.003 for the sample starting in 2013. In sum, our overall conclusions hold when including Minnesota, and when using a study period starting in 2011 rather than 2013.

Second, we cluster standard errors at the level of county rather than state (Appendix Table 5). This approach to inference is arguably less conservative than the approach we take in the main results. Clustering at this level does not change the precision of our estimates.

We also sequentially drop each treatment locality and re-estimate Equation (1) (i.e., ‘leave one out analysis’) to test whether our main findings are driven by the unique experiences of particular localities. Results, reported in Appendix Table 6 and graphed in Appendix Figure 1, are stable across different samples and imply that we are not capturing the effect of one or two localities. We note that the point estimates generated in the samples excluding Louisiana and Chicago IL are imprecise. However, these point estimates are similar in terms of sign and magnitude to the point estimate generated in the full sample (Table 2).

Finally, we re-explore the effect of e-cigarette taxes on pre-pregnancy smoking by linking the e-cigarette tax to three months prior to pregnancy rather than the date of conception (Appendix Table 7). This parametrization of the regression model leads to some mothers previously assigned to the pre-e-cigarette tax control group being now assigned to the post-e-cigarette tax treatment group. Our results are substantially similar to our baseline results.

6. Discussion and conclusion

Our study finds that adopting an e-cigarette tax increases the likelihood of prenatal smoking by 0.3 ppts (6.3%). This result appears to be driven exclusively by changes in rates of *pre-pregnancy* smoking; we observe no evidence that mothers who smoke at the beginning of their pregnancy adjust their traditional cigarette use following tax adopting that occurs after the pregnancy begins. The finding suggests that e-cigarettes are economic substitutes for traditional cigarettes among women who are pregnant or soon to be pregnant, which is in line with two recent studies that document that polices that raise the non-financial price of e-cigarettes (indoor bans and minimum legal sales age) increase prenatal smoking (Cooper and Pesko 2017, Pesko and Currie 2019). For example, Cooper and Pesko (2017) show that adoption of an e-cigarette indoor vaping ban increases any prenatal smoking by 0.9 ppts and within-pregnancy smoking by 2.0 ppts. Thus, our effect sizes are much more modest than the findings of Cooper and Pesko.

One possible reason for the more modest effects we document is that the e-cigarette taxes we explore in this study were implemented in 2016 and 2017, whereas e-cigarette indoor vaping restrictions in general pre-date e-cigarette taxes. In the earlier years pregnant women may have been more responsive to e-cigarette policies as there was less information available on the health risks associated with these products. In recent years individuals have access to more information on such risks that may make them less responsive to e-cigarette policies which may be interpreted by some women as a signal of health risk.

We also document that e-cigarette tax effects occur pre-pregnancy, with women opting to smoke traditional cigarettes where e-cigarette taxes are imposed and continuing to do so during pregnancy. One explanation for this is that women expecting to become pregnant use e-cigarettes to assist in smoking cessation prior to pregnancy, but e-cigarette taxes discourage this smoking cessation which leads to higher rates of smoking pre-pregnancy and during pregnancy.

We find no evidence that e-cigarette taxes influence the birth outcomes that we consider. From a public health standpoint, the increase in smoking might have a detrimental effect through two avenues, the first being poor birth outcomes of the fetus and the second being childhood development issues from secondhand smoke exposure. Our finding of limited effect of e-cigarette taxes on birth outcomes is consistent with the theory that nicotine is harmful regardless of the source. E-cigarettes are not likely a safe substitute for pregnant women.

However, we are unable to explore effects of e-cigarette taxes on later childhood health outcomes. The fetal origins hypothesis, which suggests that harms experienced *in utero* can lead to worse health later in life conditional on birth outcomes (Almond and Currie 2011), opens the door to the possibility that adverse health effects, while no observed in the birth outcomes we study, may emerge later in life for exposed children. A second potential pathway is through the infant potentially being exposed to more secondhand smoke exposure rather than secondhand vape exposure (assuming that the e-cigarette tax increased post-natal smoking similar to prenatal smoking). The U.S. Surgeon General has concluded that while aerosol contained in e-cigarettes is not harmless, e-cigarettes generally contains fewer toxicants than tobacco products (U.S. Department of Health and Human Services 2016). Given this evidence, it is possible that secondhand smoke exposure is worse for childhood health outcomes than exposure to vapors associated with e-cigarette use. Future work could examine such effects on children.

Our study has limitations. First, we identify the effect of e-cigarette taxes from variation in seven states, DC, and a few other localities. Although the localities are diverse in size, geography, and smoking prevalence, future research using data from time periods in which additional localities impose e-cigarette taxes will broaden our understanding of this question. Second, we are unable to investigate the effects of e-cigarette taxes on e-cigarette use directly, which is a limitation of most studies on e-cigarette policies to date (Friedman 2015, Pesko, Hughes, and Faisal 2016, Cooper and Pesko 2017, Pesko and Currie 2019). Relatedly, our estimates have an intent-to-treat (ITT) interpretation. We note that an estimate of the treatment-on-the-treated (TOT) would also be informative. Third, our measures of smoking are self-reported and could therefore be measured with some error.

In summary, we offer timely new evidence on the effect of e-cigarette taxes on pre-pregnancy and prenatal smoking, and birth outcomes. Importantly, we provide credible evidence that e-cigarettes and traditional cigarettes are substitute products among pregnant women and that, while many women who smoke may attempt to substitute to e-cigarettes during pregnancy, e-cigarettes are no less harmful to developing fetuses than traditional cigarettes.

Table 1. Summary statistics: Full sample, counties with an e-cigarette tax by 2017, and counties without an e-cigarette tax by 2017

Variables:	**Full sample**	**Counties with a tax**	**Counties without a tax**
Outcomes			
Average smoking participation rates	0.078	0.054	0.086
during-pregnancy	(0.268)	(0.227)	(0.280)
Average smoking participation rates	0.101	0.072	0.111
pre-pregnancy	(0.301)	(0.259)	(0.314)
Average number of traditional cigarettes	1.332	0.966	1.463
smoked per day pre-pregnancy	(5.097)	(4.432)	(5.310)
Average number of traditional cigarettes	0.811	0.442	0.729
smoked per day 1st trimester	(3.642)	(2.457)	(3.171)
Average number of traditional cigarettes	0.610	0.561	0.901
smoked per day 2nd semester	(2.997)	(3.055)	(3.826)
Average number of traditional cigarettes	0.539	0.407	0.683
smoked per day 3rd trimester	(2.790)	(2.441)	(3.170)
Policy variables			
E-cigarette tax (any)	0.029	0.111	-
	(0.168)	(0.314)	-
E-cigarette consumer tax (any)	0.027	0.103	-
	(0.163)	(0.304)	-
E-cigarette wholesaler tax (any)	0.002	0.008	-
	(0.045)	(0.087)	-
E-cigarette wholesaler tax (rate, in %), unconditional	0.091	0.343	-
	(2.177)	(4.223)	-
E-cigarette wholesaler tax (rate, in %), conditional	45.540	45.540	-
on any e-cigarette wholesaler tax	(17.533)	(17.533)	-
Traditional cigarette taxes ($)	2.495	2.053	2.627
	(1.044)	(0.526)	(1.113)
Traditional cigarette indoor ban (any)	0.623	0.591	0.635
	(0.485)	(0.492)	(0.482)
E-cigarette MLSA (any)	0.665	0.786	0.621
	(0.472)	(0.410)	(0.485)
E-cigarette indoor ban (any)	0.078	0.142	0.055
	(0.269)	(0.349)	(0.229)
Mother characteristics			
White, non-Hispanic	0.523	0.560	0.421
	(0.499)	(0.496)	(0.494)
Black, non-Hispanic	0.143	0.149	0.126
	(0.350)	(0.356)	(0.332)
Hispanic	0.238	0.210	0.317
	(0.426)	(0.407)	(0.465)
Other race	0.096	0.082	0.136
	(0.295)	(0.274)	(0.343)
Age at birth	28.384	28.218	28.846
	(5.860)	(5.819)	(5.949)
Medicaid primary payer	0.435	0.437	0.430
	(0.496)	(0.496)	(0.495)
Private insurance primary payer	0.473	0.469	0.484
	(0.499)	(0.499)	(0.500)

Self-pay	0.041	0.041	0.041
	(0.198)	(0.198)	(0.198)
Indian Health Service primary payer	0.001	0.001	0.000
	(0.030)	(0.034)	(0.012)
Military insurance primary payer	0.012	0.013	0.007
	(0.107)	(0.114)	(0.085)
Other government sources primary payer	0.009	0.007	0.014
	(0.094)	(0.084)	(0.117)
Other primary payer	0.021	0.022	0.018
	(0.143)	(0.147)	(0.133)
Unknown primary payer	0.008	0.009	0.005
	(0.089)	(0.094)	(0.074)
Married	0.579	0.594	0.535
	(0.494)	(0.491)	(0.499)
Not married	0.396	0.405	0.369
	(0.489)	(0.491)	(0.482)
Marital status unknown	0.026	0.000	0.096
	(0.158)	(0.008)	(0.295)
Less than high school	0.146	0.146	0.147
	(0.353)	(0.353)	(0.355)
High school	0.252	0.255	0.244
	(0.434)	(0.436)	(0.430)
Some college	0.290	0.297	0.271
	(0.454)	(0.457)	(0.445)
College or more	0.300	0.296	0.311
	(0.458)	(0.457)	(0.463)
Education unknown	0.012	0.006	0.026
	(0.107)	(0.079)	(0.159)
1st birth	0.321	0.317	0.333
	(0.467)	(0.465)	(0.471)
2nd birth	0.281	0.278	0.288
	(0.450)	(0.448)	(0.453)
3rd birth	0.183	0.183	0.180
	(0.386)	(0.387)	(0.384)
4th birth	0.101	0.103	0.097
	(0.302)	(0.304)	(0.296)
5th birth	0.052	0.053	0.048
	(0.222)	(0.224)	(0.215)
6th birth	0.026	0.027	0.023
	(0.159)	(0.161)	(0.151)
7th birth	0.013	0.014	0.012
	(0.114)	(0.117)	(0.107)
8th birth	0.016	0.017	0.013
	(0.125)	(0.129)	(0.113)
Birth order unknown	0.007	0.008	0.005
	(0.086)	(0.090)	(0.072)
Observations	17,269,246	4,565,107	12,704,139

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics January 2013 to March 2017. The unit of observation is a pregnancy in a county in a state. Standard deviations are reported in parenthesis.

Table 2. Effect of e-cigarette taxes levied at conception on any prenatal smoking

Model:	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Tax (any)	0.0032**	0.0024**	--	--	--	--
	(0.0016)	(0.0010)	--	--	--	--
% change	6.3%	4.7%	--	--	--	--
Wholesaler tax (any)	--	--	0.0057**	0.0064***	--	--
	--	--	(0.0027)	(0.0016)	--	--
% change	--	--	11.3%	12.6%	--	--
Consumer tax (any)	--	--	0.0030*	0.0019**	0.0030*	0.0019**
	--	--	(0.0016)	(0.0009)	(0.0016)	(0.0009)
% change	--	--	5.9%	3.7%	5.9%	3.7%
Wholesaler tax	--	--	--	--	0.0127**	0.0135
(rate, 100 ppt increase)	--	--	--	--	(0.0049)	(0.0081)
% change					25%	26%
County FE	✓	✓	✓	✓	✓	✓
Conception year-month FE	✓	✓	✓	✓	✓	✓
Conception year-by-state FE		✓		✓		✓
Dep. var. proportion (pre-period treated localities)	0.051	0.051	0.051	0.051	0.051	0.051
Adjusted R-squared	0.15	0.15	0.15	0.15	0.15	0.15
Number of clusters	47	47	47	47	47	47

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics January 2013 to March 2017. N=17,269,246. The unit of observation is a pregnancy in a county in a state. Standard errors are clustered around the state and are reported in parentheses. All models estimated with a linear probability model and control for mothers' demographic characteristics and state-level policy variables.
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

Table 3. Effect of e-cigarette taxes levied at conception on the average number of cigarettes smoked per day during the pregnancy

Model:	(1)	(2)	(3)	(4)	(5)	(6)
Tax (any)	0.0245*	0.0208	--	--	--	--
	(0.0141)	(0.0157)	--	--	--	--
% change	5.9%	5.0%	--	--	--	--
Wholesaler tax (any)	--	--	0.0469***	0.0444***	--	--
	--	--	(0.0135)	(0.0130)	--	--
% change	--	--	11.3%	10.7%	--	--
Consumer tax (any)	--	--	0.0227	0.0179	0.0227	0.0179
	--	--	(0.0150)	(0.0177)	(0.0150)	(0.0177)
% change	--	--	5.5%	4.3%	5.5%	4.3%
Wholesaler tax	--	--	--	--	0.0980***	0.0863
(rate, 100 ppt increase)	--	--	--	--	(0.0231)	(0.0655)
% change	--	--	--	--	24%	21%
County FE	✓	✓	✓	✓	✓	✓
Conception year-month FE	✓	✓	✓	✓	✓	✓
Conception year-by-state FE		✓		✓		✓
Dep. var. mean (pre-period treated localities)	0.415	0.415	0.415	0.415	0.415	0.415
Adjusted R-squared	0.11	0.11	0.11	0.11	0.11	0.11
Number of clusters	47	47	47	47	47	47

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics January 2013 to March 2017. N=17,269,246. The unit of observation is a pregnancy in a county in a state. Standard errors are clustered around the state and are reported in parentheses. All models estimated with least squares and control for mothers' demographic characteristics and state-level policy variables.
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

Table 4. Effect of e-cigarette taxes levied at conception on the probability of smoking in the three months prior to conception

Model:	(1)	(2)	(3)	(4)	(5)	(6)
Tax (any)	0.0046**	0.0039***	--	--	--	--
	(0.0021)	(0.0012)	--	--	--	--
% change	6.7%	5.8%	--	--	--	--
Wholesaler tax (any)	--	--	0.0087***	0.0114***	--	--
	--	--	(0.0026)	(0.0017)	--	--
% change	--	--	12.7%	16.8%	--	--
Consumer tax (any)	--	--	0.0043*	0.0030***	0.0043*	0.0030***
	--	--	(0.0022)	(0.0008)	(0.0022)	(0.0008)
% change	--	--	6.3%	4.4%	6.3%	4.4%
Wholesaler tax	--	--	--	--	0.0187***	0.0254**
(rate, 100 ppt increase)	--	--	--	--	(0.0036)	(0.0114)
% change	--	--	--	--	27%	37%
County FE	✓	✓	✓	✓	✓	✓
Conception (year-month) FE	✓	✓	✓	✓	✓	✓
Conception year-by-state FE		✓		✓		✓
Dep. var. proportion (pre-period treated localities)	0.068	0.068	0.068	0.068	0.068	0.068
Adjusted R-squared	0.16	0.16	0.16	0.16	0.16	0.16
Number of clusters	47	47	47	47	47	47

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics January 2013 to March 2017. N=17,269,246. The unit of observation is a pregnancy in a county in a state. Standard errors are clustered around the state and are reported in parentheses. All models estimated with a linear probability model and control for mothers' demographic characteristics and state-level policy variables.
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

Table 5. Effect of e-cigarette taxes levied at conception on prenatal and pre-pregnancy smoking using an event study design

Outcome:	**Any prenatal smoking**	**Cigarettes smoked per day**	**Any pre-pregnancy Smoking**
Time to e-cigarette effective date:			
>18 month	0.0012	-0.0147	0.0018
	(0.0035)	(0.0326)	(0.0045)
[15, 18) month	0.0040	0.0215	0.0049
	(0.0033)	(0.0261)	(0.0038)
[12, 15) month	0.0025	0.0126	0.0042*
	(0.0020)	(0.0161)	(0.0024)
[9, 12) month (reference)	-	-	-
	-	-	-
[6, 9) month	0.0011	0.0123	0.0011
	(0.0009)	(0.0107)	(0.0012)
[3, 6) month	0.0017**	0.0096	0.0021**
	(0.0007)	(0.0105)	(0.0009)
[0, 3) month	0.0027***	0.0171*	0.0032***
	(0.0008)	(0.0092)	(0.0009)
(0, 3] month	0.0020	-0.0014	0.0032
	(0.0016)	(0.0159)	(0.0024)
>3 month	0.0050***	0.0271*	0.0071***
	(0.0018)	(0.0140)	(0.0026)
County FE	✓	✓	✓
Conception year-month FE	✓	✓	✓
Dep. var. proportion/mean (pre-period treated localities)	0.051	0.415	0.068
Adjusted R-squared	0.15	0.11	0.16
Number of clusters	47	47	47
p-value of joint *F*-test on the policy leads	0.38	0.02	0.08

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics January 2013 to March 2017. N=17,269,246. The unit of observation is a pregnancy in a county in a state. Standard errors are clustered around the state and are reported in parentheses. The omitted category is 9 to 12 months preconception. All models estimated with a linear probability model (binary outcome) or least squares (continuous outcome), and control for mothers' demographic characteristics and state-level policy variables.
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

Table 6. Test of balance across localities that adopted and did not adopt an e-cigarette tax by 2017

Variable:	**Beta coefficient (standard error)**
Traditional cigarette tax rate ($)	0.6991***
	(0.1791)
Traditional cigarette bans (any)	0.0447
	(0.0303)
E-cigarette bans (any)	-0.0753*
	(0.0393)
E-cigarette MLSA	-0.0127
	(0.0143)
White, non-Hispanic	0.0071
	(0.0058)
Hispanic	-0.0005
	(0.0051)
Age at birth	-0.0001
	(0.0002)
Private insurance	-0.0050
	(0.0049)
Married	0.0061
	(0.0042)
Some college education	-0.0015
	(0.0028)
Birth order	0.0002
	(0.0003)
County FE	✓
Conception year-month FE	✓
Dep. var. proportion	0.047
Adjusted R-squared	0.51
Number of clusters	47

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics January 2013 to March 2017. N=176,834. The unit of observation is a county in a state in a year. Standard errors are clustered around the state and are reported in parentheses. All models estimated with a linear probability model. Omitted categories are non-white, non-Hispanic; non-private insurance; non-married; and less than college education.
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

Table 7. Heterogeneity in the effect of e-cigarette taxes levied at conception on prenatal and pre-pregnancy smoking

Sample:	< 25 yrs	≥ 25 yrs	Low education	High education	Medicaid	Private	1st birth	≥2nd birth
Any prenatal smoking								
Tax	0.0044	0.0025***	0.0048**	0.0025*	0.0070***	0.0012	0.0029	0.0033*
	(0.0033)	(0.0008)	(0.0024)	(0.0012)	(0.0026)	(0.0011)	(0.0019)	(0.0017)
% change	5.6%	5.9%	6.0%	8.5%	8.2%	5.0%	7.9%	5.5%
Dep. var. prop. (pre-period treated localities)	0.078	0.042	0.081	0.029	0.085	0.023	0.037	0.059
Cigarettes smoked per day								
Tax	0.0323	0.0193**	0.0363	0.0208**	0.0551**	0.0116	0.0279	0.0223
	(0.0321)	(0.0075)	(0.0251)	(0.0090)	(0.0229)	(0.0104)	(0.0180)	(0.0147)
% change	5.4%	5.4%	5.3%	9.4%	7.8%	6.9%	10.6%	4.5%
Dep. var. mean (pre-period treated localities)	0.594	0.354	0.68	0.22	0.707	0.169	0.262	0.496
Pre-pregnancy smoking								
Tax	0.0065*	0.0036***	0.0064**	0.0038*	0.0092***	0.0025	0.0043	0.0046**
	(0.0038)	(0.0012)	(0.0025)	(0.0020)	(0.0028)	(0.0016)	(0.0027)	(0.0020)
% change	6.2%	6.4%	6.4%	8.4%	8.8%	6.7%	7.5%	6.2%
Dep. var. prop. (pre-period treated localities)	0.105	0.056	0.099	0.045	0.104	0.038	0.057	0.074
County FE	✓	✓	✓	✓	✓	✓	✓	✓
Conception year-month FE	✓	✓	✓	✓	✓	✓	✓	✓
Observations	4,832,897	12,436,349	6,878,171	10,391,075	7,519,116	8,171,159	5,540,033	11,729,213
Adjusted R-squared	0.15	0.15	0.18	0.10	0.17	0.08	0.12	0.16
Number of clusters	47	47	47	47	47	47	47	47

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics January 2013 to March 2017. The unit of observation is a pregnancy in a county in a state. Low education is defined as high school or less. High education is defined as some college or more. Standard errors are clustered around the state and are reported in parentheses. All models estimated with a linear probability model (binary outcome) or least squares (continuous outcome), and control for mothers' demographic characteristics and state-level policy variables.
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

Table 8. Effect of e-cigarette taxes levied at conception on prenatal smoking: Panel data analysis

Sample:	**Beta coefficient (standard error)**
All mothers	
Tax	-0.0011
	(0.0040)
% change	-2.1%
Observations	69,076,984
Dep. var. proportion (pre-period treated localities)	0.051
Adjusted R-squared	0.84
Mothers who smoked before pregnancy	
Tax	-0.0006
	(0.0168)
% change	-0.1%
Observations	6,969,824
Dep. var. proportion (pre-period treated localities)	0.737
Adjusted R-squared	0.58
Mothers who did not smoke before pregnancy	
Tax	0.0001
	(0.0002)
% change	12.7%
Observations	62,107,160
Dep. var. proportion (pre-period treated localities)	0.00039
Adjusted R-squared	0.32
Pregnancy FE	✓
Trimester-by-conception (year-month) FE	✓
Number of clusters	47

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics January 2013 to March 2017. The unit of observation is a mother in a county in a state. Standard errors are clustered around the state and are reported in parentheses. All models estimated with a linear probability model and control for state-level policy variables.
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

Table 9. Effect of e-cigarette taxes levied at conception on birth outcomes

Outcome:	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Tax (any)	-0.0160	0.0026	2.9404	-0.0010	-0.0011	-0.0004	-0.0028
	(0.0132)	(0.0026)	(1.8240)	(0.0006)	(0.0020)	(0.0012)	(0.0060)
% change	-0.04%	3.2%	0.1%	-1.7%	-0.5%	-0.4%	-0.03%
County FE	✓	✓	✓	✓	✓	✓	✓
Conception year-month FE	✓	✓	✓	✓	✓	✓	✓
Dep. var. mean/prop (pre-period treated localities)	38.832	0.082	3315.236	0.058	0.242	0.091	8.850
Adjusted R-squared	0.03	0.02	0.05	0.01	0.03	0.02	0.03
Number of clusters	47	47	47	47	47	47	47

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics January 2013 to March 2017. N=17,269,246. The unit of observation is a pregnancy in a county in a state. Standard errors are clustered around the state and are reported in parentheses. All models estimated with a linear probability model (binary outcome) or least squares (continuous outcome), and control for mothers' demographic characteristics and state-level policy variables. (1) = Gestation length. (2) = Premature (<37 weeks). (3) = Birth weight. (4) = Low birth weight (<2500 Grams). (5) = Small-for-gestational age (≤25th percentile). (6) = Extra small-for-gestational age (≤10th percentile). (7) = Apgar 5.
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

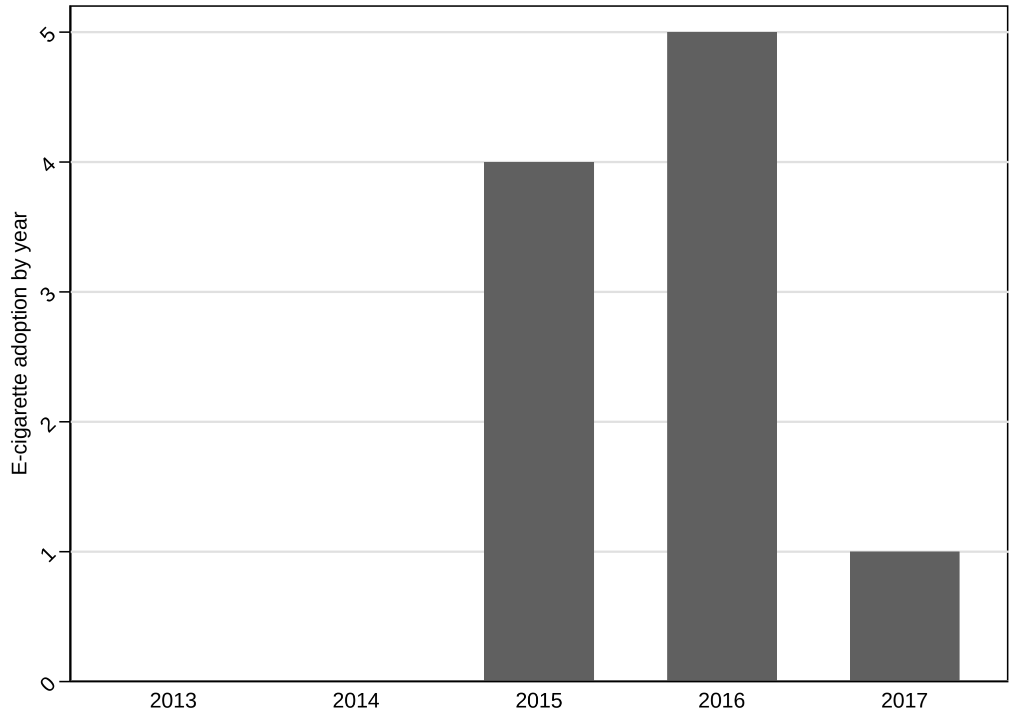
Table 10. Effect of e-cigarette taxes levied at conception on birth outcomes using an event study design

Outcome:	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Time to e-cigarette effective date:							
≥18 month	0.1446	-0.0117	18.1501	-0.0073	0.0009	0.0010	0.0261**
	(0.1148)	(0.0098)	(17.1865)	(0.0063)	(0.0010)	(0.0009)	(0.0113)
[15, 18) month	0.1586	-0.0124	19.6441	-0.0084	0.0010	0.0005	0.0117
	(0.1212)	(0.0100)	(18.8825)	(0.0071)	(0.0010)	(0.0007)	(0.0090)
[12, 15) month	0.1053	-0.0080	14.6835	-0.0054	-0.0001	0.0005	0.0068
	(0.0971)	(0.0079)	(13.9789)	(0.0052)	(0.0010)	(0.0010)	(0.0067)
[9, 12) month	-	-	-	-	-	-	-
(reference)	-	-	-	-	-	-	-
[6, 9) month	0.0114	-0.0018	-0.3783	-0.0003	0.0011	0.0011	-0.0023
	(0.0097)	(0.0012)	(1.4574)	(0.0010)	(0.0011)	(0.0008)	(0.0041)
[3, 6) month	0.0143	-0.0012	-3.9344**	0.0004	0.0037***	0.0020**	0.0002
	(0.0090)	(0.0009)	(1.9451)	(0.0010)	(0.0011)	(0.0008)	(0.0055)
[0, 3) month	0.0161	-0.0000	-1.4368	-0.0004	0.0018	0.0003	-0.0041
	(0.0102)	(0.0007)	(2.3398)	(0.0010)	(0.0014)	(0.0008)	(0.0047)
(0, 3] month	0.0401	-0.0042	8.7477	-0.0038	-0.0007	-0.0010	0.0054
	(0.0759)	(0.0064)	(11.0009)	(0.0040)	(0.0013)	(0.0010)	(0.0059)
>3 month	0.0687	-0.0055	11.0861	-0.0045	0.0004	0.0008	0.0093
	(0.0830)	(0.0072)	(12.2802)	(0.0044)	(0.0018)	(0.0011)	(0.0061)
County FE	✓	✓	✓	✓	✓	✓	✓
Conception year-month FE	✓	✓	✓	✓	✓	✓	✓
Dep. var. mean/prop (pre-period treated localities)	38.832	0.082	3315.236	0.058	0.242	0.091	8.850
Adjusted R-squared	0.03	0.02	0.05	0.01	0.03	0.02	0.03
Number of clusters	47	47	47	47	47	47	47
p-value of joint *F*-test on the policy leads	0.02	0.15	0.76	0.20	0.73	0.66	0.04

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics January 2013 to March 2017. N=17,269,246. The unit of observation is a pregnancy in a county in a state. Standard errors are clustered around the state and are reported in parentheses. All models estimated with a linear probability model (binary outcome) or least squares (continuous outcome), and control for mothers' demographic characteristics and state-level policy variables. The omitted category is 9 to 12 months preconception. (1) = Gestation length. (2) = Premature (<37 weeks). (3) = Birth weight. (4) = Low birth weight (<2500 Grams). (5) = Small-for-gestational age (≤25th percentile). (6) = Extra small-for-gestational age (≤10th percentile). (7) = Apgar 5.

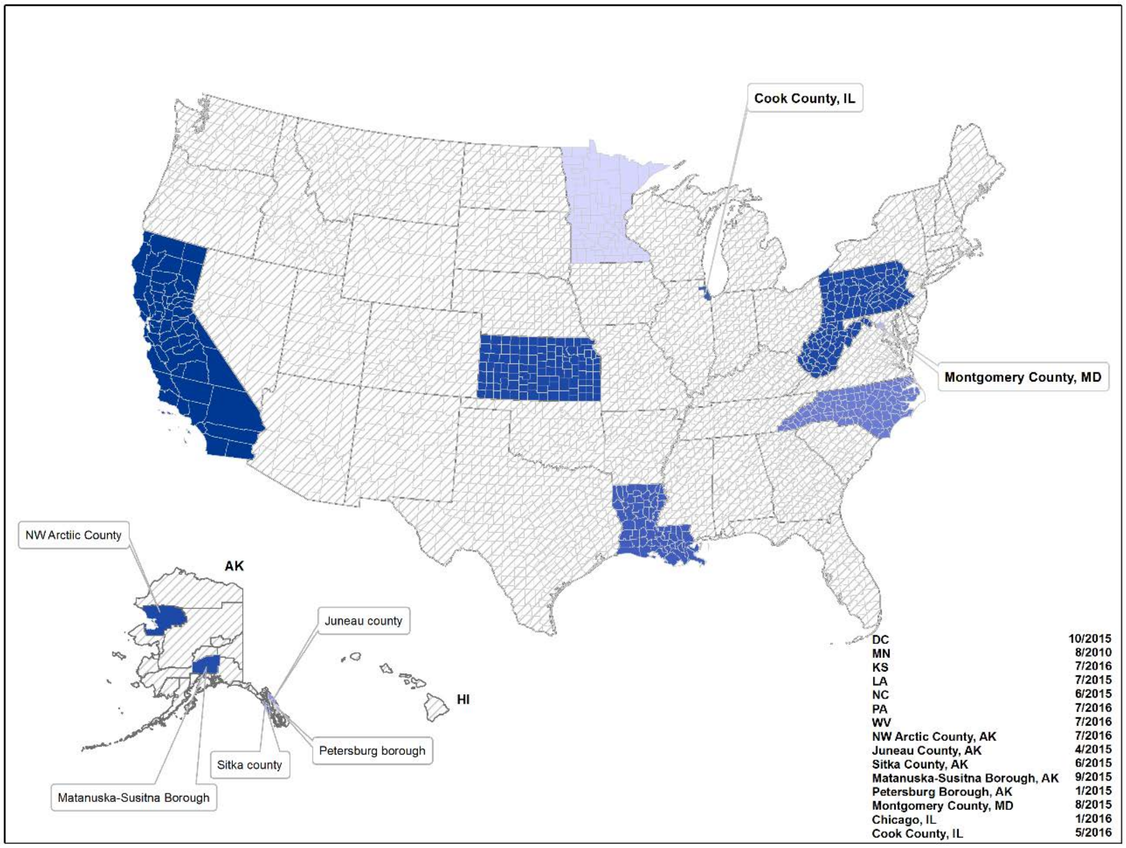
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

Figure 1. E-cigarette tax adoptions in each year 2013 to 2017



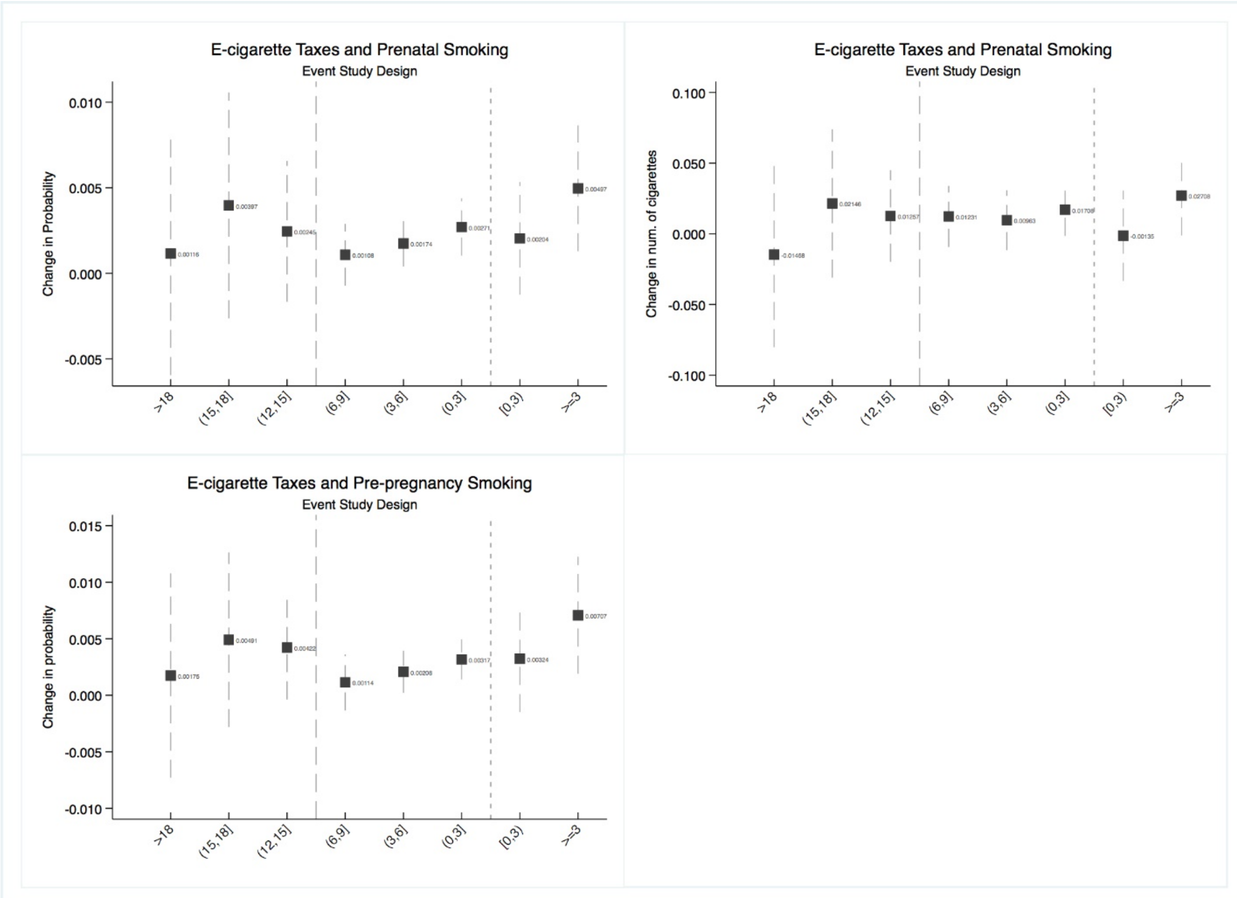
Notes: Data sources are the Vapor Products Tax Data Center, American Non-Smokers Rights Foundation (proprietary), and Tax Foundation. We include only e-cigarette tax adoptions that occur in the first quarter of 2017 to match our study period. See text for more details.

Figure 2. Localities that levied an e-cigarette tax as of March 2017



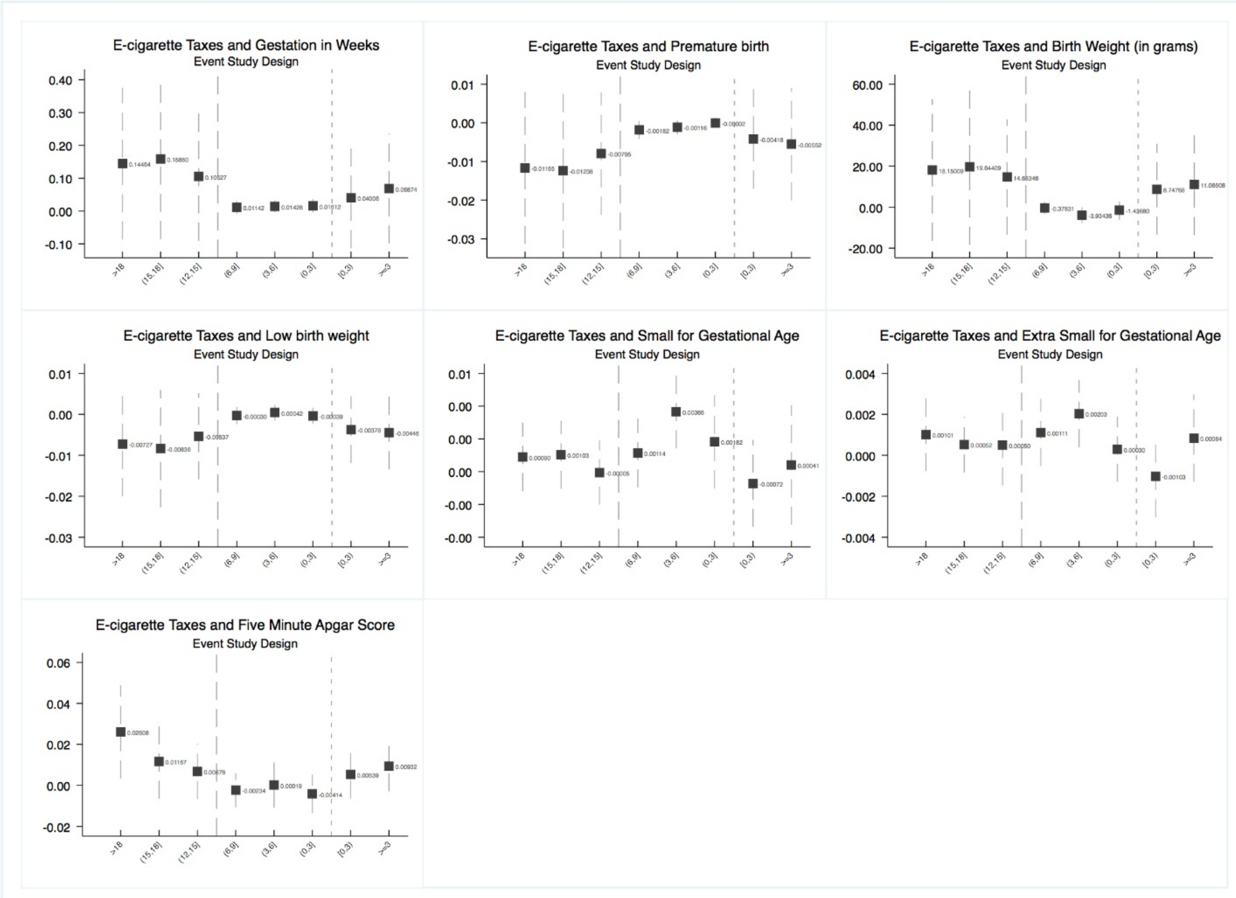
Notes: Data sources are the Vapor Products Tax Data Center, American Non-Smokers Rights Foundation (proprietary), and Tax Foundation. See text for details.

Figure 3. Effect of e-cigarette taxes levied at conception on prenatal and pre-pregnancy smoking using an event study



Notes: See Table 5 for details.

Figure 4. Effect of e-cigarette taxes levied at conception on birth outcomes using an event study



Notes: See Table 10 for details.

Appendix Table 1. E-cigarette tax effective dates among localities that adopt an e-cigarette tax by March 2017

State	Effective date	Unit taxed	Tax	Tax structure
District of Columbia	10/2015 (10/1/2016)	Wholesale price	67% (65%)	Wholesaler
Kansas	7/2016	Per fluid milliliter	$0.20	Consumer
Louisiana	7/2015	Per fluid milliliter.	$0.05	Consumer
Minnesota	8/2010 (7/1/2013)	Wholesale price	35% (95%)	Wholesaler
North Carolina	6/2015	Per fluid milliliter	$0.05	Consumer
Pennsylvania	7/2016	Purchase price	40%	Consumer
West Virginia	7/2016	Per fluid milliliter	$0.08	Consumer
County/city, State	**Effective date**	**Unit taxed**	**Tax**	**Tax structure**
Juneau County, Alaska	4/2015	Wholesale price	45%	Wholesaler
Matanuska-Susitna Borough, Alaska	9/2015	Wholesale price	55%	Wholesaler
Northwest Artic Borough, Alaska	7/2016	Wholesale price	45%	Wholesaler
Petersburg Borough, Alaska	1/2015	Wholesale price	45%	Wholesaler
Sitka County, Alaska	6/2015	Wholesale price	90%	Wholesaler
Chicago, Illinois	1/2016	Per unit / Per fluid milliliter	$0.80 / $0.55	Consumer
Cook County, Illinois	5/2016	Per fluid milliliter	$0.20	Consumer
Montgomery County, Maryland	8/2015	Wholesale price	30%	Wholesaler

Notes: Data sources are the Vapor Products Tax Data Center, American Non-Smokers Rights Foundation (proprietary), and Tax Foundation. See text for details. Incremental tax increases are indicated with parentheses.

Appendix Table 2. Effect of e-cigarette taxes levied at conception on any prenatal smoking: Full set of coefficient estimates

Model:	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
E-cigarette tax (any)	0.0032**	0.0024**	--	--	--	--
	(0.0016)	(0.0010)	--	--	--	--
E-cigarette wholesaler	--	--	0.0057**	0.0064***	--	--
tax (any)	--	--	(0.0027)	(0.0016)	--	--
E-cigarette	--	--	0.0030*	0.0019**	0.0030*	0.0019**
consumer tax (any)	--	--	(0.0016)	(0.0009)	(0.0016)	(0.0009)
E-cigarette wholesaler	--	--	--	--	0.0127**	0.0135
tax (rate)	--	--	--	--	(0.0049)	(0.0081)
Other controls						
Traditional cigarette tax	-0.0043**	-0.0006	-0.0043**	-0.0005	-0.0043**	-0.0005
($)	(0.0018)	(0.0009)	(0.0018)	(0.0008)	(0.0018)	(0.0008)
E-cigarette ban	0.0034	0.0036***	0.0034	0.0035***	0.0034	0.0035***
index	(0.0021)	(0.0013)	(0.0021)	(0.0013)	(0.0021)	(0.0013)
Traditional cigarette	-0.0001	0.0000	-0.0001	0.0000	-0.0001	0.0000
ban index	(0.0010)	(0.0011)	(0.0010)	(0.0011)	(0.0010)	(0.0011)
E-cigarette	-0.0021	-0.0020***	-0.0021	-0.0020***	-0.0021	-0.0020***
MLSA	(0.0017)	(0.0007)	(0.0017)	(0.0007)	(0.0017)	(0.0007)
Black, non-	-0.0978***	-0.0978***	-0.0978***	-0.0978***	-0.0978***	-0.0978***
Hispanic	(0.0119)	(0.0119)	(0.0119)	(0.0119)	(0.0119)	(0.0119)
Hispanic	-0.1213***	-0.1213***	-0.1213***	-0.1213***	-0.1213***	-0.1213***
	(0.0130)	(0.0130)	(0.0130)	(0.0130)	(0.0130)	(0.0130)
Other	-0.0383***	-0.0383***	-0.0383***	-0.0383***	-0.0383***	-0.0383***
	(0.0050)	(0.0050)	(0.0050)	(0.0050)	(0.0050)	(0.0050)
Private	-0.0608***	-0.0608***	-0.0608***	-0.0608***	-0.0608***	-0.0608***
insurance	(0.0085)	(0.0085)	(0.0085)	(0.0085)	(0.0085)	(0.0085)
Self-pay	-0.0608***	-0.0608***	-0.0608***	-0.0608***	-0.0608***	-0.0608***
	(0.0131)	(0.0131)	(0.0131)	(0.0131)	(0.0131)	(0.0131)
Indian Health	-0.0241	-0.0241	-0.0241	-0.0241	-0.0241	-0.0241
Service	(0.0219)	(0.0218)	(0.0219)	(0.0218)	(0.0218)	(0.0218)
Military	-0.0593***	-0.0593***	-0.0593***	-0.0593***	-0.0593***	-0.0593***
insurance	(0.0051)	(0.0051)	(0.0051)	(0.0051)	(0.0051)	(0.0051)
Other gov't	-0.0168**	-0.0170**	-0.0168**	-0.0170**	-0.0170**	-0.0170**
source	(0.0074)	(0.0073)	(0.0074)	(0.0073)	(0.0073)	(0.0073)
Other	-0.0458***	-0.0459***	-0.0458***	-0.0459***	-0.0458***	-0.0459***
	(0.0075)	(0.0074)	(0.0075)	(0.0074)	(0.0075)	(0.0074)
Payer	-0.0378***	-0.0372***	-0.0378***	-0.0372***	-0.0378***	-0.0372***
unknown	(0.0063)	(0.0062)	(0.0063)	(0.0062)	(0.0063)	(0.0062)
Married	-0.0829***	-0.0829***	-0.0829***	-0.0829***	-0.0829***	-0.0829***
	(0.0107)	(0.0107)	(0.0107)	(0.0107)	(0.0107)	(0.0107)
Marital status	-0.0461***	-0.0520***	-0.0461***	-0.0520***	-0.0460***	-0.0520***
unknown	(0.0058)	(0.0065)	(0.0057)	(0.0065)	(0.0057)	(0.0065)
High school	-0.0296***	-0.0296***	-0.0296***	-0.0296***	-0.0296***	-0.0296***
	(0.0074)	(0.0074)	(0.0074)	(0.0074)	(0.0074)	(0.0074)
Some college	-0.0678***	-0.0679***	-0.0678***	-0.0679***	-0.0678***	-0.0679***
	(0.0124)	(0.0124)	(0.0124)	(0.0124)	(0.0124)	(0.0124)
College	-0.1017***	-0.1018***	-0.1017***	-0.1018***	-0.1017***	-0.1018***
	(0.0153)	(0.0153)	(0.0153)	(0.0153)	(0.0153)	(0.0153)

Education unknown	-0.0659***	-0.0662***	-0.0659***	-0.0662***	-0.0659***	-0.0662***
	(0.0101)	(0.0101)	(0.0101)	(0.0101)	(0.0101)	(0.0101)
2nd birth	0.0099***	0.0099***	0.0099***	0.0099***	0.0099***	0.0099***
	(0.0015)	(0.0015)	(0.0015)	(0.0015)	(0.0015)	(0.0015)
3rd birth	0.0201***	0.0201***	0.0201***	0.0201***	0.0201***	0.0201***
	(0.0028)	(0.0028)	(0.0028)	(0.0028)	(0.0028)	(0.0028)
4th birth	0.0308***	0.0308***	0.0308***	0.0308***	0.0308***	0.0308***
	(0.0039)	(0.0039)	(0.0039)	(0.0039)	(0.0039)	(0.0039)
5th birth	0.0422***	0.0422***	0.0422***	0.0422***	0.0422***	0.0422***
	(0.0048)	(0.0048)	(0.0048)	(0.0048)	(0.0048)	(0.0048)
6th birth	0.0542***	0.0541***	0.0542***	0.0541***	0.0542***	0.0541***
	(0.0051)	(0.0051)	(0.0051)	(0.0051)	(0.0051)	(0.0051)
7th birth	0.0623***	0.0623***	0.0623***	0.0623***	0.0623***	0.0623***
	(0.0050)	(0.0050)	(0.0050)	(0.0050)	(0.0050)	(0.0050)
8th birth	0.0679***	0.0679***	0.0679***	0.0679***	0.0679***	0.0679***
	(0.0044)	(0.0044)	(0.0044)	(0.0044)	(0.0044)	(0.0044)
Birth order unknown	0.0195***	0.0199***	0.0195***	0.0199***	0.0195***	0.0199***
	(0.0034)	(0.0036)	(0.0034)	(0.0036)	(0.0034)	(0.0036)
County FEs	✓	✓	✓	✓	✓	✓
Conception year-month FE	✓	✓	✓	✓	✓	✓
Conception year-by-state FE		✓		✓		✓
Dep. var. proportion (pre-period treated localities)	0.051	0.051	0.051	0.051	0.051	0.051
Adjusted R-squared	0.15	0.15	0.15	0.15	0.15	0.15
Number of clusters	47	47	47	47	47	47

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics January 2013 to March 2017. N=17,269,246. The unit of observation is a pregnancy in a county in a state. Standard errors are clustered around the state and are reported in parentheses. All models estimated with a linear probability model. Omitted categories are white, non-Hispanic; Medicaid; unmarried; less than high school education; and 1st birth.

***; **; * =statistically different from zero at the 1%; 5%; 10% level.

Appendix Table 3. Effect of e-cigarette taxes levied at conception on any prenatal smoking: Include Minnesota

Model:	(1)	(2)	(3)	(4)	(5)	(6)
Tax (any)	0.0032**	0.0025***	--	--	--	--
	(0.0016)	(0.0009)	--	--	--	--
Wholesaler tax (any)	--	--	0.0058**	0.0064***	--	--
	--	--	(0.0027)	(0.0016)	--	--
Consumer tax (any)	--	--	0.0030*	0.0020**	0.0031*	0.0020**
	--	--	(0.0016)	(0.0009)	(0.0016)	(0.0009)
Wholesaler tax (rate, 100 ppt increase)	--	--	--	--	0.0023	-0.0030
	--	--	--	--	(0.0054)	(0.0064)
County FE	✓	✓	✓	✓	✓	✓
Conception year-month FE	✓	✓	✓	✓	✓	✓
Conception year-by-state FE		✓		✓		✓
Dep. var. proportion (pre-period treated localities)	0.051	0.051	0.051	0.051	0.051	0.051
Adjusted R-squared	0.15	0.15	0.15	0.15	0.15	0.15
Number of clusters	48	48	48	48	48	48

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics January 2013 to March 2017. N=17,606,102. The unit of observation is a pregnancy in a county in a state. Standard errors are clustered around the state and are reported in parentheses. All models estimated with a linear probability mode and control for mothers' demographic characteristics and state-level policy variables.
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

Appendix Table 4. Effect of e-cigarette taxes levied at conception on any prenatal smoking: Start study period in 2011

Model:	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Tax (any)	0.0017	0.0037***	--	--	--	--
	(0.0019)	(0.0011)	--	--	--	--
Wholesaler tax (any)	--	--	0.0090***	0.0095***	--	--
	--	--	(0.0021)	(0.0007)	--	--
Consumer tax (any)	--	--	0.0012	0.0029***	0.0012	0.0029***
	--	--	(0.0020)	(0.0010)	(0.0020)	(0.0010)
Wholesaler tax (rate, 100 ppt increase)	--	--	--	--	0.0194***	0.0247***
	--	--	--	--	(0.0031)	(0.0085)
County FE	✓	✓	✓	✓	✓	✓
Conception year-month FE	✓	✓	✓	✓	✓	✓
Conception year-by-state FE		✓		✓		✓
Dep. var. proportion (pre-period treated localities)	0.052	0.052	0.052	0.052	0.052	0.052
Adjusted R-squared	0.15	0.15	0.15	0.15	0.15	0.15
Number of clusters	38	38	38	38	38	38

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics January 2011 to March 2017. N=21,713,690. The unit of observation is a pregnancy in a county in a state. Standard errors are clustered around the state and are reported in parentheses. All models estimated with a linear probability model and control for mothers' demographic characteristics and state-level policy variables.
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

Appendix Table 5. Effect of e-cigarette taxes levied at conception on any prenatal smoking: Cluster standard errors around the county

Model:	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Tax (any)	0.0032**	0.0024**	--	--	--	--
	(0.0014)	(0.0009)	--	--	--	--
Wholesaler tax (any)	--	--	0.0057**	0.0064***	--	--
	--	--	(0.0025)	(0.0015)	--	--
Consumer tax (any)	--	--	0.0030**	0.0019**	0.0030**	0.0019**
	--	--	(0.0015)	(0.0010)	(0.0015)	(0.0010)
Wholesaler tax (rate,	--	--	--	--	0.0127***	0.0135**
100 ppt increase)	--	--	--	--	(0.0042)	(0.0067)
County FE	✓	✓	✓	✓	✓	✓
Conception year-month FE	✓	✓	✓	✓	✓	✓
Conception year-by-state FE		✓		✓		✓
Dep. var. proportion (pre-period treated localities)	0.051	0.051	0.051	0.051	0.051	0.051
Adjusted R-squared	0.15	0.15	0.15	0.15	0.15	0.15
Number of clusters	47	47	47	47	47	47

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics January 2013 to March 2017. N=17,269,246. The unit of observation is a pregnancy in a county in a state. Standard errors are clustered around the state and are reported in parentheses. All models estimated with a linear probability model and control for mothers' demographic characteristics and state-level policy variables.
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

Appendix Table 6. Effect of e-cigarette taxes levied at conception on any prenatal smoking: Leave one out analysis

Excluded locality:	**AK**	**CA**	**DC**	**KS**	**LA**	**NC**
Tax	0.0032**	0.0034**	0.0029*	0.0035**	0.0028	0.0041*
	(0.0016)	(0.0016)	(0.0016)	(0.0017)	(0.0017)	(0.0023)
% change	6.4%	3.5%	5.7%	7.2%	5.5%	8.7%
Observations	17,217,272	14,923,095	17,196,958	17,073,425	16,967,968	16,679,235
Dep. var. proportion (pre-period treated counties)	0.051	0.098	0.052	0.049	0.050	0.047
Adjusted R-squared	0.15	0.15	0.15	0.15	0.15	0.15
Number of clusters	46	46	46	46	46	46
Excluded locality:	**PA**	**WV**	**Montgomery Co, MD**	**Chicago, IL**	**Cook Co, IL**	**--**
Tax	0.0038**	0.0032*	0.0031*	0.0024	0.0031*	--
	(0.0018)	(0.0016)	(0.0016)	(0.0014)	(0.0016)	--
% change	9.7%	6.7%	6.0%	4.6%	6.0%	--
Observations	16,608,201	17,183,845	17,207,059	17,086,188	17,130,770	--
Dep. var. proportion (pre-period treated localities)	0.039	0.048	0.052	0.052	0.052	--
Adjusted R-squared	0.15	0.15	0.15	0.15	0.15	--
Number of clusters	46	46	47	47	47	--
County FE	✓	✓	✓	✓	✓	--
Conception year-month FE	✓	✓	✓	✓	✓	--

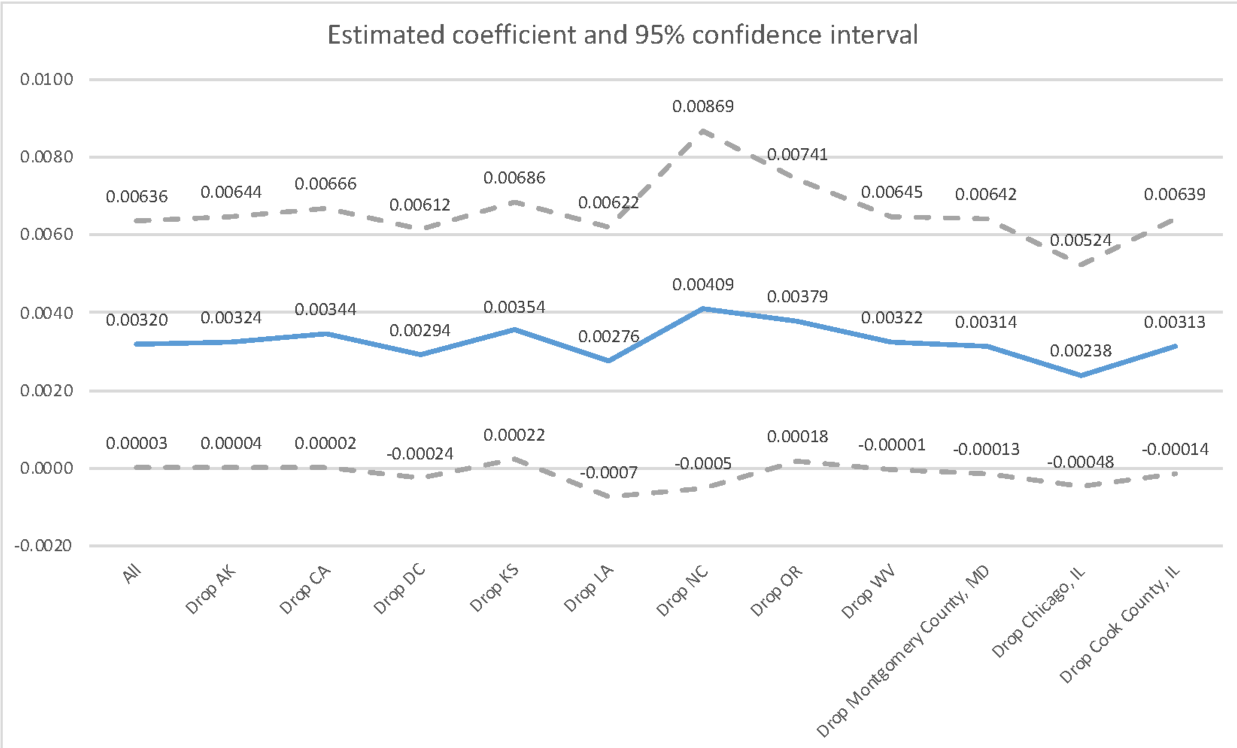
Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics January 2013 to March 2017. The unit of observation is a pregnancy in a county in a state. Standard errors are clustered around the state and are reported in parentheses. All models estimated with a linear probability model and control for mothers' demographic characteristics and state-level policy variables.
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

Appendix Table 7. Effect of e-cigarette taxes levied at conception on the probability of smoking in the three months prior to conception: Assign tax to three months prior to pregnancy

Model:	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Tax (any)	0.0045**	0.0045***	--	--	--	--
	(0.0020)	(0.0013)	--	--	--	--
Wholesaler tax (any)	--	--	0.0085***	0.0110***	--	--
	--	--	(0.0018)	(0.0030)	--	--
Consumer tax (any)	--	--	0.0042**	0.0034***	0.0042**	0.0034***
	--	--	(0.0021)	(0.0007)	(0.0021)	(0.0007)
Wholesaler tax	--	--	--	--	0.0177***	0.0217
(rate, 100 ppt increase)	--	--	--	--	(0.0028)	(0.0162)
County FE	✓	✓	✓	✓	✓	✓
Conception year-month FE	✓	✓	✓	✓	✓	✓
Conception year-by-state FE		✓		✓		✓
Dep. var. proportion (pre-period treated localities)	0.069	0.069	0.069	0.069	0.069	0.069
Adjusted R-squared	0.16	0.16	0.16	0.16	0.16	0.16
Number of clusters	47	47	47	47	47	47

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics January 2013 to March 2017. N=17,269,246. The unit of observation is a pregnancy in a county in a state. Standard errors are clustered around the state and are reported in parentheses. All models estimated with a linear probability model and control for mothers' demographic characteristics and state-level policy variables.
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

Appendix Figure 1. Effect of e-cigarette taxes levied at conception on any prenatal smoking: Leave one out analysis



Notes: Beta coefficients are reported with a solid blue line. 95% confidence intervals that account for within-state clustering are reported with dashed blue lines. See Appendix Table 7 for details.

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