NBER WORKING PAPER SERIES

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Working Paper 26126
http://www.nber.org/papers/w26126

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
July 2019

We thank Daniel Dench, Michael Grossman, Theodore Joyce, and Jenny Kenney. We thank seminar participants at Tulane University and San Diego State University's Center for Health Economics & Policy Studies. We thank conference participants at the Association for Public Policy and Management Fall Conference, American Society for Health Economists Conference, and the Hamburg Center for Health Economics' Risky Health Behaviors Workshop. 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.

The Effect of E-Cigarette Taxes on Pre-pregnancy and Prenatal Smoking
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NBER Working Paper No. 26126
July 2019, Revised June 2020
JEL No. I12

ABSTRACT

We use the universe of birth records in the United States from 2013 to 2018 to examine the effect of e-cigarette tax rates on pre-pregnancy smoking and prenatal smoking. We study these questions using two-way fixed effects models and pregnancy fixed effects models. We show that e-cigarette taxes increase pre-pregnancy smoking, increase prenatal smoking, and lower smoking cessation during pregnancy. These findings imply that e-cigarettes and traditional cigarettes are substitutes among pregnant women. We also find evidence that e-cigarette taxes reduce pre-pregnancy and third trimester e-cigarette use.

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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 (Bao et al. 2018, Filippidis et al. 2017). In the United States, the focus of our study, the adult e-cigarette regular use rate was 3.2% in 2018 (4.3% for men and 2.3% for women), which implies over eight million American adults used these products every day or some days in that year (Creamer 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 2019, 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 harm reduction 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

[1] Other names for these products include: e-cigs, e-hookahs, electronic nicotine delivery systems, ENDS, vape pens, and vapes. 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).

data show that 45% of women smoking three months before their pregnancy are unable to quit 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 and there are concerns that nicotine in NRTs may harm the developing fetus (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

[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).

(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-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 vaping and smoking outcomes among such women.

In this paper, we use comprehensive records on the universe of births from the U.S. and 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 from 2013 to 2018. We show that the levying of an e-cigarette tax leads to increased traditional cigarette smoking among pregnant women. E-cigarette taxes increase pre-pregnancy smoking and tax increases that occur during the pregnancy also increase smoking among women. We suspect that the changes in smoking that we observe are attributable to reduced propensity to quit rather than initiation into smoking. Our findings imply that e-cigarettes and traditional cigarettes are substitutes for pregnant women, which is in line with previous work that has considered this relationship using different sources of plausibly exogenous e-cigarette policy variation (Pesko and Currie 2019, Cooper and Pesko 2017).

We organize the paper as follows. Section 2 discusses taxation of e-cigarettes in the U.S. and the related literature. Data are listed in Section 3 and Section 4 outlines our methods. Section 5 reports our main results for pre-pregnancy and prenatal smoking. Sections 6 and 7 provide extensions to pre-pregnancy and prenatal e-cigarette use, and birth outcomes respectively. Finally, Section 8 concludes.

2. Background and related literature

E-cigarettes are relatively new products in the U.S. tobacco markets and 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 in the U.S., 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 has occurred at the state and local level. As of the end of 2018, the end of our study period, 13 states, counties, and cities have levied e-cigarette taxes. Unlike traditional cigarette taxation which is a standard excise tax, localities have levied e-cigarette taxes in varied ways. Delaware, Kansas, Louisiana, New Jersey, 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

[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 that agency's 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.

vaping unit. Washington DC, California, Minnesota, Montgomery County in Maryland, and Pennsylvania tax a percentage of wholesale value.

Taxes may reduce e-cigarette use by raising the relative price of the product. Indeed, three recent studies show that e-cigarette taxes are more than fully passed through to consumers (Cotti et al. 2020, Allcott and Rafkin 2020, Saffer et al. 2020). For example, Cotti et al. (2020) estimate a pass-through rate of 1.6 using sales data over the period 2011 to 2017. 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 behaviors, for example, see a 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 media 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.

Several studies use variation in e-cigarette taxes to estimate cigarette own- and cross-tax elasticities. Cotti et al. (2020) use data from the Nielsen Retail scanner data (NRSD) and show that a $1.00 increase in the e-cigarette tax reduces e-cigarette sales by 42% and increases traditional cigarette sales by 19%. Instrumenting prices with taxes, they also calculate an e-cigarette own-price elasticity of -1.5 and a cross-price elasticity of 0.9. Pesko, Courtemanche, and Maclean (2019) combine survey data from the Behavioral Risk Factor Surveillance Survey (BRFSS) and the National Health Interview Survey (NHIS) over the period 2011 to 2018 to study the effects of e-cigarette and traditional cigarette taxes on vaping and smoking. The authors find that a $1.00 increase in the e-cigarette tax rate increases daily smoking propensity by 5.3% and the probability of 'dual use' (i.e., consuming both e-cigarettes and traditional cigarettes) by 24.4%. Further, a $1.00 increase in the traditional cigarette tax rate leads to a 14.2% increase in daily vaping. Saffer et al. (2020) study the effect of the first e-cigarette tax adopted in the U.S. – in the state of Minnesota in 2010 – on adult smoking. The authors show, using synthetic control methods, that Minnesota's e-cigarette tax increased smoking and reduced cessation. In contrast to these studies suggesting that e-cigarettes and cigarettes are economic substitutes, Cotti, Nesson, and Tefft (2018) use Nielsen household scanner data to show that an increase in the traditional *cigarette* tax leads to a reduction in e-cigarette household purchases. In particular, a $1.00 increase in the traditional cigarette tax reduces household purchases of e-cigarettes by 61.0%. Finally, Allcott and Rafkin (2020) use a shift-share approach combined with the NRSD over the period 2013 to 2018 and find limited evidence of substitution.[4]

Additionally, several studies use policy variation from e-cigarette minimum legal sale age (MLSA) laws to estimate the relationship between e-cigarettes and cigarettes. An MLSA increases the non-pecuniary (or hassle) cost of e-cigarettes as youth below the MLSA are prohibited from legally purchasing the product. Friedman (2015); Pesko, Hughes, and Faisal (2016); and Dave, Feng, and Pesko (2019) show evidence of substitution: following the passage

[4] Several studies use price variation (without instrumentation) to document that e-cigarette purchases fall as e-cigarette prices rise (Stoklosa, Drope, and Chaloupka 2016, Huang et al. 2018, Pesko et al. 2018, Pesko and Warman 2017, Zheng et al. 2017, Pesko et al. 2016, Marti et al. 2019). A number of studies additionally use market-level price variation to study cross-price elasticities of demand, without a consensus reached on whether the products are economic substitutes or complements (Huang et al. 2018, Pesko et al. 2018, Stoklosa, Drope, and Chaloupka 2016, Pesko and Warman 2017, Zheng et al. 2017). Outside of two studies using discrete choice experiment methods to experimentally vary the e-cigarette prices, Pesko et al. (2016) and Marti et al. (2019), these studies do not exploit a plausibly exogenous source of price variation.

of an MLSA youth traditional cigarette use increases. However, in a sample of 12th grade students, Abouk and Adams (2017) find that MLSA adoption leads to a decrease in youth smoking, suggesting that the two products are complements.

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 smoking outcomes among pregnant women using birth record data. 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.

In summary, the literature offers definitive evidence that e-cigarette use declines when the price or tax of this product rises. Most of the available evidence to date suggests that when e-cigarette prices or taxes rise, traditional cigarette use falls. 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 (or reduce smoking cessation) following such a tax is not clear because pregnant women are different from youth and the general population. Pregnant women plausibly 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.

3. Data

3.1 Data on birth records

We use administrative birth records with geocodes provided by the National Center for Health Statistics (NCHS).[5] 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 of 2003 to 2015. Neither revised nor unrevised birth record forms include information on prenatal vaping. However, in an extension (Section 6) to our main analysis we use data from the Pregnancy Risk Assessment and Monitoring System (PRAMS) to examine e-cigarette use.

As of May 2020, the time of writing, revised birth records are available from the NCHS through the end of 2018. We restrict our analysis sample to mothers giving birth on after 2013

[5] As discussed in Section 7, we also study the effect of e-cigarette taxes on infant mortality. To do so, we combine the birth record data with administrative data on infant deaths administered by NCHS. As of May, 2020, these data are available through 2017 (compared to through 2018 for birth certificate data). Absent the one-year lag compared to standard birth certificate data, the birth/infant death period data are identical except for including an indicator for if the infant died in the same calendar year in which they were born. These data capture approximately 86% of infant mortality, only missing mortality for infants born in one calendar year and died in the next calendar year (but within one year of their birth).

or conceiving[6] before April 2018 to avoid censoring the data based on gestational length.[7] That is, mothers who conceive after March 2018 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 format. Minnesota was the first locality in the U.S. to adopt an e-cigarette tax (August 2010). In robustness checks reported later in the manuscript we show that our results are insensitive to beginning the sample in 2011 and excluding the 13 states that had not adopted the revised birth record format by that year.

We make several additional exclusions to form our analysis sample. First, we exclude mothers giving birth in Hawaii and Alaska because these states are not included in the Nielsen Retail Scanner data that is used to create standardized e-cigarette taxes (described in Section 3.2). Second, we exclude non-singleton births to reduce potential confounding from fertility treatment availability (Kulkarni et al. 2013). Third, we exclude a small number (2.4%) of mothers with missing smoking information pre-pregnancy and in any of the three trimesters. These exclusions leave us with 20,965,502 mothers.

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

[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 conception 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 2018 would only appear in our data in the event of a premature birth. By restricting our sample to conceptions occurring on or before March 2018, we avoid this issue of our sample only containing premature births, which are very different from full term births, beyond March 2018.

pregnancy, and (iii) any smoking during the three months prior to conception (‘pre-pregnancy smoking’). As mentioned above, birth records do not include vaping information.

3.2 Data on e-cigarette taxes

We identify dates of e-cigarette and traditional cigarette taxes from the Vapor Products Tax Data Center (2019), American Nonsmokers Rights Foundation (proprietary data), and the Tax Foundation (2018). Online Appendix Table 1 lists the localities levying e-cigarette taxes at different points in time through the end of 2018. Figure 1 reports the number of new e-cigarette tax adoptions in each year of our study and Figure 2 graphically displays the tax variation. 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 heterogeneity in the size of these taxes. While traditional cigarette excise tax units are common across localities (i.e., a dollar value per pack of 20 traditional cigarettes), e-cigarette taxes are levied in different ways. Of the 13 localities levying an e-cigarette tax by the end of our study period, five use an ad valorem tax on the wholesaler and eight use an excise tax per milliliter (ml) of vaping liquid. 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. Ad valorem taxes range from 27.3% to 96.0% during our study period, implying these taxes are much larger than excise taxes.

Washington DC’s tax is unique in that the ad valorem tax rate is set to match 100% of the traditional cigarette tax, suggesting that each one percentage point or ‘ppt’ of ad valorem tax is

4.3 cents. Following Cotti et al. (2020), we use this relationship to convert e-cigarette ad valorem taxes into excise tax equivalents for each relevant locality. Please see the Online Appendix for a detailed discussion of our conversion process, which utilizes Nielsen Retail Scanner data. Our primary e-cigarette tax measure is therefore a continuous tax variable representing the actual excise tax rate, or the excise tax rate equivalency for an ad valorem tax. We refer to the converted tax as the 'standardized' e-cigarette tax.

3.3 Data on additional policies

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); state and county e-cigarette MLSA laws[8] (Pesko and Currie 2019); Tobacco 21 laws (Centers for Disease Control and Prevention 2019); and county-level share of the population covered by indoor vaping restrictions and indoor smoking restrictions in bars, restaurants, and private workplaces.[9] We also control for Affordable Care Act (ACA) Medicaid expansion status (Maclean, Pesko, and Hill 2019, Kaiser Family Foundation 2020). We control for ACA Medicaid expansion as, following expansion, lower income women may have gained eligibility for this insurance program prior to conceiving. Medicaid expansion plans covered a range of effective cessation medications and (non-

[8] We incorporate the adoption of a federal minimum legal purchase age law of 18 in August, 2016.

[9] The American Non-Smokers Rights Foundation tracks when municipalities, counties, and states pass indoor air laws for vaping or smoking in different venues. We use this information to create two separate measures for the share of the population in each county living with indoor smoking and indoor vaping restrictions for private workplaces, restaurants, or bars. We weight laws applying to bars, restaurants, and private workplaces equally. For indoor smoking restrictions, we also consider laws applying to only part of the establishment (but not the full establishment) with ½ weight. Partial laws are uncommon for indoor vaping restrictions.

pharmacological) treatments with low cost-sharing for enrollees (Maclean, Pesko, and Hill 2019). All monetary values are consumer price index-adjusted to 2010 dollars.

4. Methods

We first estimate the effects of e-cigarette taxes on pre-pregnancy and prenatal smoking in a two-way fixed effects specification outlined in Equation (1):

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

i indexes a pregnancy with conception year-month t of conception year y, 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. $Tax_{c,s,t}$ is either e-cigarette tax adoption or the standardized e-cigarette tax rate. $X_{i,c,s,t}$ 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 or more, and unknown), and birth count (one, two, …, seven, eight or more, and unknown). $TP_{c,s,t}$ includes tobacco control and ACA Medicaid policies.

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.[10]

Time controls include month-by-year of conception fixed effects (ω_t) and state-by-year of conception fixed effects ($\mu_{s,y}$). Including month-by-year of conception fixed effects allows us to account for time varying factors affecting the nation as a whole, such as the increase in the popularity of e-cigarettes that occurred over our study period. Additionally, state-by-year of conception fixed effects isolates the impact of e-cigarette taxes on smoking outcomes within the conception year in which the e-cigarette tax is levied for that specific state, allowing us to account for other potential sources of omitted variable bias.

$\hat{\beta}$ 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.

A necessary assumption for the two-way fixed effects 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

[10] 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.

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) into an event study design, which is standard within the economic literature (Autor 2003).

To implement the event study, we replace the e-cigarette tax variable (i.e., indicator for any tax/standardized tax) 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): conception >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 conception, and >3 months after conception.[11] Apart from including tax leads and lags instead of the e-cigarette tax, the event study equation is identical to Equation (1).

In the 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 there are 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 plausibly satisfied in the birth record data and that our two-way fixed

[11] Between the end of our study period in 2018 and the end of 2019, eight additional states enacted new e-cigarette laws (i.e., Connecticut, Illinois, New Mexico, New York, Ohio, Vermont, Washington, and Wisconsin). We use these additional taxes in constructing the policy leads and lags (Schmidheiny and Siegloch 2019).

effects 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. We focus on any smoking and number of cigarettes smoked at each of the four time periods in the panel data analysis. We estimate the regression 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. As these variables do not vary within-mother, we replace individual mother characteristics with pregnancy fixed effects (δ_i). We control for period-by-year-by-month fixed effects ($\kappa_{p,t}$). Pregnancy fixed effects incorporate locality fixed effects.

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 2018. 7.6% and 9.9% 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 1.3. Smoking declines monotonically as the birth date approaches: the unconditional average number of traditional cigarettes smoked per day in the first, second, and third trimesters is 0.79, 0.60, and 0.53, respectively. 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 number of traditional cigarettes smoked in counties that levy an e-cigarette tax is 0.97 and this average is 1.43 in counties that did not levy such a tax.

The racial/ethnic breakdown of the sample is 52.6% non-Hispanic White, 14.3% non-Hispanic Black, 23.6% Hispanic, and 9.5% other race. The average age of mothers at the birth of their child in our sample is just over 28 years. Private insurance finances 47.9% (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 43.2%, 4.1%, and 5.0% 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 Two-way fixed effects regression results

Our main results are reported in Table 2, with panel A showing results for any prenatal smoking, panel B showing results for average number of traditional cigarettes smoked per day during the pregnancy, and panel C showing results for any pre-pregnancy smoking. We model e-cigarette taxes, measured at the time of conception, in two ways: (i) any e-cigarette tax indicator, and (ii) standardized e-cigarette tax rate (i.e., excise tax equivalency per fluid ml). For each approach to modelling e-cigarette taxes, we report coefficient estimates generated in specifications with controls for (i) county and time fixed effects (i.e., month-by-year of conception and state-by-year of conception); (ii) county and time fixed effects, and mothers' demographics; and (iii) county and time fixed effects, mothers' demographics, and other policies. A full set of coefficient estimates for the any prenatal smoking specification is reported in Online Appendix Table 2.

The levying of an e-cigarette tax leads to a 0.4 percentage point (ppt) increase in the probability of any smoking during pregnancy (Table 2, panel A, columns 1 to 3). Comparing this coefficient estimate to the prenatal smoking proportion in localities that levy e-cigarette taxes prior to the tax adoption (all coefficient estimates are compared to this baseline henceforth), the relative effect size is 7.7%. A $1.00 increase in the standardized e-cigarette tax increases prenatal smoking by 0.3 to 0.4 ppts (5.8 to 7.7%). This pattern of results suggests that e-cigarettes and traditional cigarettes are substitute products among pregnant women.

Results for the average number of traditional cigarettes smoked per day (Table 2, panel B) closely mirror our any prenatal smoking findings. The levying of an e-cigarette tax leads to 0.037 to 0.039 (8.9 to 9.3%) more traditional cigarettes smoked per day among pregnant women. Similarly, the number of traditional cigarettes smoked per day increases by 0.037 to 0.044 (8.9 to 10.5%) following a $1.00 increase in the standardized e-cigarette tax. In Table 2, panel C we test the effect of e-cigarette taxes on smoking in the three months prior to conception. We find that adoption of an e-cigarette tax leads to a 0.5 ppt (7.4%) increase in the probability of pre-pregnancy smoking and a $1.00 increase in the standardized e-cigarette tax leads to a 0.4 to 0.5 ppt increase (5.9 to 7.4%) in the probability of this outcome. The coefficient estimates are similar to the 0.4 to 0.3 ppt increase in the probability of any prenatal smoking shown in panel A, suggesting that the increase in prenatal smoking attributable to e-cigarette taxes is mostly due to women smoking more *before* becoming pregnant.

Having demonstrated similarity between the any e-cigarette tax measure and the standardized e-cigarette tax rate in previously discussed results, for brevity we only present results using the standardized e-cigarette tax rate going forward. Full results using the any tax indicator are available on request.

5.3 Internal validity of the research design

Event study coefficient estimates and associated standard errors for our three smoking outcomes are reported in Table 3, using the first e-cigarette tax adoption as the relevant event to form the policy leads and lags. We also report these results graphically in Figure 3. Coefficient estimates appear to increase in the post period. For example, women conceiving during a time in which e-cigarette taxes had been in place for three or more months are 0.5 ppts more likely to prenatally smoke and 0.7 ppts more likely to pre-pregnancy smoke (relative to women conceiving nine to twelve months before an e-cigarette tax came into effect).

The event study results for any prenatal smoking and any pre-pregnancy smoking provide suggestive evidence of parallel pre-trends in our outcomes between localities that levy and do not levy an e-cigarette tax by 2018. All coefficient estimates are smaller in absolute value than the effects measured for conceiving during a time in which e-cigarette taxes had been in place for three or more months. Only one coefficient estimate is statistically significant at the 10% level, which is within what we would expect to observe from random chance.

For pre-pregnancy smoking, the period of time nine to 12 months prior to the e-cigarette tax may not be an appropriate reference group because that includes the period of time in which pre-pregnancy smoking behaviors may be affected by the tax. For that reason, we alternatively use 12 to 15 months prior as a reference as well. Event study results are not materially different regardless of the reference group used; see column (4) in Table 3.

Additionally, we test the internal validity of the two-way fixed effects models 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-conception year/month counts as the dependent variable and controlling for aggregated information from the birth records (i.e., share non-Hispanic White, share Hispanic, average age at birth, share married, shares with different education levels, and average birth order), county fixed effects, year-by-month of conception fixed effects, state-by-conception year fixed effects, and time-varying controls included in Equation (1). We report findings from this analysis in Table 4, first for all mothers and then for mothers of different ages, education levels, insurance types, and birth orders. None of the coefficient estimates on the e-cigarette tax variable (representing the effect of a large e-cigarette tax increase of $1) are statistically significant different from zero. Thus, we find no evidence of substantial COP bias stemming from fertility rates changing in response to e-cigarette taxes.

Finally, we test for balance in observable characteristics across treatment and comparison groups following Pei, Pischke, and Schwandt (2018). Specifically, we regress the standardized 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).[12] Results are reported in Table 5. We find that traditional cigarette taxes (p<0.01) are correlated with e-cigarette taxes, 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 correlations are perhaps not surprising. For example, this correlation may simply reflect an overall tobacco control policy strategy, which targets both e-cigarettes and traditional cigarettes, adopted by a locality. Previous research provides evidence for this hypothesis (Maclean et al. 2018). Of note, we control for tobacco control policies in all specifications.

Overall, we interpret the findings from our examination of the two-way fixed effects identification strategy to imply that the birth records data satisfy necessary assumptions.

5.4 Heterogeneity in e-cigarette tax effects across mother characteristics

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[12] Because our outcome variable in this regression is the standardized e-cigarette rate, we are testing for balance across localities with different levels of treatment (i.e., the standardized e-cigarette tax rate) intensity. Results are very similar if we instead use the any e-cigarette tax rate indicator as our outcome variable (available on request).

We next explore the extent to which e-cigarette tax effects vary across mother characteristics. More specifically, we estimate separate regressions by mother's age (30 years or less vs. older than 30 years), 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 6 for smoking outcomes. Results for any smoking are broadly similar across age, education, and parity groups. While coefficient estimates vary across sub-samples we note that 95% confidence intervals overlap preventing us from drawing strong conclusions regarding heterogeneous treatment effects. For example, among younger mothers (under age 30), the probability of prenatal smoking increases by 0.4 ppts (6.7%) following a $1.00 increase in the e-cigarette tax while the corresponding increase among older mothers (30 years and above) is 0.3 ppts (9.1%). Among mothers with no college education the probability of smoking increases by 0.6 ppts (7.5%) for a $1.00 increase in the e-cigarette tax while the corresponding increase among mothers with a college degree or more is 0.2 ppts (7.4%). Among mothers whose delivery is financed by Medicaid, following a $1.00 increase in the e-cigarette tax the probability of smoking increases by 0.3 ppts (4.0%) compared to 0.1 ppts (4.6%) for mothers whose delivery is financed by private insurance (we acknowledge that these coefficient estimates are imprecise within insurance-stratified samples). Finally, among first time mothers, a $1.00 increase in the standardized e-cigarette tax leads to a 0.5 ppt (12.4%) increase in smoking and among mothers with previous births smoking increases by 0.4 ppts (7.2%) following such an e-cigarette tax increase. Results for traditional cigarettes smoked per day and any pre-pregnancy smoking are similar to the findings 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, along with pregnancy and trimester fixed effects. Results are reported in Table 7.

We find that increases in the standardized e-cigarette tax rate raises trimester-specific smoking by 1.1 ppts (21.0%) and the number of cigarettes smoked during pregnancy by 0.29 cigarettes daily (51.6%). These findings suggest that e-cigarette tax increases reduce rates of smoking cessation during pregnancy. Two other studies have also documented that e-cigarette regulations reduce smoking cessation during the pregnancy (Cooper and Pesko 2017, Pesko and Currie 2019). Therefore, e-cigarette taxes appear to affect prenatal smoking both through raising pre-pregnancy smoking levels and reducing smoking cessation during the course of pregnancy.

5.6 Robustness checks

Our results are stable across several alternative specifications. We explore only the outcome of prenatal smoking having previously demonstrated similarities across our three smoking outcomes. We first re-run the analysis, but begin the sample in 2011 and exclude 13 states that had not adopted revised birth records by 2011 from the analysis sample to maintain a balanced cohort of states through the analysis. These results are reported in Online Appendix Table 3 and are virtually unchanged from those reported in Table 2.

Second, we cluster standard errors at the level of county rather than state (Online Appendix Table 4). This approach to inference is arguably less conservative than the approach we take in the main results in which we cluster by state. Clustering at this level does not change the precision of our coefficient estimates.

Third, we use an alternative construction of the e-cigarette standardized tax variable to address possible sources of endogeneity (Online Appendix Table 5, see the Online Appendix for details on the alternative measure and potential endogeneity). Results are substantially similar.

Fourth, 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 Online Appendix Tables 6A through 6C and displayed graphically in Online Appendix Figure 1, are stable across different 'leave-one-out' samples and imply that we are not capturing the effect of one or two localities.

Fifth, we exclude (collectively) California, Minnesota, Pennsylvania, and Montgomery County Maryland from the sample and re-estimate Equation (1). The purpose of this exercise is to provide testing on a key assumption of our e-cigarette tax conversion process. In our conversion process (see the Online Appendix for full details) we assume that these four localities (which use ad valorem taxes) have wholesale prices that are identical to Washington DC's wholesale price. While we have no information to suspect that these market structures differ across these localities, we wish to explore the importance of this assumption for our findings. Results, reported in Appendix Table 6C (final column), are very similar to our main coefficient estimates. In particular, a $1.00 increase in the standardized e-cigarette tax rate leads to a 0.7 ppt increase in the probability of any prenatal smoking compared to a 0.5 ppt increase in our main specification (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 (Online Appendix Table 7). This alternative linking procedure leads to some mothers previously assigned to the pre-e-cigarette tax comparison group being now assigned to the post-e-cigarette tax treatment group. The coefficient estimate remains identical to that generated in our main specification (Table 2).

6. Pre-pregnancy and prenatal e-cigarette use

In the first extension to our main analysis, we test whether e-cigarette taxes reduce e-cigarette use among pregnant women. For this, we use data from the PRAMS, which collects information on maternal attitudes and experiences before, during, and shortly after pregnancy for randomly-sampled pregnant women (Centers for Disease Control and Prevention 2020). Between 2016 and 2018, the PRAMS core module includes separate questions on how often the respondent uses e-cigarettes in the three months before becoming pregnant and in the last three months of pregnancy. Individuals can respond with the following options: more than once a day, once a day, two-six days a week, one day a week or less, or none. We use these questions to create outcomes of any pre-pregnancy e-cigarette use, any third trimester e-cigarette use, and estimated weekly frequency for both time periods separately.[13] We estimate a model identical to Equation (1) (including the same controls) with a few changes based on the information that is contained in the PRAMs. In particular, we (1) exclude Illinois and Maryland since sub-state taxes are present in these states and sub-state identifiers are not available in PRAMS; (2) include Connecticut, New Jersey, or Rhode Island (these states are excluded from our main analysis as they not have revised birth records as of 2013 in the NCHS data); (3) do not control for state-by-conception year fixed effects because of limited time horizon (three years) and smaller sample sizes in PRAMS;[14] and (4) we match the timing of the e-cigarette tax to either three months before conception or the start of the third trimester depending on the outcome.[15]

Our results are present in Table 8. We find that a \$1.00 increase in the standardized e-cigarette tax leads to a reduction in pre-pregnancy e-cigarette use of 1.3 ppt (p<0.01). The same \$1.00 increase in the standardized e-cigarette tax has a large reduction in the probability of third trimester e-cigarette use of 0.9 ppt (p<0.01). An average (conditional) e-cigarette tax of 45 cents during our sample period is estimated to reduce the probability of pre-pregnancy e-cigarette use by 14.3% of the pre-period sample mean for treated states, and third trimester e-cigarette use by 36.8%. Additionally, a \$1.00 increase in the e-cigarette tax reduces vaping by approximately 0.15 times per week pre-pregnancy and by 0.10 times per week in the third trimester. We therefore find early evidence that e-cigarette taxes reduce e-cigarette use among women who will

[13] We use values of 0, 0.5, 4, 7, and 14 for estimated weekly frequency.
[14] However, we do continue to control for conception year-by-month fixed effects.
[15] We view the NCHS birth records as our preferred data set as these data allow us to include three additional years of data and thus additional policy changes, incorporate sub-state taxes, and leverage a larger sample size. Finally, we are able to examine four points in time in each pregnancy in the NCHS birth records and just two in the PRAMS.

shortly become pregnant or who are pregnant, which provides evidence to support that e-cigarette taxes lead to higher traditional cigarette use by reducing e-cigarette use.

7. Birth outcomes

In the second extension to our main analysis, we estimate the effect of e-cigarette taxes on birth outcomes. This supplementary analysis sheds light on the extent to which the effect of e-cigarette taxes on traditional cigarettes and e-cigarettes that we document in Sections 5 and 6 may improve or harm fetal development.

Several economic studies establish that increases in the traditional cigarette tax rate improve both birth outcomes and health later in the child's life by reducing smoking among pregnant women (Ringel and Evans 2001, Evans and Ringel 1999, Lien and Evans 2005, Simon 2016). For example, Evans and Ringel (1999) show that a $1.00 increase in the traditional cigarette tax increases birth weight by 16 grams (0.5%) and prenatal smoking reduces birthweight by 360 grams (11%).

The extent to which substituting e-cigarettes for traditional cigarettes affects fetal health is *a-priori* less obvious than the documented effect of reductions in smoking. This ambiguity is due to the fact that vaping itself may adversely affect birth outcomes. While e-cigarettes contain few if any of the carcinogens found in traditional cigarettes, these products generally contain nicotine which is an important risk factor for 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).

Two recent studies explore the effects of e-cigarette non-tax policies on birth outcomes and broadly confirm the meta-analysis findings of Whittington et al. (2018). First, 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 (the same data that we utilize). E-cigarette indoor air laws reduce prenatal smoking cessation, but the laws have no effect on birth outcomes. Second, Pesko and Currie (2019) examine the effect of MLSA laws on teenage prenatal smoking and birth outcomes, also using birth records, and similarly find that MLSA laws reduce prenatal smoking cessation rates for rural youth but have no effect on birth outcomes.[16] These studies foreshadow our findings that e-cigarette taxes have no discernable effect on birth outcomes.

We also note that our estimated effect sizes for smoking and vaping outcomes are relatively small in magnitude. For example, our main model suggests a 0.4 ppt increase in prenatal smoking (Table 2) and a 0.9 ppt reduction in third trimester vaping (Table 8); therefore, we do not anticipate observing an effect of e-cigarette taxes on birth outcomes.[17] Nonetheless, for comparison with previous related economic work, we also consider e-cigarette tax effects on birth outcomes.

We use the birth record data (rather than PRAMS data) to study the effect of e-cigarette taxes on birth outcomes to maximize sample sizes and to leverage as much policy variation as

[16] Rural youth are the only sub-group for which the data appear to satisfy the parallel trends assumption.

[17] We thank Daniel Dench, Theodore Joyce, and Michael Grossman for very helpful discussions on this issue.

possible. We 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 ($\leq 10^{th}$ percentile), Apgar 5 score, and first-year infant mortality. 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 (excellent 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).

We report results for the standardized e-cigarette tax rate 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 except for possibly a decrease in the probability of premature birth of 0.5 ppts (5.9%). Taken together, our results suggest little effect of e-cigarette taxes on birth outcomes, which is in line with null findings documented in the two above-noted studies examining non-tax e-cigarette policies (Pesko and Currie 2019, Cooper and Pesko 2017).[18]

8. Conclusion

Our study finds that e-cigarette taxes lead to increases in prenatal smoking. In terms of effect sizes, prenatal smoking increases by 0.4 ppts or 7.7% following a $1.00 increase in the standardized e-cigarette tax. This result appears to be driven by changes in the rates of pre-pregnancy smoking. Additionally, using a panel data model, we find that trimester-specific smoking increases by 1.1 ppts (21.0%), suggesting that e-cigarette taxes reduce smoking

[18] We note that event study analysis (not reported but available on request) suggests some evidence that the data may not satisfy parallel trends for small for the gestation age, extra small for gestational age, and infant mortality outcomes. Given the potential differential pre-trends, in addition to concerns noted above, we interpret the birth outcome findings cautiously. Full results available on request.

cessation during pregnancy. Our results suggest 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 vaping bans and MLSA laws) 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 smoking within a given trimester by 2.0 ppts. Thus, our effect sizes are somewhat more modest than the findings of Cooper and Pesko (2017).

One possible reason for the somewhat more modest effect sizes we document is that the e-cigarette taxes we explore in this study were implemented between 2016 and 2018, with the exception of Minnesota, 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 of e-cigarettes, so the e-cigarette policies may have had extra impact through health signaling. In recent years individuals have access to more information on such risks that may make them less responsive to e-cigarette policies.

Our study has limitations. First, we identify the effect of e-cigarette taxes from variation in nine states, Washington DC, two counties, and one city. 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, 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 error.

In summary, we offer timely new evidence on the effect of e-cigarette taxes on pre-pregnancy and prenatal smoking, and vaping. Importantly, we provide credible evidence that e-cigarettes and traditional cigarettes are substitute products among pregnant women.

Table 1. Summary statistics: Full sample, counties with and without an e-cigarette tax by March 2018

Sample:	All counties	Counties with an e-cigarette tax	Counties without an e-cigarette tax
Outcomes			
Any prenatal smoking	0.076	0.056	0.084
Any pre-pregnancy smoking	0.099	0.074	0.108
Cigarettes smoked per day pre-pregnancy	1.297	0.969	1.425
	(5.039)	(4.416)	(5.256)
Cigarettes smoked per day 1st trimester	0.794	0.573	0.880
	(3.610)	(3.075)	(3.795)
Cigarettes smoked per day 2nd trimester	0.598	0.420	0.668
	(2.978)	(2.477)	(3.149)
Cigarettes smoked per day 3rd trimester	0.529	0.369	0.591
	(2.776)	(2.294)	(2.940)
Policy variables			
E-cigarette tax (any)	0.081	0.288	-
Standardized e-cigarette tax ($)	0.065	0.232	-
	(0.273)	(0.477)	-
Traditional cigarette tax ($)	2.660	2.508	2.720
	(1.106)	(0.950)	(1.155)
Index of indoor smoking restrictions	0.789	0.880	0.753
	(0.241)	(0.120)	(0.266)
Index of indoor vaping restrictions	0.146	0.251	0.104
	(0.316)	(0.385)	(0.274)
Minimum legal sale age law on e-cigarette	0.725	0.833	0.683
Tobacco 21 law	0.044	0.154	0.001
ACA Medicaid expansion	0.399	0.551	0.339
Mother characteristics			
White, non-Hispanic	0.526	0.440	0.560
Black, non-Hispanic	0.143	0.127	0.150
Hispanic	0.236	0.298	0.211
Other race	0.095	0.136	0.079
Age at birth	28.481	28.963	28.294
	(5.846)	(5.901)	(5.813)
Medicaid primary payer	0.432	0.420	0.437
Private insurance primary payer	0.479	0.497	0.472
Self-pay	0.041	0.039	0.041
Indian Health Service primary payer	0.001	0.000	0.001
Military insurance primary payer	0.011	0.007	0.012
Other government sources primary payer	0.009	0.013	0.007
Other primary payer	0.021	0.018	0.022
Unknown primary payer	0.008	0.005	0.008
Married	0.571	0.508	0.595
Not married	0.387	0.343	0.405
Marital status unknown	0.042	0.149	0.000
Less than high school	0.142	0.141	0.143
High school	0.252	0.239	0.256
Some college	0.289	0.274	0.295
College or more	0.305	0.321	0.299
Education unknown	0.012	0.025	0.006
1st birth	0.319	0.329	0.315
2nd birth	0.281	0.287	0.279
3rd birth	0.183	0.181	0.184

4^{th} birth	0.102	0.098	0.103
5^{th} birth	0.052	0.049	0.054
6^{th} birth	0.026	0.024	0.027
7^{th} birth	0.013	0.012	0.014
8^{th} birth	0.016	0.014	0.017
Birth order unknown	0.007	0.004	0.008
Observations	20,965,502	5,879,879	15,085,623

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics for all mothers who conceived between January 2013 and March 2018. The unit of observation is a pregnancy in a county in a state. Standard deviations for continuous variables are reported in parentheses.

Table 2. **Effect of e-cigarette taxes on prenatal smoking and smoking in the three months prior to conception**

Specification:	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Any prenatal smoking						
Any e-cigarette tax	0.004***	0.004***	0.004***	--	--	--
	(0.001)	(0.001)	(0.001)			
Standardized e-cigarette tax	--	--	--	0.003***	0.003**	0.004***
				(0.001)	(0.001)	(0.002)
Percent change	7.7%	7.7%	7.7%	5.8%	5.8%	7.7%
Mean, pre-tax in adopting counties	0.052	0.052	0.052	0.052	0.052	0.052
Panel B: Traditional cigarettes smoked per day						
Any e-cigarette tax	0.038**	0.039**	0.037**	--	--	--
	(0.014)	(0.017)	(0.017)			
Standardized e-cigarette tax	--	--	--	0.037**	0.037*	0.044*
				(0.017)	(0.021)	(0.024)
Percent change	9.1%	9.3%	8.9%	8.9%	8.9%	10.5%
Mean, pre-tax in adopting counties	0.418	0.418	0.418	0.418	0.418	0.418
Panel C: Any pre-pregnancy smoking						
Any e-cigarette tax	0.005***	0.005***	0.005***	--	--	--
	(0.001)	(0.001)	(0.001)			
Standardized e-cigarette tax	--	--	--	0.004***	0.004**	0.005***
				(0.001)	(0.001)	(0.002)
Percent change	7.4%	7.4%	7.4%	5.9%	5.9%	7.4%
Mean, pre-tax in adopting counties	0.068	0.068	0.068	0.068	0.068	0.068
County FE	✓	✓	✓	✓	✓	✓
Conception year-by-month FE	✓	✓	✓	✓	✓	✓
State-by-conception year FE	✓	✓	✓	✓	✓	✓
Demographic characteristics		✓	✓		✓	✓
Locality policy variables			✓			✓

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics for all mothers who conceived between January 2013 and March 2018. N=20,965,502. FE = fixed effects. 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). There are 46 clusters in the data.
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

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

Outcome:	**Any prenatal smoking**	**Traditional cigarettes smoked per day**	**Any pre-pregnancy smoking**	**Any pre-pregnancy smoking**
Time to tax effective date:				
>18 months	-0.001	-0.042*	-0.001	-0.001
	(0.002)	(0.024)	(0.002)	(0.002)
(15, 18] months	0.0003	-0.018	0.0001	-0.0001
	(0.002)	(0.022)	(0.002)	(0.002)
(12, 15] months	-0.0002	-0.001	0.0002	[Reference]
	(0.001)	(0.013)	(0.001)	--
(9, 12] months	[Reference]	[Reference]	[Reference]	-0.0002
	--	--	--	(0.001)
(6, 9] months	0.0003	0.010	0.0001	-0.0001
	(0.001)	(0.013)	(0.002)	(0.001)
(3, 6] months	0.001	0.024	0.001	0.001
	(0.001)	(0.022)	(0.002)	(0.001)
(0, 3] months	0.001	0.030	0.002	0.001
	(0.002)	(0.020)	(0.002)	(0.002)
[0, 3] months	0.002	0.018	0.003*	0.003
	(0.001)	(0.015)	(0.002)	(0.002)
>3 months	0.005***	0.055***	0.007***	0.006***
	(0.001)	(0.017)	(0.001)	(0.002)
Mean, pre-tax in adopting counties	0.052	0.418	0.068	0.068
County FE	✓	✓	✓	✓
Conception year-by-month FE	✓	✓	✓	✓
State-by-conception year FE	✓	✓	✓	✓
Demographic characteristics	✓	✓	✓	✓
Locality policy variables	✓	✓	✓	✓

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics for all mothers who conceived between January 2013 and March 2018. N=20,965,502. FE = fixed effects. 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). There are 46 clusters in the data.

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

Table 4. **Heterogeneity in the effect of e-cigarette taxes on birth rates**

Sample:	All	≤ 30	> 30	Low education	High education	Medicaid	Private	1st birth	≥2nd birth
Standardized e-cigarette tax	-13.941	-14.566	-1.063	-10.016	-5.546	-17.793	-0.522	-7.297	-7.58
	(18.423)	(17.269)	(4.583)	(11.039)	(9.617)	(14.248)	(7.412)	(7.432)	(11.864)
Percent change	-14.4%	-23.8%	-2.7%	-25.0%	-9.2%	-40.4%	-1.1%	-22.0%	-11.4%
Mean, pre-tax in adopting counties	96.79	61.28	39.53	40.01	60.02	44.06	48.47	33.21	66.70
County FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
Conception year-by-month FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
State-by-conception year FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
Demographic characteristics	✓	✓	✓	✓	✓	✓	✓	✓	✓
Locality level policy variables	✓	✓	✓	✓	✓	✓	✓	✓	✓

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics for all mothers who conceived between January 2013 and March 2018. N=216,637. FE = fixed effects. Low education = no college education. High education = some college education or more. The unit of observation is a county in a state. Standard errors are clustered around the state and are reported in parentheses. All models estimated with least squares. There are 46 clusters in the data.

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

Table 5. **Test of balance across localities across localities with different levels of e-cigarette taxes by 2018**

Sample proportion with an e-cigarette tax	0.052
Traditional cigarette tax rate	0.362***
	(0.069)
Index of indoor smoking restrictions	0.004
	(0.012)
Index of indoor vaping restrictions	0.000
	(0.012)
Minimum legal sale age law on e-cigarette	-0.056
	(0.038)
Tobacco 21 law	-0.024
	(0.018)
ACA Medication expansion	0.008
	(0.007)
White, non-Hispanic	-0.001
	(0.001)
Hispanic	-0.002
	(0.001)
Age at birth	0.000
	(0.000)
Private insurance	-0.001
	(0.000)
Married	0.000
	(0.000)
Some college education	-0.001
	(0.001)
Birth order	0.000
	(0.000)
County FE	✓
Conception year-by-month FE	✓
State-by-conception year FE	✓

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics for all mothers who conceived between January 2013 and March 2018. The outcome variable in this regression is the standardized e-cigarette tax rate. N=216,637. The unit of observation is a county in a state in a year. FE = fixed effects. Standard errors are clustered around the state and are reported in parentheses. The model is estimated with least squares. There are 46 clusters in the data. Omitted categories are non-white, non-Hispanic; non-private insurance; non-married; and less than a college education.
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

Table 6. **Heterogeneity in the effect of e-cigarette taxes levied at conception on prenatal and pre-pregnancy smoking**

Sample:	**< 30 yrs**	**≥ 30 yrs**	**Low education**	**High education**	**Medicaid**	**Private**	**1st birth**	**≥2nd birth**
Panel A: Any prenatal smoking								
Standardized e-cigarette tax	0.004^{**}	0.003^{**}	0.006^{**}	0.002^{*}	0.003	0.001	0.005^{*}	0.004^{***}
	(0.002)	(0.001)	(0.003)	(0.001)	(0.003)	(0.002)	(0.003)	(0.002)
Percent change	6.7%	9.1%	7.5%	7.4%	4.0%	4.6%	12.4%	7.2%
Mean, pre-tax in adopting counties	0.066	0.031	0.081	0.030	0.086	0.023	0.037	0.059
Panel B: Traditional cigarettes smoked during pregnancy								
Standardized e-cigarette tax	0.044	0.035^{**}	0.068	0.021	0.053	0.006	0.036	0.047^{*}
	(0.032)	(0.013)	(0.044)	(0.016)	(0.051)	(0.014)	(0.032)	(0.024)
Percent change	8.5%	13.1%	9.9%	9.6%	7.4%	3.7%	13.7%	9.5%
Mean, pre-tax in adopting counties	0.521	0.268	0.685	0.22	0.713	0.169	0.262	0.499
Panel C: Any pre-pregnancy smoking								
Standardized e-cigarette tax	0.005^{**}	0.004^{***}	0.006^{**}	0.004^{**}	0.005	0.002	0.006^{*}	0.005^{***}
	(0.002)	(0.001)	(0.003)	(0.002)	(0.004)	(0.002)	(0.003)	(0.002)
Percent change	6.0%	8.6%	5.8%	8.8%	4.4%	6.1%	10.0%	6.9%
Mean, pre-tax in adopting counties	0.087	0.041	0.100	0.044	0.105	0.038	0.057	0.074
Demographic characteristics	✓	✓	✓	✓	✓	✓	✓	✓
County FE	✓	✓	✓	✓	✓	✓	✓	✓
Conception year-by-month FE	✓	✓	✓	✓	✓	✓	✓	✓
State-by-conception year FE	✓	✓	✓	✓	✓	✓	✓	✓
Observations	13,114,921	7,850,581	8,260,279	12,705,219	9,060,584	10,039,155	6,692,777	14,272,724

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics for all mothers who conceived between January 2013 and March 2018. 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. FE = fixed effects. All models estimated with a linear probability model (binary outcome) or least squares (continuous outcome). There are 46 clusters in the data.
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

Table 7. **Effect of e-cigarette taxes levied at conception on prenatal smoking: Panel data analysis**

Outcome:	**Any prenatal smoking**	**Traditional cigarettes Smoked per day**
Standardized e-cigarette tax	0.011*	0.285**
	(0.006)	(0.137)
Percent change	21.0%	51.6%
Mean, pre-tax in adopting counties	0.051	0.553
Pregnancy FE	✓	✓
Trimester-by-conception (year-month) FE	✓	✓
Locality policy variables	✓	✓

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics for all mothers who conceived between January 2013 and March 2018. N=83,863,208. The unit of observation is a pregnancy in a county in a state at one of four periods of time. Standard errors are clustered around the state and are reported in parentheses. FE = fixed effects. All models estimated with a linear probability model (binary outcome) or least squares (continuous outcome). There are 46 clusters in the data.
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

Table 8. **Effect of e-cigarette taxes levied at conception on e-cigarette use**

Outcome:	Any pre-pregnancy vaping	Any 3rd trimester vaping	Frequency of pre-pregnancy vaping	Frequency of 3rd trimester vaping
Standardized e-cigarette tax	-0.013***	-0.009***	-0.150***	-0.100***
	(0.005)	(0.003)	(0.035)	(0.023)
Percent change (for $1.00 increase in the tax)	-31.7%	-81.8%	-60.5%	-147.1%
Percent change (for 'average' tax of 45 cents)	-14.3%	-36.8%	-27.2%	-66.2%
Mean, pre-tax in adopting counties	0.041	0.011	0.248	0.068
Demographic characteristics	✓	✓	✓	✓
County FE	✓	✓	✓	✓
Conception year-by-month FE	✓	✓	✓	✓

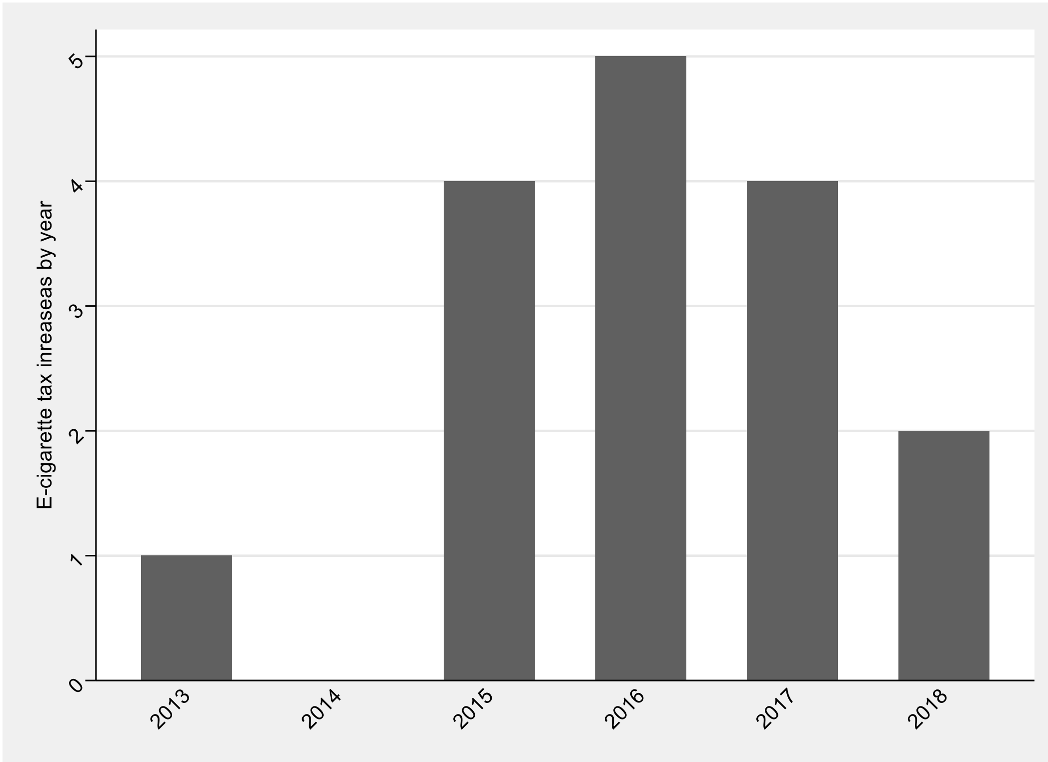
Notes: Data source is Pregnancy Risk Assessment Monitoring System for all mothers who conceived between January 2016 and March 2018. N=92,629. The unit of observation is a pregnancy in a county in a state. Standard errors are clustered around the state and are reported in parentheses. All models estimated with a linear probability model (binary outcome) or least squares (continuous outcome). There are 36 clusters in the data.
***; **; * =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)**	**(8)**
Standardized e-cigarette tax	-0.002	-0.005**	3.308	-0.001	0.001	-0.0002	-0.002	-0.0003
	(0.011)	(0.002)	(3.196)	(0.002)	(0.002)	(0.002)	(0.013)	(0.0003)
Percent change	0.0%	-5.9%	0.1%	-1.8%	0.4%	-0.3%	-0.0%	-7.8%
Mean, pre-tax in adopting counties	38.83	0.08	3314.49	0.06	0.24	0.09	8.85	0.00
Demographic characteristics	✓	✓	✓	✓	✓	✓	✓	✓
County FE	✓	✓	✓	✓	✓	✓	✓	✓
Conception year-by-month FE	✓	✓	✓	✓	✓	✓	✓	✓
State-by-conception year FE	✓	✓	✓	✓	✓	✓	✓	✓

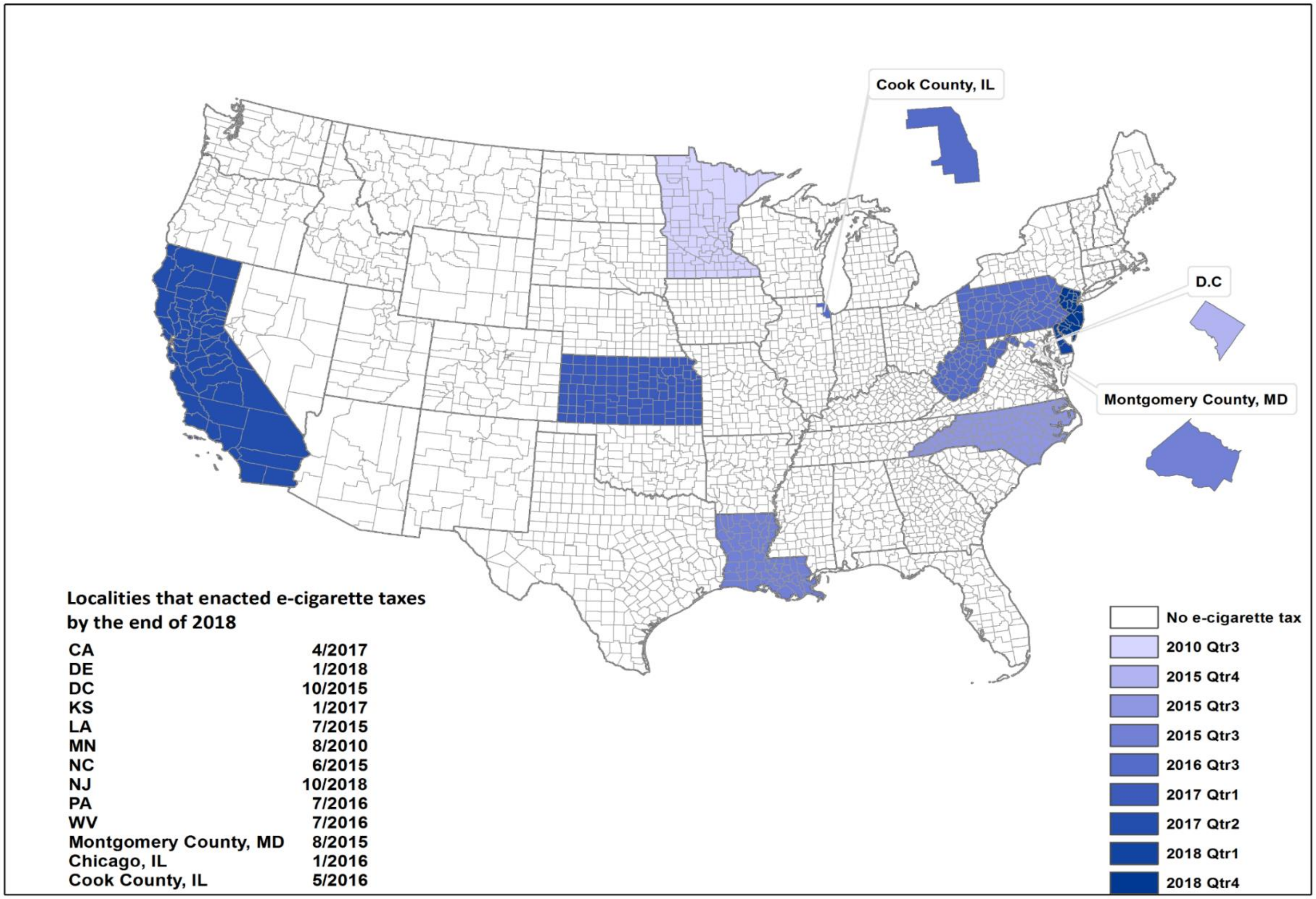
Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics for all mothers who conceived between January 2013 and March 2018. N=20,952,400. The unit of observation is a pregnancy in a county in a state. Standard errors are clustered around the state and are reported in parentheses. All models estimated with a linear probability model (binary outcome) or least squares (continuous outcome). There are 46 clusters in the data. (1) = Gestation length. (2) = Premature (<37 weeks). (3) = Birth weight (grams). (4) = Low birth weight (<2500 grams). (5) = Small-for-gestational age (≤25th percentile). (6) = Extra small-for-gestational age (≤10th percentile). (7) = Apgar 5. (8) = One-year infant mortality.
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

Figure 1. **E-cigarette tax increases by year: 2013 to 2018**



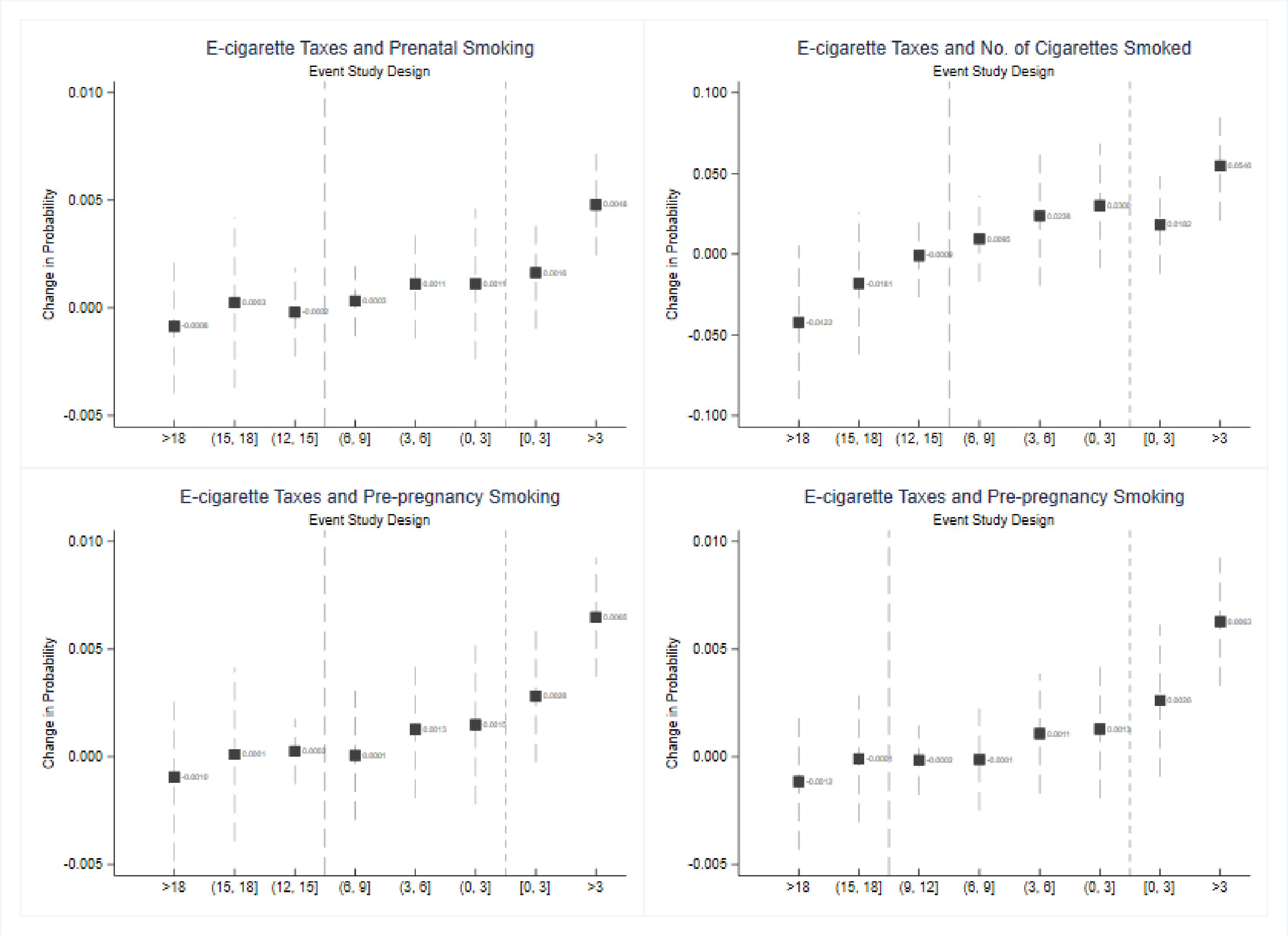
Notes: Data sources are the Vapor Products Tax Data Center, American Non-Smokers Rights Foundation (proprietary), and Tax Foundation. See text for more details.

Figure 2. **Localities that levied an e-cigarette tax as of March 2018**



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 3 for details.

Online appendix: Standardizing e-cigarette taxes

Our procedure was pioneered by Cotti et al. (2020). Through 2018, e-cigarette taxes have been levied using either specific excise taxes or ad valorem taxes. To standardize e-cigarette taxes levied in different ways into a single measure, we combine policy data on e-cigarette taxes and data from the Nielsen Retail Scanner data. Chicago, Cook County, Delaware, Kansas, Louisiana, New Jersey, North Carolina, and West Virginia use an excise tax on liquid volume. California, Minnesota, Montgomery County, Pennsylvania, and Washington DC use an ad valorem tax. Chicago uses an excise tax on both liquid volume and the number of disposable or refill units sold. Several Alaskan counties also have e-cigarette taxes, but Alaska is not included in the Nielsen retail data and is therefore not included in our standardization exercise that follows Cotti et al. (2020). Between the end of our study period in 2018 and the end of 2019, eight additional states adopted new e-cigarette taxes (Connecticut, Illinois, New Mexico, New York, Ohio, Vermont, Washington, and Wisconsin).

We standardize e-cigarette ad valorem taxes into an excise tax equivalency (per ml of fluid) using the following formula:

$$ad\ valorem\ rate_{st} * 0.044 * \frac{sales\ volume\ in\ retail\ units_{st}}{sales\ volume\ in\ ml\ of\ fluid_{st}} = \frac{tax\ revenue_{st}}{sales\ volume\ in\ ml\ of\ fluid_{st}} = tax\ per\ ml\ of\ fluid_{st}$$

Where *s* indexes a tax jurisdiction *s* on a year-by-quarter basis *t*. Tax jurisdictions are defined as state, except for Illinois and Maryland that have sub-state tax variation in which case the tax jurisdiction is either the sub-state (i.e., Chicago, Cook County, and Montgomery County) or the rest of the state.

Washington DC's ad valorem tax is benchmarked to be equal to the value of the traditional cigarette tax (as determined by DC's tax authority, using a weighted average of all e-cigarette products) (Public Health Law Center 2020). In the 1st quarter of 2017, the traditional cigarette tax was $2.92 per pack in DC and the e-cigarette ad valorem tax (as a percent of the wholesale price) was 67 percent. Therefore, a 67 percent ad valorem tax equals $2.92, and the wholesale price (inclusive of the tax) in DC is equal to $4.36 ($2.92 / 0.67).[19] We assume other ad valorem tax localities (California, Minnesota, Montgomery County, and Pennsylvania) similarly have wholesale prices of $4.36; therefore, each one percent of ad valorem tax has a value of

[19] This is somewhat larger than the wholesale price estimate (inclusive of the tax) of $3.52 for replacement pods in Minnesota in 2012 estimated by Saffer et al. (2020). This difference could reflect wholesale prices being larger in 2017 than in 2012, wholesale prices being larger in Minnesota than in Washington DC, or wholesale prices for replacement pods being different than for a broader array of e-cigarette products. To the extent that wholesale prices change nationally over time, or that wholesale prices exhibit time-invariant differences across localities, our identification strategy using year and county fixed effects removes this as a potential source of bias.

approximately $0.044.[20] We multiply the ad valorem rate (e.g., 40, 65, 95) by 0.044 for all ad valorem localities.

Next, we multiply by total sales volume in retail units to obtain overall tax revenue for each tax jurisdiction *s* on a year-by-quarter basis *t*. Sales units include all disposable e-cigarettes, starter kits, and replacement pods in the Nielsen data, after omitting products for which fluid amounts or container amounts could not be identified using internet search and visits to retailers. E-cigarette product characteristics are identified for 93.5% of sales-weighted e-cigarette units as identified by the Nielsen data.

Lastly, we divide total volume in ml of fluid for each tax jurisdiction *s* on a year-by-quarter basis *t*, again after omitting products for which fluid amounts or container amounts could not be identified using internet search and visits to retailers.

One concern with our conversion is that the ratio of sales volume in units to ml of fluid may be endogenous to the e-cigarette tax adoption. Therefore, our primary standardized tax measure uses the ratio for all locations that have not adopted e-cigarette taxes by January 2020. As a sensitivity analysis, we use the ratio specific to each tax jurisdiction. Results are similar regardless of which measure is used.

For Cook County, we do not have the ability to separate Chicago from the rest of Cook County in the Nielsen data. For the Chicago portion of the tax, Chicago uses a $0.55 tax per ml of fluid and a $0.80 tax per container of products containing liquid nicotine (e.g., cartridge, disposable). We, therefore, calculate tax per ml of fluid in the following way:

$$0.55 + \frac{sales\ volume\ in\ containers_{st}}{sales\ volume\ in\ ml\ of\ fluid_{st}} * 0.80 = tax\ per\ ml\ of\ fluid_{st}$$

For the Cook County tax, similar to the approach mentioned earlier to address potential concerns of endogeneity, we used the ratio of sales volume in containers to sale volume in ml of fluid for all locations that have not adopted e-cigarette taxes by January 2020 for our primary standardized e-cigarette tax rate. As a sensitivity analysis, we use the ratio specific to Chicago. Results are similar regardless of which measure is used.

Since Chicago constitutes approximately 52.1% of the population of Cook County in 2017, we weight the Chicago tax by this share of the population to approximate the Cook County tax. Cook County later passed its own tax per fluid ml of fluid that we added in whole to the weighted tax from Chicago. In the manuscript we show that our results are insensitive to excluding Cook County.

As of the time of writing Nielsen retail data is not yet available for year 2018 to standardize the ad valorem taxes into an excise tax equivalency. For 2018 we use December 2017 values, with the exception of the new e-cigarette taxes enacted in Delaware and New Jersey (both excise

[20] We show in Online Appendix Table 6c that our main result is largely unchanged when dropping these tax jurisdictions.

taxes), in which case we use the values of the excise tax for these states from the point in time at which the tax was enacted.

Online Appendix Table 1. **E-cigarette tax changes through 2018**

Locality	**Effective Date(s)**	**Unit taxed**	**Tax amount**	**Tax value Q4 2018 ($)**
State/District				
Washington, DC	10/2015, 10/2016, 10/2018	Wholesale price	67.0%, 65.0%, 96%	1.25
California	4/2017, 7/2017	Wholesale price	27.3%, 65.1%	1.25
Delaware	1/2018	Per fluid milliliter	$0.05	0.05
Kansas	1/2017, 7/2017	Per fluid milliliter	$0.20, $0.05	0.05
Louisiana	7/2015	Per fluid milliliter	$0.05	0.05
Minnesota	8/2010, 7/2013	Wholesale price	35.0%, 95.0%	1.82
New Jersey	10/2018	Per fluid milliliter	$0.10	0.10
North Carolina	6/2015	Per fluid milliliter	$0.05	0.05
Pennsylvania	7/2016	Wholesale price	40.0%	0.77
West Virginia	7/2016	Per fluid milliliter	$0.075	0.075
County/City				
Chicago, IL	1/2016	Per unit / per fluid milliliter	$0.80 / $0.55	0.61^
Cook County, IL	5/2016	Per fluid milliliter	$0.20	0.61^
Montgomery County, MD	8/2015	Wholesale price	30.0%	0.58

Notes: Data sources are the Vapor Products Tax Data Center, American Non-Smokers Rights Foundation (proprietary), and Tax Foundation. See text for full details. ^ The Chicago tax is added to the Cook County tax based on the share of the population residing in Chicago, see the online appendix for further details.

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

Specification:	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Mean, pre-tax in adopting counties	0.052	0.052	0.052	0.052	0.052	0.052
Any e-cigarette tax	0.004***	0.004***	0.004***	--	--	--
	(0.001)	(0.001)	(0.001)			
Standardized e-cigarette tax	--	--	--	0.003***	0.003**	0.004***
				(0.001)	(0.001)	(0.002)
Traditional cigarette tax	--	--	-0.001	--	--	-0.001
			(0.001)			(0.0010)
Index of indoor smoking restrictions	--	--	0.000	--	--	0.000
			(0.009)			(0.009)
Index of indoor vaping restrictions	--	--	0.005**	--	--	0.005**
			(0.002)			(0.002)
Tobacco 21 law	--	--	0.003***	--	--	0.003***
			(0.001)			(0.001)
ACA Medicaid expansion	--	--	-0.003	--	--	-0.002
			(0.002)			(0.002)
Black, non- Hispanic	--	-0.097***	-0.097***	--	-0.097***	-0.097***
		(0.012)	(0.012)		(0.012)	(0.012)
Hispanic	--	-0.119***	-0.119***	--	-0.119***	-0.119***
		(0.0130)	(0.013)		(0.0130)	(0.013)
Other	--	-0.037***	-0.037***	--	-0.037***	-0.037***
		(0.005)	(0.005)		(0.005)	(0.005)
Private insurance	--	-0.060***	-0.060***	--	-0.060***	-0.060***
		(0.008)	(0.008)		(0.008)	(0.008)
Self-pay	--	-0.060***	-0.060***	--	-0.060***	-0.060***
		(0.013)	(0.013)		(0.013)	(0.013)
Indian Health Service	--	-0.033	-0.033	--	-0.033	-0.033
		(0.023)	(0.023)		(0.023)	(0.023)
Military insurance	--	-0.058***	-0.058***	--	-0.058***	-0.058***
		(0.005)	(0.005)		(0.005)	(0.005)
Other government source	--	-0.015*	-0.015*	--	-0.015*	-0.015*
		(0.007)	(0.007)		(0.007)	(0.007)
Other	--	-0.044***	-0.044***	--	-0.044***	-0.044***
		(0.007)	(0.007)		(0.007)	(0.007)
Payer unknown	--	-0.037***	-0.037***	--	-0.037***	-0.037***
		(0.006)	(0.006)		(0.006)	(0.006)
Married	--	-0.084***	-0.084***	--	-0.084***	-0.084***
		(0.010)	(0.010)		(0.010)	(0.010)
Marital status unknown	--	-0.050***	-0.055***	--	-0.050***	-0.055***
		(0.006)	(0.006)		(0.006)	(0.006)
High school	--	-0.030***	-0.030***	--	-0.030***	-0.030***
		(0.007)	(0.007)		(0.007)	(0.007)
Some College	--	-0.068***	-0.068***	--	-0.068***	-0.068***
		(0.012)	(0.012)		(0.012)	(0.012)
College	--	-0.101***	-0.101***	--	-0.101***	-0.101***
		(0.015)	(0.015)		(0.015)	(0.015)
Education unknown	--	-0.067***	-0.067***	--	-0.067***	-0.067***
		(0.010)	(0.010)		(0.010)	(0.010)
2nd birth	--	0.009***	0.009***	--	0.009***	0.009***
		(0.001)	(0.001)		(0.001)	(0.001)

3rd birth	--	0.019***	0.019***	--	0.019***	0.019***
		(0.003)	(0.003)		(0.003)	(0.003)
4th birth	--	0.030***	0.030***	--	0.030***	0.030***
		(0.004)	(0.004)		(0.004)	(0.004)
5th birth	--	0.041***	0.041***	--	0.041***	0.041***
		(0.005)	(0.005)		(0.005)	(0.005)
6th birth	--	0.053***	0.053***	--	0.053***	0.053***
		(0.005)	(0.005)		(0.005)	(0.005)
7th birth	--	0.061***	0.061***	--	0.061***	0.061***
		(0.005)	(0.005)		(0.005)	(0.005)
8th birth	--	0.067***	0.067***	--	0.067***	0.067***
		(0.004)	(0.004)		(0.004)	(0.004)
Birth order unknown	--	0.019***	0.019***	--	0.019***	0.019***
		(0.004)	(0.004)		(0.004)	(0.004)
County FE	--	✓	✓	✓	✓	✓
Conception year-by-month FE	✓	✓	✓	✓	✓	✓
State-by-conception year FE	✓	✓	✓	✓	✓	✓
Demographic characteristics		✓	✓		✓	✓
Locality policy variables			✓			✓

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics for all mothers who conceived between January 2013 and March 2018. N=20,965,502. 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. There are 46 clusters in the data. 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.

Online Appendix Table 3. **Effect of e-cigarette taxes levied at conception on any prenatal smoking: Begin study period in 2011**

Specification:	**(1)**	**(2)**	**(3)**
Standardized e-cigarette tax	0.004***	0.004**	0.005***
	(0.001)	(0.001)	(0.002)
Percent change	7.5%	7.5%	9.4%
Mean, pre-tax in adopting counties	0.053	0.053	0.053
County FE	✓	✓	✓
Conception year-by-month FE	✓	✓	✓
State-by-conception year FE	✓	✓	✓
Demographic characteristics		✓	✓
Locality policy variables			✓

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics for all mothers who conceived between January 2013 and March 2018. N=23,143,407. 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. There are 39 clusters in the data, the number of clusters is lower in this analysis as we lose states that had not revised their birth records in 2011 and 2012.
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

Online Appendix Table 4. **Effect of e-cigarette taxes levied at conception on any prenatal smoking: Cluster standard errors around the county**

Specification:	**(1)**	**(2)**	**(3)**
Standardized e-cigarette tax	0.003***	0.003***	0.004***
	(0.001)	(0.001)	(0.001)
Percent change	5.8%	5.8%	7.7%
Mean, pre-tax in adopting counties	0.052	0.052	0.052
County FE	✓	✓	✓
Conception year-by-month FE	✓	✓	✓
State-by-conception year FE	✓	✓	✓
Demographic characteristics		✓	✓
Locality policy variables			✓

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics for all mothers who conceived between January 2013 and March 2018. N=20,965,502. 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. There are 3,076 clusters in the data.
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

Online Appendix Table 5. **Effect of e-cigarette taxes levied at conception on any prenatal smoking: Alternative standardized e-cigarette tax rate**

Specification:	**(1)**	**(2)**	**(3)**
Panel A: Any prenatal smoking			
Standardized e-cigarette tax	0.004***	0.003***	0.005***
	(0.001)	(0.001)	(0.002)
Percent change	7.7%	5.8%	9.6%
Mean, pre-tax in adopting counties	0.052	0.052	0.052
County FE	✓	✓	✓
Conception year-by-month FE	✓	✓	✓
State-by-conception year FE	✓	✓	✓
Demographic characteristics		✓	✓
Locality policy variables			✓

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics for all mothers who conceived between January 2013 and March 2018. N=20,965,502. FE = fixed effects. 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). There are 46 clusters in the data.
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

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

Excluded locality:	**CA**	**DE**	**DC**	**KS**	**LA**
Standardized e-cigarette tax	0.003	0.004***	0.004***	0.004**	0.005***
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Percent change	5.8%	7.7%	7.7%	7.7%	9.6%
Mean, pre-tax in adopting counties (using all tax localities)	0.052	0.052	0.052	0.052	0.052
County FE	✓	✓	✓	✓	✓
Conception year-by-month FE	✓	✓	✓	✓	✓
State-by-conception year FE	✓	✓	✓	✓	✓
Demographic characteristics	✓	✓	✓	✓	✓
Locality policy variables	✓	✓	✓	✓	✓
Observations	18,181,984	20,898,540	20,879,453	20,732,053	20,606,815
Number of clusters	45	45	45	45	45

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics for all mothers who conceived between January 2013 and March 2018. 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.
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

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

Excluded locality:	**MN**	**NC**	**NJ**	**PA**	**WV**
Standardized e-cigarette tax	0.005***	0.004***	0.004***	0.006***	0.004***
	(0.002)	(0.002)	(0.002)	(0.001)	(0.001)
Percent change	9.6%	7.7%	7.7%	11.5%	7.7%
Mean, pre-tax in adopting counties (using all tax localities)	0.052	0.052	0.052	0.052	0.052
County FE	✓	✓	✓	✓	✓
Conception year-by-month FE	✓	✓	✓	✓	✓
State-by-conception year FE	✓	✓	✓	✓	✓
Demographic characteristics	✓	✓	✓	✓	✓
Locality policy variables	✓	✓	✓	✓	✓
Observations	20,257,601	20,257,601	20,965,502	20,175,788	20,859,770
Number of clusters	45	45	45	45	45

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics for all mothers who conceived between January 2013 and March 2018. 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.

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

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

Excluded locality:	**Montgomery County, MD**	**City of Chicago, IL**	**Cook County, IL**	**No wholesale price assumption┼**
Standardized e-cigarette tax	0.004**	0.004**	0.005**	0.007***
	(0.002)	(0.002)	(0.002)	(0.001)
Percent change	7.7%	7.7%	9.6%	13.5%
Mean, pre-tax in adopting counties (using all tax localities)	0.052	0.052	0.052	0.052
County FE	✓	✓	✓	✓
Conception year-by-month FE	✓	✓	✓	✓
State-by-conception year FE	✓	✓	✓	✓
Demographic characteristics	✓	✓	✓	✓
Locality policy variables	✓	✓	✓	✓
Observations	20,891,353	20,750,047	20,800,242	16,915,387
Number of clusters	46	46	46	43

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics for all mothers who conceived between January 2013 and March 2018. 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.

┼We exclude California, Minnesota, Montgomery County, and Pennsylvania from the sample at the same time because e-cigarette wholesale prices were assumed to be constant to Washington D.C.'s wholesale price during our conversion process. See the Online Appendix for full details.

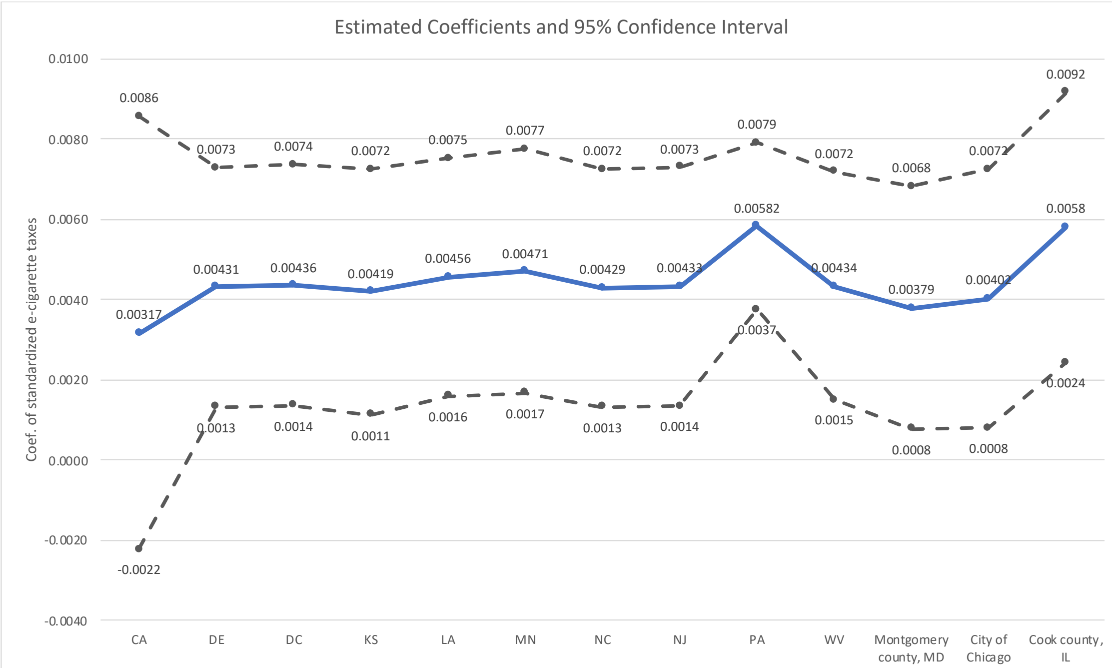
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

Online 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**

Variable:	**Beta (standard error)**
Standardized e-cigarette tax	0.004***
	(0.001)
Percent change	5.9%
Mean, pre-tax in adopting counties	0.068
County FE	✓
Conception year-by-month FE	✓
State-by-conception year FE	✓
Demographic characteristics	✓
Locality policy variables	✓
Observations	20,965,502
Number of clusters	46

Notes: Data source is administrative birth records with geocodes provided by the National Center for Health Statistics for all mothers who conceived between January 2013 and March 2018. 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.
***; **; * =statistically different from zero at the 1%; 5%; 10% level.

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



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 Tables 6A to 6B for details.

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