Three Essays in Health Economics

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Abstract

This thesis focuses on infant and maternal health through the examination of different government regulated policy interventions. Specifically, this thesis comprises of three essays. First, I examine the effect of a reduction in coal-fired power plant emissions on infant health outcomes of downwind counties. Second, I analyze how limiting lawyers' contingency fees affects physicians' decision to perform C-sections on women and, ultimately, its effect on infant mortality. The third, and final, paper investigates whether or not medical malpractice tort reforms have altered physicians' decision to take part in defensive medicine.

Chapter 1 examines the Clean Air Interstate Rule (CAIR) which mandated the reduction of power plant emissions in the eastern United States. This policy improved air quality in neighbouring downwind counties, greatly reducing exposure to a specific form of pollution—fine particulate matter. I investigate the impact of this reduction exposure on birth outcomes using data from the U.S. Natality Detail Files. I find that female babies experience improvements in premature birth and low/very low birth weight status which are driven by the reduction in prematurity. I also focus on full-term babies to better isolate the impact of prematurity from fetal growth on birth weight. Consistent with recent work, I find that full-term male babies experience an increase in birth weight, demonstrating an improvement in intrauterine growth due to lower exposure to fine particulates. Finally, I find a reduction in infant mortality for babies whose mothers were categorized as "high-risk" pregnancies, suggesting that reduced exposure may lead to improved birth outcomes among those most at risk.

Chapter 2 analyzes a limit on contingency fees for lawyers in medical malpractice cases enacted in Nevada. Generally, such limits are thought to change the composition of liability cases as they induce lawyers to drop more frivolous cases in favour of ones involving death and serious injury. Inadvertently, obstetricians faced a greater fear of litigation. Applying synthetic control methods, I find a 2.8 percentage point increase in the C-section rates of high school dropout patients, translating to a ten percent increase after the reform. There is no statistically significant difference in C-section rates after the enactment of the reform on patients with at least a college degree, and further, no statistically significant effect on infant mortality. Limiting contingency fees in medical malpractice cases induces obstetricians to engage in defensive medicine by performing more C-sections on low income patients, illustrating that tort reform can alter physician procedural patterns, albeit in heterogeneous ways.

Chapter 3 continues with the theme of government regulated policy intervention by examining the effects of medical malpractice tort reform on maternal and infant health. Numerous papers examined the effects of tort reforms on physician behaviour using data from the 1990s. However, a medical malpractice "crisis" in the early 21st century saw many US states adopt tort reforms to alleviate this issue. Using data from 1995 to 2012 I observe that tort reforms are not as effective as they once were. However, I find evidence that physicians' procedural choices are affected by tort reforms. Not only are C-section rates and "preventable" complications affected by tort reforms, but I also observe that tort reforms influence physicians' decisions with non-risky patients.

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"If I have seen further than others, it is by standing on the shoulders of giants."

-Isaac Newton

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Declaration of Academic Achievement

The material in this dissertation consists of my own research. I conducted all the empirical analysis, as well as writing of the manuscripts from 2015 to 2018.

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Introduction

This thesis focuses on infant and maternal health through the examination of different government regulated policy interventions. Specifically, this thesis comprises of three essays. First, I examine the effect of a reduction in coal-fired power plant emissions on infant health outcomes of downwind counties. Second, I analyze how limiting lawyers' contingency fees affects physicians' decision to perform C-sections on women and, ultimately, its effect on infant health. The third, and final, paper investigates whether or not medical malpractice tort reforms have altered physicians' decision to take part in defensive medicine. This research uses micro-econometric techniques such as difference-in-differences, synthetic control, and linear probability models. The ultimate goal of this thesis is to apply econometric techniques to empirical data in order to answer relevant policy questions.

The first chapter of my thesis, "When Good Fences Aren't Enough: The Effect of Neighbouring Air Pollution on Infant Health Outcomes," is, to my knowledge, the first to examine the causal effect the Clean Air Interstate Rule (CAIR) had on infant health. Moreover, it is among the first to examine the impact of a specific form of pollution—fine particulate matter—that has received very little attention from economists. In the mid-2000s the United States Environmental Protection Agency (EPA) mandated air pollution reductions from coal fired power plants whose emissions were travelling downwind to neighbouring counties. Using U.S. data from 1995 to 2013, I find that the reductions in emissions from neighbouring power plants decreases the number of premature births as well as increases the birth weight of infants in downwind counties. Moreover, I find heterogeneous responses by mother's age, education, season of birth, gender, and whether or not the mother had a "high-risk" pregnancy. For example, when examining the proportion of premature births, and the incidence of low and very low birth weight, I find that female babies experience statistically significant improvements. However, given the baby is full-term it is male babies that will experience an increase in birth weight, demonstrating an improvement in intrauterine growth due to lower fine particulate exposure. There is also evidence that those most likely to suffer from negative health effects experience the greatest benefit from reduced exposure. I find a reduction in infant mortality for babies whose mothers were categorized as high-risk pregnancies. Simple back of the envelope calculations show that the reduction in premature births alone due to the CAIR saves over $100 million in medical expenses every year and that just represents the first year of life. It is, therefore, essential that debate over environmental policies, like CAIR, include discussion of potential benefits to infant health, like those found in this study.

In the second chapter of my thesis, "C-Sections and Lawyers' Fees: The Effects of Contingency Fee Reform on Maternal and Infant Health," I apply the latest econometric techniques to investigate whether a change in the legal system influenced physicians to alter their procedural choice between normal (vaginal) and C-section delivery. This paper contributes to a large existing literature by being the first to analyze the effect of contingency fee reform on maternal and infant health. More specifically, using synthetic control methods, I exploit a tort reform in Nevada (U.S.) in 2004 that limited lawyers' fees for medical malpractice cases and unintentionally increased obstetricians' liability perceptions for lower income patients who tend to use lawyers that work on a contingency fee basis. Post reform, I find that doctors perform more C-sections on lower income patients with no change occurring for higher income patients who are more likely to rely on lawyers who bill hourly. This pattern suggests that physician practice patterns do indeed respond to liability concerns. Moreover, I find no statistically significant effect on infant mortality, illustrating that doctors are successfully engaging in defensive medicine. This paper contributes to a long literature on the impact of liability reforms on physician practice patterns.

The final chapter of my thesis, “A Re-Examination of the Effects of Tort Reforms on Obstetrical Procedures and Health Outcomes,” contributes to a large existing literature on medical malpractice tort reform. This paper aims to examine the effect of tort reforms on obstetrical procedures and infant health outcomes in the early twenty-first century. Numerous papers examine the effects of tort reforms on physician behaviour using data from the 1980s and 1990s. However, since then the United States experienced a medical malpractice “crisis” in the early 21st century, which saw many states adopt tort reforms to alleviate this issue. Using more current data, I observe that tort reforms are not as effective as they once were, contrary to prominent work (see Currie and McLeod, 2008). I find robust evidence that physicians are engaging in defensive medicine; C-section rates and “preventable” complications are affected by tort reforms, specifically influencing physicians’ decisions with non-risky patients.

Maternal factors affect infant health, and infant health outcomes are markers for future life success. Infants with worse health outcomes, such as low birth weight, experience lower cognitive ability, lower future earnings, and worse adult health outcomes (see Bhutta et al., 2012; Johnson and Schoeni, 2007). It is, thus, imperative that infant and maternal health outcomes are analyzed when government policy interventions are introduced. This research provides evidence that air pollution, even at fine levels, affects intrauterine growth development, and medical malpractice tort reform affects physicians’ decision to perform procedures, such as C-sections.

References

Bhutta A. T., Cleves M. A., Casey P. H., et al. 2002. “Cognitive and Behavioural Outcomes of School Aged Children Who Were Born Preterm: A Meta-analysis.” *Journal of the American Medical Association*, *288*,728-737.

Currie, J., and W. B. MacLeod. 2008. “First do no harm? Tort reform and birth outcomes.” *Quarterly Journal of Economics* 123(2): 795–830.

Johnson, R. C., & Schoeni, R. F. 2007. “The Influence of Early-Life Events on Human Capital, Health Status, and Labour Market Outcomes Over the Life Course.” National Poverty Center Working Paper Series #07-05.

Chapter One

When Good Fences Aren't Enough: The Effect of Neighbouring Air Pollution on Infant Health

1.1 Introduction

Though mainly descriptive, mounting evidence suggests that exposure to air pollution may be harming infant health in developed countries like the United States. More recent evidence implies that a specific form of air pollution—fine particulate air pollution—may also have deleterious impacts on newborn babies. "Fine particles" are formed by sulphur dioxide (SO_2) and oxides of nitrogen (NO_x) emitted primarily from coal fired power plants and, until recently, this form of pollution was largely unregulated. In addition to these power plants producing harmful emissions locally, such emissions may cross state boundaries due to prevailing downwind air patterns. As a result, pregnant women in neighbouring states may be harmed by the negative spillover effects of coal fired power plants. In 2005, the Environmental Protection Agency (EPA) implemented the Clean Air Interstate Rule (CAIR) in order to limit emissions from power plants in the eastern United States that were found to interfere with the National Ambient Air Quality Standards (NAAQS) of other states. In essence, the CAIR sought to and achieved reductions in exposure to fine particulate matter in states neighbouring other states with coal fired power plants. This paper is the first to examine the impacts that the CAIR has had on infant health outcomes, including prematurity, birth weight status and infant mortality.

I find evidence that reduced exposure to fine particulate matter improves the health outcomes of newborn children, many of which are recognized as markers for future life success such as improved educational attainment (c.f., Johnson and Schoeni, 2007). Overall, I find the implementation of the CAIR reduced the proportion of premature births in affected areas, as well as the proportion of newborns with low birth weight in these areas. Simple calculations based on my estimates reveal that on average approximately 2000 premature births are averted each year in downwind counties. This finding may have longer-run impacts because several studies find that premature birth is connected with lower cognitive ability and later behavioural issues (see Bhutta et al., 2002). Furthermore, premature births are very costly; the average medical cost for a premature baby from birth through the first year is $55,393 according to Truven Health Analytics, Inc. (2013). Meanwhile, the average medical cost for a healthy, full-term baby from birth through the first year is $5,085.[1] Simple back of the envelope calculations show that the CAIR saves over $100 million in medical expenses every year and that is just for the first year of life and includes none of the other expenses that may be associated with premature birth. Moreover, I find that babies categorized as being in “high-risk” pregnancies (i.e., those with conditions such as diabetes, hypertension, or eclampsia) experience a reduction in infant mortality. Since the “high-risk” label is disproportionately associated with older mothers, my findings suggest that reductions in fine particulate matter may have greater impacts for children

[1] Costs are adjusted to 2011 US dollars.

already prone to negative birth outcomes. My estimates translate into roughly 60 fewer cases per year of infant mortality among children whose mothers experience "high-risk" pregnancy.[2]

In addition to examining all births, regardless of gestational age at birth, I also focus on full-term births in isolation. By focusing on full-term births I am able to address the concern that low birth weight may be due to shorter gestational length (i.e., prematurity), as opposed to slowed fetal growth from in-utero exposure to power plant emissions. When examining the proportion of premature births, and the incidence of low and very low birth weight, I find that female babies experience statistically significant improvements. However, given the baby is full-term, I find that male babies experience an increase in birth weight, demonstrating an improvement in intrauterine growth due to lower power plant emissions. My estimates imply that over 300 full-term male babies per year are not classified as low birth weight due to the reductions in power plant emissions from neighbouring states. Evidently, policies reducing emissions, such as the CAIR, are producing healthier babies.

The next section provides relevant background and is separated into two major parts: the first explains the specifics of the CAIR policy, focusing on the period over which it was binding, while the second part focuses on relevant existing studies which assess the potential relationship between air pollution and infant health. While there are strong clinical reasons to expect a relationship between the two, relatively little systematic evidence exists, especially for fine particulates whose emissions, until relatively recently, were largely unregulated. Section 1.3 describes my data, which is drawn from the U.S. Natality Detail Files, while Section 1.4 presents my estimation strategy. Section 1.5 presents my findings, and Section 1.6 concludes the paper.

[2] This is based on an average of 360 infant deaths per year among "high-risk" pregnancies in the pre-policy treated group.

1.2 Background

1.2.1 The Clean Air Interstate Rule (CAIR)

The Clean Air Interstate Rule (CAIR) was adopted in March 2005 by the U.S. Environmental Protection Agency (EPA) in order to enforce the ‘good neighbor’ provision in the longstanding Clean Air Act. Specifically, section 110(a)(2)(D)(i)(I) of the Clean Air Act requires each state to prohibit emissions that will “contribute significantly to non-attainment in, or interfere with maintenance by, any other state” with respect to any National Ambient Air Quality Standards (NAAQS). Many counties in the eastern United States were failing the 1997 NAAQS set out by the EPA because of trans-boundary emissions travelling from coal fired power plants in upwind states. Both sulphur dioxide (SO_2) and oxides of nitrogen (NO_x) emitted from power plants contribute to the formation of fine particulates. Physiologically, this particulate matter ($PM_{2.5}$) can harm health through brief exposure to high concentrations, as well as long-term exposure to moderate levels.[3] The EPA claims that power plant emission abatement improves health by reducing premature deaths, nonfatal heart attacks, hospital and emergency room visits, acute bronchitis, upper and lower respiratory symptoms, aggravated asthma, and lost works days or school absences. These results were presented in the Mercury Study Report to Congress (EPA, 1997) and the Utility Air Toxics Report to Congress (EPA, 1998). These reports indicated that coal fired power plants were the nation’s largest source of mercury air emissions and particulate matter. The reports mainly focus on mercury air emissions and proceed to qualitatively discuss the potential benefits of also reducing SO_2 and NO_x emissions. Unlike past reports this study is able to shed light on the direct causal effect of reducing SO_2 and NO_x emissions on infant health outcomes.

[3] $PM_{2.5}$ stands for particulate matter that is smaller than or equal to 2.5 micrometers in diameter.

Since the ‘good neighbor’ provision in the Clean Air Act was vague (and largely thought to be ineffective), the EPA implemented the CAIR which specified emission “budgets” for each state in an effort to lower power plant emissions of SO_2 and NO_x, which are the major precursors to potentially health harming particulate pollution. Specifically, the EPA used a “fuel factor” approach to establish regional budgets that are further divided into state budgets for annual and seasonal NO_x emissions.[4] The SO_2 emission budgets were based on the Acid Rain Program 1998 Reallocation of Allowances with a 50 percent reduction by 2010 and a 65 percent reduction by 2015 (EPA, 2005). In addition to banking features, the EPA also administered an interstate trading program for SO_2 and NO_x allowances. This allowed states to emit more or less than their specified emission budget, which was calculated based on air quality modeling by the EPA.

Immediately, the state of North Carolina filed legal proceedings against the EPA. North Carolina successfully argued that the interstate trading program was inconsistent with the CAIR as it allowed contributors of downwind violations to continue polluting by purchasing emission allowances from other states. The court’s decision led to a virtual collapse of the emission trading market and states were forced to stay within their emission budgets which acted as caps on state-specific emissions (Schmalensee and Stavins, 2013). Although states were able to cap and trade prior to the court’s decision, there was still a significant reduction in power plant emissions prior to the collapse of the emission trading market. In 2008, the D.C. Circuit Court of Appeals decided the CAIR should be eliminated, but it would stay in effect until the EPA could create a new mandate to better enforce the ‘good neighbor’ provision. In 2011 the Cross-State Air Pollution Rule was created as the CAIR’s replacement, however, it too was subject to

[4]These NO_x emission budgets were derived by analyzing 1999 through 2002 average heat input and emissions for each fuel type, in each state.

numerous court proceedings causing the CAIR to remain in effect through 2014. Therefore, although the CAIR was bombarded with numerous court proceedings, its caps remained binding from March 2005 until it was replaced in January 2015. I evaluate the corresponding reduction in fine particulate matter due to the CAIR using data from 1995 to 2013.

1.2.2 Existing Studies on Air Pollution and Infant Health

Existing studies have shown a clear association between pollution and poor health outcomes in infants (see DeRegnier and Desai, 2010; Engle, 2010; Evans, 2006; Walker et al., 2011). These associations are consistent with medical evidence which implies a fetus is especially vulnerable to pollutants since it has not fully developed (Perera et al., 1999). Studies that attempt to move beyond statistical association also find evidence of a link between various forms of pollution and birth and longer run outcomes. For example, recent work finds that babies exposed in-utero to carbon monoxide (CO) levels below the EPA standard have shortened gestation length at birth and weigh less than their unexposed siblings (Currie and Neidell, 2005; Currie et al. 2009). Several additional studies also find that exposure to various forms of pollution at birth negatively affects future outcomes such as education and earnings.[5] Almond, Edlund, and Palme (2009) show that low levels of radiation, thought to be harmless, in-utero reduced mathematics test scores for exposed children. Rauch and Lanphear (2012) argue that disabilities such as asthma, autism, and attention deficit hyperactivity disorder (ADHD) might be growing due to persistent low levels of pollution.

A seminal paper by Chay and Greenstone (2003a) was the first to credibly suggest a causal effect of air pollution on infant health. These authors find that counties forced to comply

[5] See Almond and Currie (2010) for a detailed review.

with the U.S. Clean Air Act of 1970 resulted in roughly 1,300 fewer infant deaths in 1972. At the time, the EPA focused on limiting total suspended particulates with diameters less than or equal to 100 micrometers; in 1987 federal regulation shifted to particulates with diameters less than or equal to 10 micrometers, and since 1997 has raised its standards to focus on particulates with diameters less than or equal to 2.5 micrometers. Interestingly, one study examined the closure and reopening of a steel mill in Utah in the 1980s. Parker et al. (2008) observed preterm births decline with the closure and then resurge when the mill reopened, suggesting that airborne particulates affect fetal development before birth. Additionally, Currie et al. (2015) examined the opening and closures of more than 1,600 industrial plants from five large states between 1989 and 2003. They find living within a mile of these toxic plants increases the incidence of low birth weight by three percent. While these toxic chemicals affect air quality within one mile, this differs substantially from particulate matter, which can affect air quality several hundred miles away from its source.

In addition to examining the effect of in-utero exposure to power plant emissions on shortened gestational length and birth weight among all newborns, it is important to observe health outcomes among full-term births because it allows for separation of the effect of in-utero exposure to power plant emissions on slowed fetal growth from low birth weight due to being born premature. To address this issue, some studies have included birth weight among full-term babies as a separate outcome variable.[6] Most similar to our study is Yang and Chou (2016) who examine one large power plant contributing to downwind violations of the 1997 $PM_{2.5}$ NAAQS on another state. In particular, they examine the impact of a single power plant in Pennsylvania on the border of New Jersey. Yang and Chou (2016) find that prenatal exposure to this power

[6] Some examples are Dugandzic et al. (2006), Lin et al. (2004), Maisonet et al. (2001) and Wang et al. (1997).

plant's emissions resulted in slow fetal growth among full-term births. They stress the significance of focusing on full-term births to disentangle the effect of power plant emissions on shortened gestational length versus slowed fetal growth. I share their concern in my empirical work and in addition to examining low birth weight among full-term babies, I also examine other health outcomes, such as Apgar scores, and infant mortality, as well as examining the effect of air particulates on premature births. Moreover, Yang and Chou (2016) focus on one large air-polluting power plant with a large reduction in airborne particulates, whereas I analyze the larger-scale effect of the CAIR on infant health.

Another important reason to study low birth weight in full-term births is because there is evidence of far-reaching deleterious consequences in later life, even for these full-term children. Caudri et al. (2007), for example, find that low birth weight full-term babies have significantly higher risks of developing respiratory symptoms as a child than low birth weight babies that were premature. The authors note that this can be explained by intrauterine growth disturbances in lung development, as opposed to low birth weight caused by shortened gestation length. Moreover, Wiles et al. (2005) find evidence of psychological distress in adults born at full-term with low birth weight, but not in preterm births with low birth weight. These authors link impaired neurodevelopment due to a disturbance in fetal growth with adult mental health issues rather than low birth weight per se.

1.3 Data

1.3.1 Vital Statistics

My primary data come from the United States Linked Birth and Infant Death Records from 1995-2013 for all nineteen eastern states named in CAIR***;*** please see footnote 10 for the actual states. These data include virtually all infant deaths under one year of age linked to exceptionally detailed birth certificate data.[7] Given that the CAIR designated areas at the county level, I aggregate to the county-year level in order to analyze the effect the CAIR's non-attainment designation had on infant health outcomes. With this linked dataset, I am able to examine infant mortality (i.e. death within first year of life) expressed as a county-year proportion, as well as other infant health outcomes. For example, I examine the proportion of babies at the county-year level with a gestational length less than 37 weeks, which is traditionally characterized as a premature birth. I also examine the proportion of babies at the county-year level that are considered to have low and very low birth weight, which are categorized as a birth weight below 2,500 grams, and less than 1,500 grams, respectively**,** as well as the proportion of babies at the county-year level with an Apgar score under 9.[8]

Explanatory variables include standard demographic variables such as race, mother's education, marital status, and age indicators, all defined at the county-year level. In addition to demographic variables about the mother, I also include characteristics about her pregnancy in some models. For example, I account for the proportion of women that smoked during pregnancy as well as the average number of prenatal health care visits. Moreover, I incorporate a dummy variable that indicates a patient's "riskiness", defined as a mother suffering from any of the following conditions during their pregnancy: diabetes, chronic hypertension, pregnancy hypertension, or eclampsia.[9] Other controls include the proportion of women having a first

[7] Around only two percent of infant deaths that occur in the United States cannot be linked to birth certificates.
[8] An Apgar score is a measure from zero to ten that quickly summarizes the health of a baby. It stands for Appearance, Pulse, Grimace, Activity, and Respiration.
[9] Diabetes is a metabolic disease in which the body's inability to produce any or enough insulin causes elevated levels of glucose in the blood. Chronic hypertension is defined as a long-term condition of having blood pressure greater than 140/90 mm Hg. Pregnancy hypertension is the development of new hypertension in a pregnant woman after 20 weeks gestation without the presence of protein in the urine or other signs of pre-eclampsia. Eclampsia is a

child, baby's sex, and whether the baby was born on the weekend, since descriptive research has shown that babies born on weekends experience worse health outcomes (Palmer et al., 2015). I exclude multiple births because there is evidence that these babies experience lower birth weight, as well as other unfavorable health outcomes (Blondel et al., 2002) and since there is no reason to suspect that the incidence of multiple births is related to exposure to fine particulate matter. Instead I examine the health outcomes of singleton births, which account for around 96 percent of live births in the United States.

1.3.2 County Designations

As of December 2004, prior to implementation of the CAIR, the EPA compiled a list of counties that were designated in violation of the 1997 $PM_{2.5}$ NAAQS based on air monitor site readings. Specifically, the 1997 $PM_{2.5}$ NAAQS were: (1) 15 $\mu g/m^3$ – annual arithmetic mean of 24-hour averaged concentration readings, averaged over three years; and (2) 65 $\mu g/m^3$ – annual 98th percentile of 24-hour averaged concentration readings, averaged over three years. These 172 counties, which span 19 states, were listed as non-attainment areas that had unhealthy levels of fine particles from upwind states' coal fired power plant emissions. The EPA also classified 72 counties where a portion of the county was designated non-attainment, as well as 7 counties that could not be classified. By default, all other counties in the CAIR region are considered "attainment" counties, though I exclude these 79 counties that are either partly designated non-attainment or unclassified from my sample.[10] I thus treat non-attainment counties as those

condition in which one or more convulsions occur in a pregnant woman suffering from high blood pressure, often followed by coma and posing a threat to the health of both mother and baby.

[10]There are 1,191 of these attainment counties. Included states are Alabama, Connecticut, Delaware, Georgia, Illinois, Indiana, Kentucky, Maryland, Michigan, Missouri, Montana, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia.

potentially affected by the CAIR, and hence classify them as treated counties, while the attainment counties serve as controls.

1.3.3 Additional Data

In addition to a host of individual level characteristics, I also include two key aggregate level controls which prior work suggests might be strong predictors of birth outcomes. First, I control for annual county-level unemployment rates from the labour force data collected by the Bureau of Labour Statistics. It is important to control for business cycle fluctuations as studies have shown that they affect health outcomes. For example, Dehejia and Lleras-Muney (2004) find evidence that economic conditions, as proxied by unemployment rates, affect birth outcomes including birth weight, congenital malformations, and infant mortality. Perhaps even more relevantly, Chay and Greenstone (2003b) find that infant mortality declined during the 1982 recession due to the closure of many polluting power plants. Since economic fluctuations and pollution changes can occur simultaneously (making it difficult to disentangle effects), it is important to account for both since they can each affect birth outcomes independent of the other. Prior research has also shown that cigarette smoking and tobacco-related policies can impact outcomes like birth weight and premature birth (Evans and Ringel, 1999; Eibner and Evans, 2005). As a result, I include the annual state cigarette tax rate collected by the U.S. Department of Treasury's Alcohol and Tobacco Tax Trade Bureau to reduce the possibility that cigarette tax increases contemporaneous with the CAIR are responsible for my estimates. Tables 1.1 and 1.2 display all summary statistics separated by policy period and treatment group for all singleton births, and all full-term singleton births, respectively.

1.4 Empirical Strategy

I employ a difference-in-differences model with county and year fixed effects. The following model is estimated:

$$(1)\ A_{ct} = \beta_0 + COUNTY_c + YEAR_t + \beta_1(NONATTAINMENT_c * POLICY_t) + \beta_2 POLICY_t + \beta_3 X_{ct} + \beta_4 P_{ct} + \beta_5 S_{ct} + \varepsilon_{ct}$$

Here, A_{ct} represents the various infant health outcomes I examine at the county-year level, with *c* representing county and *t* representing year. All models include county fixed effects, $COUNTY_c$, as well as year fixed effects, $YEAR_t$. Since non-attainment counties experienced larger average reductions in SO_2 and NO_x driven fine particulate pollution, my main variable of interest is the interaction of a dummy which indicates whether a county is non-attainment ($NONATTAINMENT_c$) with the period over which the CAIR policy was binding ($POLICY_t$). The coefficient on this interaction term (i.e. β_1) will yield the causal effect of these CAIR-induced particulate reductions to the extent that attainment counties experience identical secular trends in birth outcomes. I also include the variable $POLICY_t$ separately, but do not include the variable $NONATTAINMENT_c$ because the constant variable is collinear with the county fixed effects already included. X_{ct} and P_{ct} represent characteristics of mothers and their pregnancies at the county-year level, respectively. S_{ct} includes controls for the annual state cigarette tax rate, as well as the annual county unemployment rate for reasons discussed in section 3.3. Lastly, standard errors are clustered at the county level to match the level of variation created by the EPA's non-attainment designation classification system.

That said, the computation of appropriate standard errors is likely to be more complicated. White (1984) implied that the cluster robust variance estimator is consistent when: the number of clusters goes to infinity, the within-cluster error correlations are the same for all clusters, and each cluster contains an equal number of observations. Angrist and Pischke (2008) suggested that 42 clusters are large enough for reliable inference, however, MacKinnon and Webb (2017) find that is not the case when the clusters are not equal-sized. Generally, state and county sizes vary greatly. Therefore, Bertrand, Duflo and Mullainathan (2004) use data averaged over state-year pairs to address this concern. By aggregating my data to the county-year level I am able to also impose White's (1984) third assumption of equal-sized clusters. Although clustering at the county level seems to be sufficient, in order to ensure the reliability of my standard errors, a wild cluster bootstrap procedure, as proposed by Cameron, Gelbach and Miller (2008), will also be estimated on all statistically significant results.

I begin by estimating the effect of the CAIR on the proportion of premature births, low birth weight, very low birth weight, low Apgar scores, and infant mortality for all singleton births in the sample. Then I estimate all the above mentioned infant health outcomes, except premature births, for full-term singleton babies. Since premature babies generally weigh less because they have less time for intrauterine growth, it is unclear how much of any observed low birth weight is attributed to a lack of time in-utero, or due to slow fetal growth. By analyzing full-term babies I provide stronger evidence that slow fetal growth is attributed to prenatal exposure to power plant emissions. Using a difference-in-differences model relies on the strong assumption of parallel trends between the treatment and control groups in the pre-policy period. Figures 1.1 through 1.4 provide evidence that the parallel paths assumption is maintained for the infant health outcomes that show signs of improvement once the CAIR is implemented.

After estimating the model on all singleton and all full-term singleton births in the sample, I perform sub-sample analyses by mother's education, age, riskiness of the pregnancy as defined earlier, the gender of the baby, and season of birth. By re-estimating equation (1) for each sub-sample, I am better able to evaluate which groups experience the greatest health impact from the CAIR-induced fine particle emissions reduction, as past research stresses heterogeneous responses from the same level of pollution (e.g. Currie et al., 2013; and Nilsson, 2009). Moreover, Yang and Chou (2016) find full-term male babies suffer from lower birth weight caused from $PM_{2.5}$ more than full-term female babies, while other work finds that the risk of infant mortality due to carbon monoxide (CO) is greater for babies whose mothers smoked cigarettes during pregnancy (Currie et al. 2009).

In addition to examining heterogeneous effects based on characteristics of the mother and pregnancy, I will also examine if the season of birth has an interactive effect with the CAIR. Research examining electricity emissions in the eastern U.S. from 2003 to 2014 observed that power plants released 3.35 percent more SO_2 and 3.60 percent more NO_x on average per degree Celsius increase in temperature (Abel et al., 2017). They find states with more coal fired power plants such as Ohio and Pennsylvania released the most electricity-related SO_2 emissions in the summer. Since hotter temperatures increase power plant emissions it is important to examine if the decline in power plant emissions has an interactive effect with the seasons.

1.5 Results

Table 1.3 displays a progression of equation (1) by starting with Model A, then including pregnancy characteristics in Model B, and finally including controls for cigarette tax and unemployment rates in Model C. Model C is the final specification that will be used for Tables 1.4-1.6 with varying sub-samples. The main variable of interest is the interaction term of non-attainment counties with the CAIR policy. From the first row in Table 1.3 we see that although the interaction term is not statistically significant in Model A it is very close to the 10 percent level, with a p-value of 0.125. Model B and C are closer in value with statistically significant coefficients on the interaction term of -0.1761 and -0.1652, respectively.[11] The complete model, Model C, translates to a 1.6 percent drop in premature births for non-attainment counties after the CAIR is enacted.

Table 1.4 follows the same specification as Model C in Table 1.3 now examining all other birth outcomes for singleton newborns. The effect on low birth weight status and very low birth weight status is statistically significant, whereas there is no statistically significant effect for low Apgar scores or infant mortality. My estimates imply the CAIR lead to about a 1.5 and 2.4 percent drop for the proportion of low and very low birth weight for all singleton births, respectively. As discussed in previous sections, low birth weight from all singleton births could also be attributed to shorter gestational length. Thus, Table 1.5 addresses this concern by limiting the sample to full-term singleton births. Here we see that the CAIR did, in fact, have a statistically significant effect on the birth weight of full-term singleton births. The -0.0546 coefficient on the interaction of non-attainment counties with the CAIR policy translates to a 2.2 percent drop in the proportion of full-term babies with low birth weight. This implies that exposure to fine particulate matter slowed intrauterine growth as well. Note, however, that if the CAIR indeed induced fewer premature births, this may cause a compositional change in the health of full-term infants. In particular, the set of full-term infants may now include more babies just above low birth weight cutoffs. If this selection issue is present it would tend to weaken my results, biasing them against finding a relationship between implementation of the CAIR and infant health outcomes.

[11] All coefficients and standard errors in this paper are multiplied by 100.

Table 1.6 examines the CAIR effect on birth outcomes by different sub-samples of interest. Every coefficient is from a separate regression. The first three outcomes are for singleton births, while the last column focuses on full-term singleton births. The first row repeats the results from the interaction of non-attainment counties with the CAIR policy from the previous tables discussed in this section. The rest of the rows estimate the same model but sub-sampling by education, riskiness of pregnancy, age, and sex of the baby. Surprisingly, I find high school dropouts are statistically unaffected by the CAIR in comparison to mothers with higher levels of education. When examining mothers categorized with a "risky" pregnancy versus those that are not, I find that there is a stronger effect for all the outcomes in Table 1.6 for those with a "risky" pregnancy. Also, infants whose mothers are categorized with a "risky" pregnancy are the only group to illustrate a statistically significant effect on infant mortality. There is a 16 percent reduction in infant mortality for babies of "risky" pregnancies.[12] This follows a literature that suggests that improvements in air pollution are greater for infants already at risk of poor birth outcomes (Currie, 2013).

When I estimate my model separately by child gender, I find stark differences. Recent literature on the effect of pollution on full-term births finds that boys are more vulnerable than girls (Yang and Chou, 2016). My estimates are consistent with this finding, which also pertains to fine particular matter; full-term singleton males experience a 3.8 percent drop in the proportion of males with low birth weight, while the estimate for full-term singleton females is statistically insignificant. However, when expanding to all singleton births, it is evident that it is females that are more positively affected by the policy intervention. In particular, while there is a 1.5 percent drop in the proportion of premature males, females experience a 3.3 percent drop in

[12] The coefficient is -0.104, the standard error clustered at the county level is 0.048, and the p-value is 0.032.

their premature proportion. Also when examining the incidence of low and very low birth weight among singleton babies, female babies experience statistically significant improvements. However, given the baby is full-term, I find that male babies experience an increase in birth weight, demonstrating an improvement in intrauterine growth due to lower power plant emissions. My estimates imply that roughly 730 and 1360 premature births will be averted per year for male and female babies in non-attainment counties, respectively.[13] Furthermore, my estimates imply over 300 full-term singleton male babies per year will not be classified as low birth weight due to the reductions in power plant emissions from upwind counties.

In addition to robustness checks on my point estimates, which I present below, I also make efforts to ensure proper variance computation. In particular, I implement the Wild Cluster Bootstrap on all statistically significant results in Table 1.6. I find that all such results maintain significance with only slight changes in corresponding p-values for two regressions. The p-value for low birth weight full-term singleton babies increases from 0.097 to 0.120, while the p-value for premature baby boys increases from 0.089 to 0.130. Although these standard errors fall outside the conventional bounds of ten percent significance, once the Wild Cluster Boostrap is implemented, they are marginally significant and still imply the existence of a relationship. Given their close correspondence, the standard errors clustered at the county level in Table 1.6 seem to be valid.

Table 1.7 examines the effect of the CAIR sub-sampled by season of birth. First, we observe that births in models which include data from all seasons experience fewer premature births. Specifically, for fall and winter we see this translate into higher birth weight by fewer

[13] The corresponding effect size from Table 1.6 is multiplied with the number of premature births by gender that occurred in the pre-policy period for non-attainment counties. That number was then divided by the number of years in the pre-policy period to provide a rough estimate of the number of premature births averted per year.

births being categorized as low and very low birth weight. However, when examining full-term low birth weight the fall and winter estimates are no longer statistically significant, illustrating that the improvement in birth weight is channelled through a longer gestational period. Interestingly, when examining the effect of reduced power plant emissions on full-term low birth weight, I find that births that occurred in the summer months experienced the largest, statistically significant, effect. In particular, six percent fewer full-term summer births were categorized as low birth weight. Thus, the CAIR appears to have led to improved intrauterine growth due to reduced power plant emissions on summer births, which are more likely to suffer from increased power plant emissions as observed by Abel et al. (2017).

Finally, in Table 1.8, I conduct a robustness check by creating a placebo test for my main findings. A group of control counties are randomly assigned as "nonattainment" counties to construct a treated placebo group. In Table 1.8, each coefficient is the policy's effect from a separate linear regression model with county fixed effects, year fixed effects, and all other explanatory variables equivalent to Table 1.3 (Model C) and Table 1.4. The results are all statistically insignificant and the coefficients are not in the correct direction. The p-values are also very large, relative to my main findings.

1.6 Conclusion

This paper is the first to examine the full effect of the CAIR on infant health outcomes, including prematurity, low birth weight status and infant mortality. My findings indicate that the reduction of emissions from neighbouring power plants associated with the CAIR has reduced the proportion of newborns that are premature and low birth weight. This suggests two primary implications: first, even at the considerably small size of 2.5 micrometers in diameter, fine particulates can impact infant health outcomes, and they may do so differentially by child gender. Second, since numerous studies link premature birth and low birth weight with negative outcomes later in life (see Bhutta et al., 2002; Johnson and Schoeni, 2007), my findings suggest that the CAIR may lead to even greater long-run health improvements than what I find in this study. It is, therefore, essential that debate over environmental policies, like CAIR, include discussion of potential benefits to infant health, like those found in this study.

1.7 References

Abel, D., Holloway, T., Kladar, R. M., et al. 2017. "Response of Power Plant Emissions to Ambient Temperature in the Eastern United States." *Environmental Science and Technology, 51*, 5838-5846.

Almond, D., & Currie, J. 2010. "Human capital development before age five." In The handbook of labour economics, 4b (pp. 1315–1486). Amsterdam, the Netherlands: Elsevier.

Almond, D., Edlund, L., & Palme, M. 2009. "Chernobyl's subclinical legacy: Prenatal exposure to radioactive fallout and school outcomes in Sweden." *Quarterly Journal of Economics, 124*, 1729– 1772.

Angrist, J. D., & Pischke, J. S. 2008. "Mostly Harmless Econometrics: An Empiricist's Companion." Princeton: Princeton University Press.

Bertrand, M., Duflo, E., & Mullainathan, S. 2004. "How much should we trust differences-in differences estimates?" *Quarterly Journal of Economics, 119*, 249-275.

Bhutta A. T., Cleves M. A., Casey P. H., et al. 2002. "Cognitive and Behavioural Outcomes of School Aged Children Who Were Born Preterm: A Meta-analysis." *Journal of the American Medical Association, 288,*728-737.

Blondel, B., Kogan, M. D., Alexander, G. R., et al. 2002. "The impact of the increasing number of multiple births on the rates of preterm birth and low birthweight: an international study." *American Journal of Public Health, 92,*1323-1330.

Cameron, A. C., Gelbach, J. B., & Miller, D. L. 2008. "Bootstrap-based improvements for inference with clustered errors." *Review of Economics and Statistics, 90*, 414-427.

Caudri, D., Wijga, A., Gehring, U., et al. 2007. "Respiratory Symptoms in the First 7 Years of Life and Birth Weight at Term." *American Journal of Respiratory and Critical Care Medicine, 175*, 1078-1085.

Chay, K. Y., & Greenstone, M. 2003a. "Air quality, infant mortality, and the Clean Air Act of 1970." (NBER Working Paper No. 10053). Cambridge, MA: National Bureau of Economic Research.

Chay, K. Y., & Greenstone, M. 2003b. "The impact of air pollution on infant mortality: Evidence from geographic variation in pollution shocks induced by a recession." *Quarterly Journal of Economics, 118*, 1121–1167.

Currie, J. 2013. "Pollution and Infant Health." *Child Development Perspectives, 7*, 237-242.

Currie, J., Davis, L., Greenstone, M., & Walker, R. 2015. "Environmental Health Risks and Housing Values: Evidence from 1,600 Toxic Plant Openings and Closings." *American Economic Review*, *105*, 678-709.

Currie, J., Graff-Zivin, J., Meckel, K., Neidell, M., & Schlenker, W. 2013. "Something in the water: Contaminated drinking water and infant health." (NBER Working Paper No. w18876). Cambridge, MA: National Bureau of Economic Research.

Currie, J., & Neidell, M. 2005. "Air pollution and infant health: What can we learn from California's recent experience?" *Quarterly Journal of Economics*, *125*, 1003–1030.

Currie, J., Neidell, M., & Schmeider, J. F. 2009. "Air pollution and infant health: Lessons from New Jersey." *Journal of Health Economics, 28*, 688–703.

Dehejia, R., & Lleras-Muney, A. 2004. "Booms, busts, and babies' health." *Quarterly Journal of Economics, 119*, 1091-1130.

DeRegnier, R., & Desai, S. 2010. "Bioecological risks—Fetal development." In J. G. Bremner & T. D. Wachs (Eds.), Wiley-Blackwell handbook of infant development (Vol. 2, 2nd ed., pp. 9-32.). Malden, MA: Blackwell.

Dugandzic, R., Dodds, L., Stieb, D., & Smith-Doiron, M. 2006. "The Association between Low Level Exposures to Ambient Air Pollution and Term Low Birth Weight: A Retrospective Cohort Study." *Environmental Health, 5*, 3.

Eibner, C., & Evans, W. N. 2005. "Relative deprivation, poor health habits, and mortality." *Journal of Human Resources, 40*, 591-620.

Engle, P. 2010. "Infant development in the developing world." In J. G. Bremner & T. D. Wachs (Eds.), Wiley-Blackwell handbook of infant development (Vol. 2, 2nd ed., pp.9-32.). Malden, MA: Blackwell.

Environmental Protection Agency, EPA. 1997. "Mercury Study Report to Congress. Office of Air Quality Planning and Standards." EPA-452/R-97-003.

Environmental Protection Agency, EPA. 1998. "Study of Hazardous Air Pollutant Emissions from Electric Utility Steam Generating Units – Final Report to Congress (Utility Air Toxics Report)." Office of Air Quality Planning and Standards. EPA-453/R-98-004.

Environmental Protection Agency, EPA. 2005. "Regional and State SO_2 and NO_x Emissions Budgets. Technical Support Document for the Clean Air Interstate Rule Notice of Final Rulemaking." EPA Docket: OAR 2003-0053.

Evans, G. W. (2006). "Child development and the physical environment." *Annual Review of Psychology, 57*, 423–451.

Evans, W. N., & Ringel, J. S. 1999. "Can higher cigarette taxes improve birth outcomes?" *Journal of Public Economics, 72*, 135-154.

Johnson, R. C., & Schoeni, R. F. 2007. "The Influence of Early-Life Events on Human Capital, Health Status, and Labour Market Outcomes Over the Life Course." National Poverty Center Working Paper Series #07-05.

Lin, C., Li, C., Yang, G., & Mao, I. 2004. "Association between Maternal Exposure to Elevated Ambient Sulfur Dioxide during Pregnancy and Term Low Birth Weight." *Environmental Research, 96*, 41-50.

MacKinnon, J. G., & Webb, M. D. 2017. "Wild bootstrap inference for wildly different cluster sizes." *Journal of Applied Econometrics, 32*, 233-254.

Maisonet, M., Bush, T., Correa, A., & Jaakkola, J. 2001. "Relation between Ambient Air Pollution and Low Birth Weight in the Northeastern United States." *Environmental Health Perspectives*, *109*, 351-356.

Nilsson, P. 2009. "The long-term effects of early childhood lead exposure: Evidence from the phase-out of leaded gasoline." (IFAU Working Paper). Uppsala, Sweden: Institute for Labour Market Policy Evaluation.

Palmer, W., Bottle, A., & Aylin, P. 2015. "Association between day of delivery and obstetric outcomes: observational study." *British Medical Journal*, *351*, h5774.

Parker, J., Mendola, P., & Woodruff, T. 2008. "Preterm birth after the Utah Valley steel mill closure: A natural experiment." *Epidemiology*, *19*, 820–823.

Perera, F. P., et al. 1999. "Molecular epidemiologic research on the effect of environmental pollutants on the fetus." *Environmental Health Perspectives*, *107*, 451–460.

Rauch, S. A., & Lanphear, B. P. 2012. "Prevention of disability in children: Elevating the role of environment." *The Future of Children, 22*, 193–209.

Schmalensee, R., & Stavins, R. 2013. "The SO_2 Allowance Trading System: The Ironic History of a Grand Policy Experiment." *Journal of Economic Perspectives, 27*, 103-22.

Truven Health Analytics, Inc. 2013. Costs of Preterm Birth. Prepared for March of Dimes.

Walker, S., Wachs, T., Grantham-McGregor, S., Black, M., et al. 2011. "Inequality in early childhood: Risk and protective factors for early child development." *The Lancet, 378*, 1325–1338.

Wang, X., Ding, H., Ryan, L., & Xu, X. 1997. "Association between Air Pollution and Low Birth Weight: A Community-Based Study." *Environmental Health Perspectives, 105*, 514-520.

White H. 1984. Asymptotic Theory for Econometricians. Orlando: Academic Press.

Wiles, N., Peters, T., Leon, D., & Lewis, G. 2005. "Birth Weight and Psychological Distress at Age 45-51 Years: Results from the Aberdeen Children of the 1950s Cohort Study." *British Journal of Psychiatry*, *187*, 21-28.

Yang, M., & Chou, S. 2016. "Transboundary Power Plant Emissions, Fetal Health, and the U.S. EPA's Precedent-Setting Portland Rule." Working Paper: Lehigh University.

Table 1.1: Summary Statistics for all singleton births (1995-2013)

	non-attainment counties (172)		control counties (1191)	
outcome variables:	pre-policy	post-policy	pre-policy	post-policy
premature	0.101	0.108	0.107	0.115
	(0.020)	(0.021)	(0.031)	(0.034)
low birth weight	0.061	0.065	0.065	0.069
	(0.015)	(0.015)	(0.022)	(0.025)
very low birth weight	0.011	0.012	0.012	0.012
	(0.004)	(0.004)	(0.008)	(0.008)
low apgar score	0.092	0.135	0.101	0.143
	(0.035)	(0.098)	(0.040)	(0.100)
infant mortality	0.005	0.005	0.006	0.006
	(0.002)	(0.002)	(0.006)	(0.005)
# of year-county observations	1720	1543	11910	10719

Table 1.1 Continued: Summary Statistics for all singleton births (1995-2013)

	non-attainment counties (172)		control counties (1191)	
explanatory variables:	pre-policy	post-policy	pre-policy	post-policy
caucasian	0.751	0.685	0.823	0.805
	(0.201)	(0.219)	(0.197)	(0.205)
hispanic	0.072	0.114	0.034	0.057
	(0.089)	(0.108)	(0.053)	(0.072)
africanamerican	0.137	0.152	0.121	0.116
	(0.148)	(0.151)	(0.181)	(0.174)
teenager	0.106	0.086	0.149	0.121
	(0.044)	(0.036)	(0.050)	(0.044)
40+ years old	0.021	0.027	0.015	0.017
	(0.011)	(0.013)	(0.010)	(0.012)
high school dropout	0.164	0.158	0.218	0.195
	(0.072)	(0.068)	(0.083)	(0.083)
some college and higher	0.516	0.580	0.388	0.464
	(0.121)	(0.119)	(0.111)	(0.115)
married	0.699	0.621	0.666	0.582
	(0.108)	(0.111)	(0.105)	(0.106)
smoke during pregnancy	0.140	0.115	0.197	0.181
	(0.077)	(0.088)	(0.088)	(0.109)
first born	0.331	0.328	0.343	0.338
	(0.032)	(0.036)	(0.046)	(0.048)
baby boy	0.513	0.512	0.512	0.512
	(0.012)	(0.012)	(0.035)	(0.035)
risky pregnancy	0.073	0.103	0.086	0.109
	(0.023)	(0.033)	(0.034)	(0.040)
born on a weekend	0.211	0.192	0.203	0.177
	(0.024)	(0.028)	(0.039)	(0.040)
number of prenatal visits	11.681	11.171	11.712	11.481
	(1.084)	(1.043)	(1.067)	(1.085)
annual county unemployment rate	4.421	6.921	5.749	8.012
	(1.478)	(2.500)	(2.286)	(2.974)
annual state cigarette tax rate	25.153	36.004	22.200	31.433
	(7.965)	(9.465)	(8.032)	(9.314)
# of year-county observations	1720	1543	11910	10719

Note: Standard errors are in parenthesis.

Table 1.2: Summary Statistics for full-term singleton births (1995-2013)

	non-attainment counties (172)		control counties (1191)	
outcome variables:	pre-policy	post-policy	pre-policy	post-policy
low birth weight	0.025	0.027	0.028	0.031
	(0.007)	(0.008)	(0.014)	(0.016)
very low birth weight	0.0004	0.0005	0.0004	0.0005
	(0.001)	(0.001)	(0.002)	(0.002)
low apgar score	0.075	0.119	0.083	0.124
	(0.034)	(0.097)	(0.039)	(0.101)
infant mortality	0.002	0.002	0.002	0.002
	(0.001)	(0.001)	(0.004)	(0.004)
explanatory variables:				
caucasian	0.758	0.692	0.829	0.809
	(0.197)	(0.216)	(0.192)	(0.201)
hispanic	0.072	0.113	0.034	0.057
	(0.088)	(0.107)	(0.053)	(0.072)
africanamerican	0.130	0.145	0.115	0.111
	(0.142)	(0.146)	(0.175)	(0.169)
teenager	0.103	0.084	0.145	0.117
	(0.043)	(0.036)	(0.050)	(0.045)
40+ years old	0.021	0.026	0.014	0.017
	(0.011)	(0.013)	(0.011)	(0.012)
high school dropout	0.159	0.152	0.213	0.189
	(0.072)	(0.068)	(0.083)	(0.084)
some college and higher	0.523	0.590	0.394	0.474
	(0.121)	(0.120)	(0.112)	(0.117)
married	0.709	0.633	0.675	0.592
	(0.105)	(0.109)	(0.103)	(0.106)
smoke during pregnancy	0.136	0.110	0.193	0.175
	(0.075)	(0.085)	(0.088)	(0.107)
first born	0.331	0.328	0.342	0.336
	(0.032)	(0.036)	(0.048)	(0.050)
baby boy	0.510	0.510	0.509	0.510
	(0.013)	(0.013)	(0.037)	(0.038)
risky pregnancy	0.066	0.095	0.079	0.101
	(0.021)	(0.032)	(0.033)	(0.041)
born on a weekend	0.208	0.188	0.199	0.171
	(0.025)	(0.029)	(0.041)	(0.043)
number of prenatal visits	11.851	11.338	11.899	11.658
	(1.075)	(1.034)	(1.076)	(1.088)
county unemployment rate	4.421	6.921	5.749	8.012
	(1.478)	(2.500)	(2.286)	(2.974)
annual state cigarette tax rate	25.153	36.004	22.200	31.433
	(7.965)	(9.465)	(8.032)	(9.314)
# of year-county observations	1720	1543	11910	10719

Note: Standard errors are in parenthesis.

Table 1.3: Fixed Effects Model for Premature Outcome for All Singleton Births

	Model A		Model B		Model C	
Interact: nonattainment * policy	-0.1243		-0.1761	**	-0.1652	**
	(0.0809)		(0.0799)		(0.0796)	
	[0.125]		[0.028]		[0.038]	
policy	0.6854	***	0.4666	***	0.7586	***
	(0.1685)		(0.1746)		(0.1869)	
caucasian	-3.9167	***	-3.6196	***	-3.6065	***
	(0.8094)		(0.8544)		(0.8509)	
hispanic	-5.7769	***	-5.9608	***	-5.9403	***
	(1.4060)		(1.4518)		(1.4523)	
africanamerican	0.0940		-0.2875		-0.2815	
	(1.3016)		(1.3565)		(1.3531)	
40+ years old	2.7580		1.6733		1.7720	
	(2.7307)		(2.7553)		(2.7568)	
teenager	-4.8608	***	-3.8421	***	-3.8128	***
	(1.1227)		(1.1784)		(1.1777)	
some college and higher	-0.0616		-0.2736		-0.2467	
	(0.6085)		(0.6038)		(0.6028)	
high school dropout	0.1486		-0.0587		-0.0497	
	(0.8267)		(0.8218)		(0.8223)	
married	-4.7144	***	-4.9308	***	-4.9143	***
	(0.6848)		(0.6836)		(0.6858)	
smoke during pregnancy			-0.2582		-0.1656	
			(0.3593)		(0.3642)	
baby boy			1.4564	**	1.4555	**
			(0.6871)		(0.6870)	
first born			-1.8744	**	-1.8512	**
			(0.7782)		(0.7787)	
risky pregnancy			5.3732	***	5.3678	***
			(0.7977)		(0.7972)	
born on a weekend			0.2413		0.2392	
			(0.8686)		(0.8692)	
number of prenatal visits			-0.1144	***	-0.1145	***
			(0.0306)		(0.0307)	
annual county unemployment rate					0.0089	
					(0.0159)	
annual state cigarette tax rate					-0.0075	
					(0.0050)	
constant	17.3496	***	18.1210	***	18.2016	***
	(1.0726)		(1.2177)		(1.2279)	
R-squared	0.1791		0.1942		0.2079	

Note: Linear regression models include county fixed effects and year fixed effects (1995-2013). Coefficients and standard errors are multiplied by 100. Nonattainment counties are downwind of power plants. Control counties are other counties in the same states that were not designated nonattainment or partial attainment in December 2004. Premature is the proportion of babies at the county-year level with a gestational length less than 37 weeks. "Risky pregnancy" is defined as the proportion of mothers at the county-year level that have diabetes, chronic hypertension, pregnancy hypertension, or eclampsia when they begin labour. Standard errors clustered at the county level are in parenthesis. The p-value of the interaction term is in square brackets. * Significant at the 10% level; ** Significant at the 5% level; *** Significant at the 1% level.

Table 1.4: Fixed Effects Model for Infant Health Outcomes for All Singleton Births

	Low Birth Weight		Very Low Birth Weight		Low APGAR		Infant Mortality	
Interact: nonattainment * policy	-0.0917	*	-0.0274	*	0.0706		-0.0032	
	(0.0487)		(0.0164)		(0.5370)		(0.0122)	
	[0.060]		[0.095]		[0.895]		[0.793]	
policy	0.3284	**	0.2378	***	3.4386	***	0.0103	
	(0.1514)		(0.0601)		(0.5737)		(0.0453)	
caucasian	-1.6178	***	-0.4029	**	-10.8270	**	0.0027	
	(0.5158)		(0.1848)		(5.0289)		(0.1078)	
hispanic	-3.6586	***	-0.8709	***	-12.3073	*	-0.5524	***
	(0.9125)		(0.3266)		(6.9432)		(0.2101)	
africanamerican	2.0649	**	0.8529	***	-20.2565	**	0.3679	
	(0.9242)		(0.3292)		(8.0335)		(0.2244)	
40+ years old	1.4025		1.1071		-3.9812		0.4435	
	(2.2263)		(0.8312)		(5.8667)		(0.5759)	
teenager	-1.4362	*	0.1652		0.5512		0.2393	
	(0.7769)		(0.3669)		(3.0306)		(0.2370)	
some college and higher	-1.7215	***	-0.8346	***	7.5226	***	-0.2174	*
	(0.4909)		(0.1849)		(2.1260)		(0.1139)	
high school dropout	-0.3498		-1.0230	***	2.4198		-0.0841	
	(0.5744)		(0.2274)		(2.2965)		(0.1605)	
married	-2.9122	***	0.0434		-2.8194		0.0220	
	(0.4931)		(0.2132)		(1.9685)		(0.1796)	
smoke during pregnancy	0.2940		0.2306	**	-12.9641	***	0.1293	*
	(0.2665)		(0.1084)		(1.9994)		(0.0746)	
baby boy	-1.6425	***	0.3146		3.5274	**	0.5035	***
	(0.4915)		(0.2369)		(1.3923)		(0.1826)	
first born	0.0511		0.0213		-17.4319	***	-0.0846	
	(0.5031)		(0.2222)		(4.9960)		(0.1448)	
risky pregnancy	4.7088	***	0.9658	***	8.4935	***	-0.0212	
	(0.6603)		(0.2586)		(2.9088)		(0.1503)	
born on a weekend	0.2360		0.8458	***	6.3968	***	0.2590	*
	(0.7302)		(0.2515)		(2.1402)		(0.1549)	
number of prenatal visits	-0.1207	***	-0.0424	***	0.0998		-0.0192	***
	(0.0209)		(0.0084)		(0.1170)		(0.0057)	
annual county unemployment rate	-0.0143		-0.0047		0.4135	***	0.0009	
	(0.0118)		(0.0043)		(0.0524)		(0.0028)	
annual state cigarette tax rate	-0.0023		-0.0001		-0.0402	*	-0.0004	
	(0.0033)		(0.0014)		(0.0210)		(0.0009)	
constant	12.4068	***	1.8531	***	22.2930	***	0.5451	**
	(0.8296)		(0.3312)		(6.1362)		(0.2253)	
R-squared	0.3262		0.1540		0.0901		0.0477	

Note: Linear regression models include county fixed effects and year fixed effects (1995-2013). Coefficients and standard errors are multiplied by 100. Nonattainment counties are downwind of power plants. Control counties are other counties in the same states that were not designated nonattainment or partial attainment in December 2004. Low birth weight is the proportion of babies at the county-year level with a birth weight below 2,500 grams, and very low birth weight is defined as less than 1,500 grams. Low apgar is the proportion of babies at the county-year level with an apgar score under 9. "Risky pregnancy" is defined as the proportion of mothers at the county-year level that have diabetes, chronic hypertension, pregnancy hypertension, or eclampsia when they begin labour. Standard errors clustered at the county level are in parenthesis. The p-value of the interaction term is in square brackets. * Significant at the 10% level; ** Significant at the 5% level; *** Significant at the 1% level.

Table 1.5: Fixed Effects Model for Infant Health Outcomes for All Full-term Singleton Births

	Low Birth Weight		Very Low Birth Weight		Low APGAR		Infant Mortality	
Interact: nonattainment * policy	-0.0546	*	0.0018		0.2067		-0.0002	
	(0.0329)		(0.0035)		(0.5378)		(0.0077)	
	[0.097]		[0.617]		[0.701]		[0.975]	
policy	0.2715	***	0.0119		3.1176	***	-0.0095	
	(0.0947)		(0.0115)		(0.5780)		(0.0293)	
caucasian	-0.6738	**	-0.0700	**	-9.6753	**	-0.0617	
	(0.3012)		(0.0349)		(4.8809)		(0.0572)	
hispanic	-1.5582	***	-0.1096	**	-9.2344		-0.2573	**
	(0.5702)		(0.0518)		(6.8322)		(0.1083)	
africanamerican	0.6335		-0.0825		-19.2780	**	-0.0158	
	(0.5464)		(0.0588)		(7.6362)		(0.1202)	
40+ years old	0.1218		0.1970		-6.4025		0.5249	
	(1.3117)		(0.1694)		(5.9545)		(0.3627)	
teenager	-1.2782	**	0.0155		0.9380		0.0425	
	(0.5555)		(0.0693)		(2.9000)		(0.1556)	
some college and higher	-1.3450	***	-0.0360		7.1739	***	-0.0418	
	(0.2814)		(0.0331)		(1.9838)		(0.0729)	
high school dropout	0.3554		-0.0270		1.7117		0.0766	
	(0.4045)		(0.0475)		(2.1824)		(0.1023)	
married	-1.4141	***	-0.0051		-3.7048	**	0.0164	
	(0.2916)		(0.0481)		(1.8882)		(0.0970)	
smoke during pregnancy	0.3276		0.0044		-12.4434	***	0.0004	
	(0.2275)		(0.0242)		(1.9815)		(0.0529)	
baby boy	-1.6621	***	-0.0441		3.7404	***	0.1716	*
	(0.3680)		(0.0382)		(1.2689)		(0.1012)	
first born	0.9870	***	0.0484		-15.5197	***	-0.0406	
	(0.3206)		(0.0355)		(4.7785)		(0.1016)	
risky pregnancy	1.9256	***	0.0289		6.4530	**	0.0017	
	(0.5273)		(0.0446)		(2.8940)		(0.1188)	
born on a weekend	-0.8293	*	0.0126		5.8215	***	0.0677	
	(0.4379)		(0.0450)		(1.9118)		(0.1004)	
number of prenatal visits	-0.0597	***	-0.0005		0.1458		0.0036	
	(0.0162)		(0.0016)		(0.1154)		(0.0036)	
county unemployment rate	-0.0099		0.0010		0.4272	***	-0.0001	
	(0.0085)		(0.0011)		(0.0526)		(0.0021)	
state cigarette tax rate	-0.0006		0.0003		-0.0427	**	-0.0007	
	(0.0025)		(0.0003)		(0.0213)		(0.0007)	
constant	6.2161	***	0.1196	*	19.0591	***	0.1815	
	(0.4878)		(0.0691)		(5.8722)		(0.1253)	
R-squared	0.1860		0.0015		0.0987		0.0087	

Note: Linear regression models include county fixed effects and year fixed effects (1995-2013). Coefficients and standard errors are multiplied by 100. Nonattainment counties are downwind of power plants. Control counties are other counties in the same states that were not designated nonattainment or partial attainment in December 2004. Low birth weight is the proportion of babies at the county-year level with a birth weight below 2,500 grams, and very low birth weight is defined as less than 1,500 grams. Low apgar is the proportion of babies at the county-year level with an apgar score under 9. "Risky pregnancy" is defined as the proportion of mothers at the county-year level that have diabetes, chronic hypertension, pregnancy hypertension, or eclampsia when they begin labour. Standard errors clustered at the county level are in parenthesis. The p-value of the interaction term is in square brackets. * Significant at the 10% level; ** Significant at the 5% level; *** Significant at the 1% level.

Table 1.6: CAIR Effect on Infant Health Outcomes by Sub-sample

	Premature (singleton births)			Low Birth Weight (singleton births)			Very Low Birth Weight (singleton births)			Low birth weight (full-term singleton births)		
Sub-sample	Effect Size	Coef.		Effect Size	Coef.		Effect Size	Coef.		Effect Size	Coef.	
all	-0.0164	-0.1652	**	-0.0151	-0.0917	*	-0.0243	-0.0274	*	-0.0223	-0.0546	*
		(0.0796)			(0.0487)			(0.0164)			(0.0329)	
		[0.038]			[0.060]			[0.095]			[0.097]	
high school dropout	0.0055	0.0706		0.0116	0.0998		0.0553	0.0824		-0.0138	-0.0545	
		(0.2404)			(0.2088)			(0.1054)			(0.1270)	
		[0.769]			[0.633]			[0.434]			[0.668]	
high school graduate	-0.0433	-0.4702	**	-0.0664	-0.4501	**	-0.0899	-0.1145		-0.0523	-0.1485	*
		(0.1934)			(0.1884)			(0.0962)			(0.0761)	
		[0.015]			[0.017]			[0.234]			[0.051]	
some college and higher	-0.0342	-0.3016	**	-0.0435	-0.2111	*	-0.1699	-0.1583	**	-0.0074	-0.0130	
		(0.1403)			(0.1130)			(0.0758)			(0.0549)	
		[0.032]			[0.062]			[0.037]			[0.813]	
“risky” pregnancy	-0.0405	-0.7631	***	-0.0367	-0.4940	**	-0.0658	-0.2006	*	-0.0427	-0.2087	*
		(0.2564)			(0.2132)			(0.1118)			(0.1230)	
		[0.003]			[0.021]			[0.073]			[0.090]	
“non-risky” pregnancy	-0.0198	-0.1868	**	-0.0152	-0.0839	*	-0.0336	-0.0332	**	-0.0189	-0.0432	
		(0.0780)			(0.0483)			(0.0168)			(0.0332)	
		[0.017]			[0.083]			[0.048]			[0.193]	
under 20 years old	-0.0419	-0.5381	***	-0.0373	-0.3262	**	-0.0936	-0.1550	***	-0.0372	-0.1431	
		(0.1893)			(0.1310)			(0.0580)			(0.1004)	
		[0.005]			[0.013]			[0.008]			[0.154]	
20 to 29 years old	-0.0228	-0.2239	**	-0.0330	-0.1956	***	-0.0220	-0.0236		-0.0515	-0.1266	***
		(0.0933)			(0.0612)			(0.0200)			(0.0435)	
		[0.017]			[0.001]			[0.237]			[0.004]	
30 to 39 years old	-0.0528	-0.5103	***	-0.0268	-0.1476	*	-0.0797	-0.0836	**	-0.0084	-0.0173	
		(0.1161)			(0.0782)			(0.0350)			(0.0547)	
		[0.000]			[0.059]			[0.017]			[0.752]	
40+ years old	-0.0502	-0.6570	*	-0.0357	-0.2887		-0.0990	-0.1630		-0.0908	-0.2823	
		(0.3771)			(0.3100)			(0.1359)			(0.2160)	
		[0.082]			[0.352]			[0.231]			[0.191]	
baby boy	-0.0154	-0.1631	*	-0.0148	-0.0834		-0.0205	-0.0233		-0.0381	-0.0760	*
		(0.0958)			(0.0544)			(0.0219)			(0.0390)	
		[0.089]			[0.126]			[0.287]			[0.051]	
baby girl	-0.0331	-0.3155	***	-0.0251	-0.1646	***	-0.0528	-0.0589	**	-0.0214	-0.0626	
		(0.0909)			(0.0630)			(0.0261)			(0.0476)	
		[0.001]			[0.009]			[0.024]			[0.189]	

Note: Coefficients and standard errors are multiplied by 100. Each coefficient is the policy's effect from a separate linear. “Risky pregnancy” is defined as the proportion of mothers at the county-year level that have diabetes, chronic hypertension, pregnancy hypertension, or eclampsia when they begin labour. The effect size is the coefficient divided by the treatment group's pre-policy mean. Standard errors clustered at the county level are in parenthesis. The p-value of the interaction term is in square brackets. * Significant at the 10% level; ** Significant at the 5% level; *** Significant at the 1% level.

Table 1.7: CAIR Effect on Infant Health Sub-Sample by Seasons

	Premature (singleton births)			Low Birth Weight (singleton births)			Very Low Birth Weight (singleton births)			Low birth weight (full-term singleton births)		
Sub-sample	Effect Size	Coef.		Effect Size	Coef.		Effect Size	Coef.		Effect Size	Coef.	
summer	-0.0241	-0.2331	**	-0.0272	-0.1627	*	-0.0008	-0.0009		-0.0615	-0.1669	*
		(0.1067)			(0.0899)			(0.0297)			(0.0896)	
		[0.029]			[0.071]			[0.977]			[0.063]	
fall	-0.0332	-0.3367	***	-0.0486	-0.3031	***	-0.0833	-0.0964	***	-0.0372	-0.1040	
		(0.1164)			(0.0820)			(0.0338)			(0.0720)	
		[0.004]			[0.000]			[0.004]			[0.149]	
winter	-0.0345	-0.3549	***	-0.0346	-0.2138	**	-0.0667	-0.0750	**	-0.0244	-0.0679	
		(0.1171)			(0.0850)			(0.0334)			(0.0881)	
		[0.002]			[0.012]			[0.025]			[0.441]	
spring	-0.0431	-0.4406	***	-0.0217	-0.1300		-0.0412	-0.0474		0.0060	-0.0155	
		(0.1249)			(0.0866)			(0.0327)			(0.0675)	
		[0.000]			[0.133]			[0.147]			[0.819]	

Note: Coefficients and standard errors are multiplied by 100. Each coefficient is the policy's effect from a separate linear regression model with county fixed effects, year fixed effects, and all other explanatory variables. The effect size is the coefficient divided by the treatment group's pre-policy mean. Standard errors clustered at the county level are in parenthesis. The p-value of the interaction term is in square brackets. Premature is the proportion of babies at the county-year level with a gestational length less than 37 weeks. Low birth weight is the proportion of babies at the county-year level with a birth weight below 2,500 grams, and very low birth weight is defined as less than 1,500 grams. * Significant at the 10% level; ** Significant at the 5% level; *** Significant at the 1% level.

Table 1.8: Placebo Test for Infant Health Outcomes for All Singleton Births

	Premature	Low Birth Weight	Very Low Birth Weight	Low APGAR	Infant Mortality
Interact: “nonattainment” * policy	0.0456	0.0842	-0.0051	0.7243	0.0013
	(0.1285)	(0.0819)	(0.0282)	(0.8342)	(0.0213)
	[0.723]	[0.304]	[0.857]	[0.385]	[0.951]

Note: A group of control counties were randomly assigned as “nonattainment” counties to create a treated placebo group. Each coefficient is the policy's effect from a separate linear regression model with county fixed effects, year fixed effects, and all other explanatory variables equivalent to Table 3 (Model C) and Table 4. Coefficients and standard errors are multiplied by 100. Standard errors clustered at the county level are in parenthesis. The p-value of the interaction term is in square brackets. Premature is the proportion of babies at the county-year level with a gestational length less than 37 weeks. Low birth weight is the proportion of babies at the county-year level with a birth weight below 2,500 grams, and very low birth weight is defined as less than 1,500 grams. Low apgar is the proportion of babies at the county-year level with an apgar score under 9.

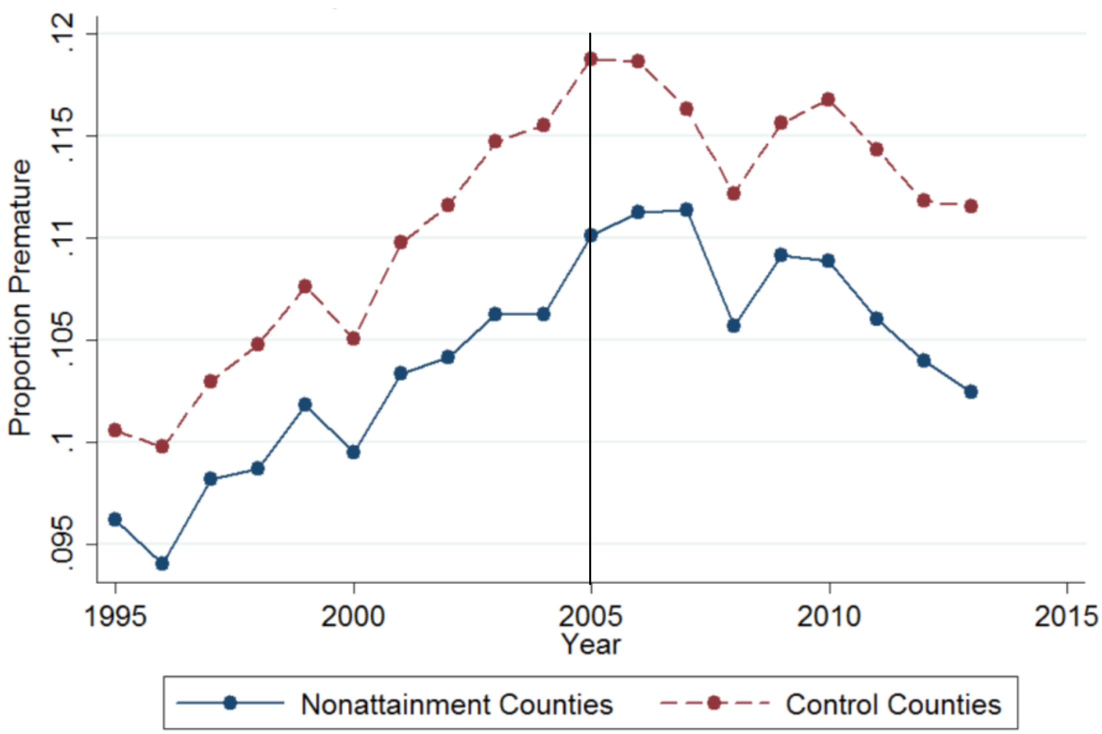


FIGURE 1.1: PROPORTION OF BABIES BORN PREMATURELY

Note: Nonattainment counties are downwind of power plants. Control counties are other counties in the same states that were not designated nonattainment or partial attainment in December 2004. Premature is the proportion of babies at the county-year level with a gestational length less than 37 weeks.

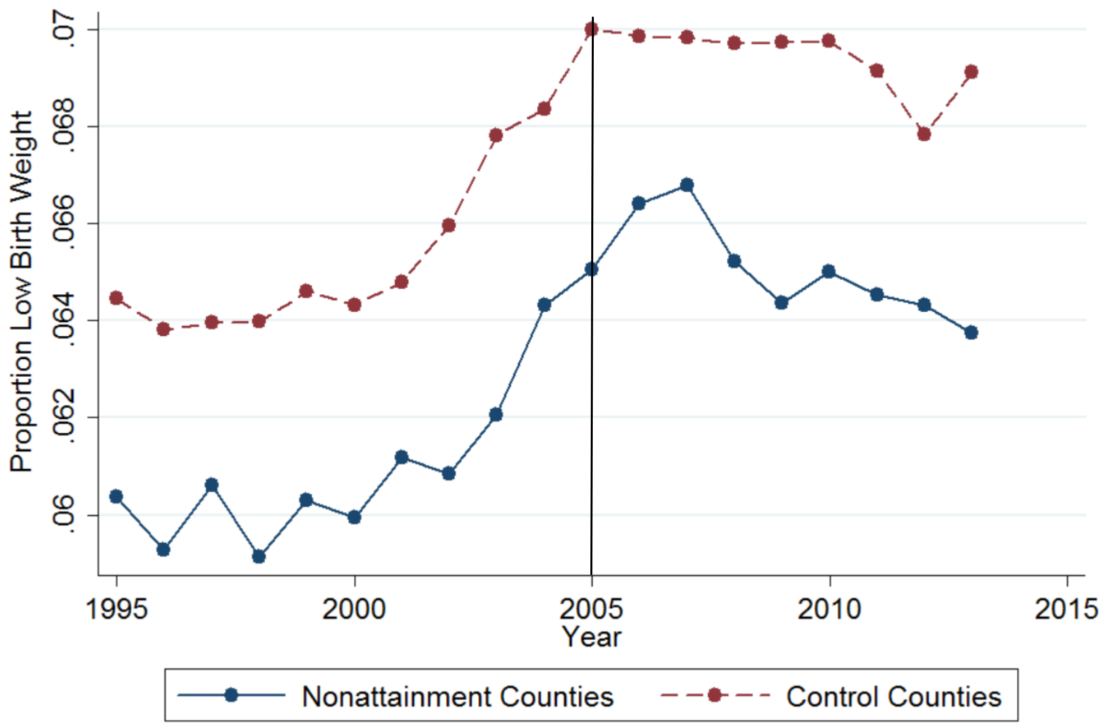


FIGURE 1.2: PROPORTION OF BABIES WITH LOW BIRTH WEIGHT

Note: Nonattainment counties are downwind of power plants. Control counties are other counties in the same states that were not designated nonattainment or partial attainment in December 2004. Low birth weight is the proportion of babies at the county-year level with a birth weight below 2,500 grams.

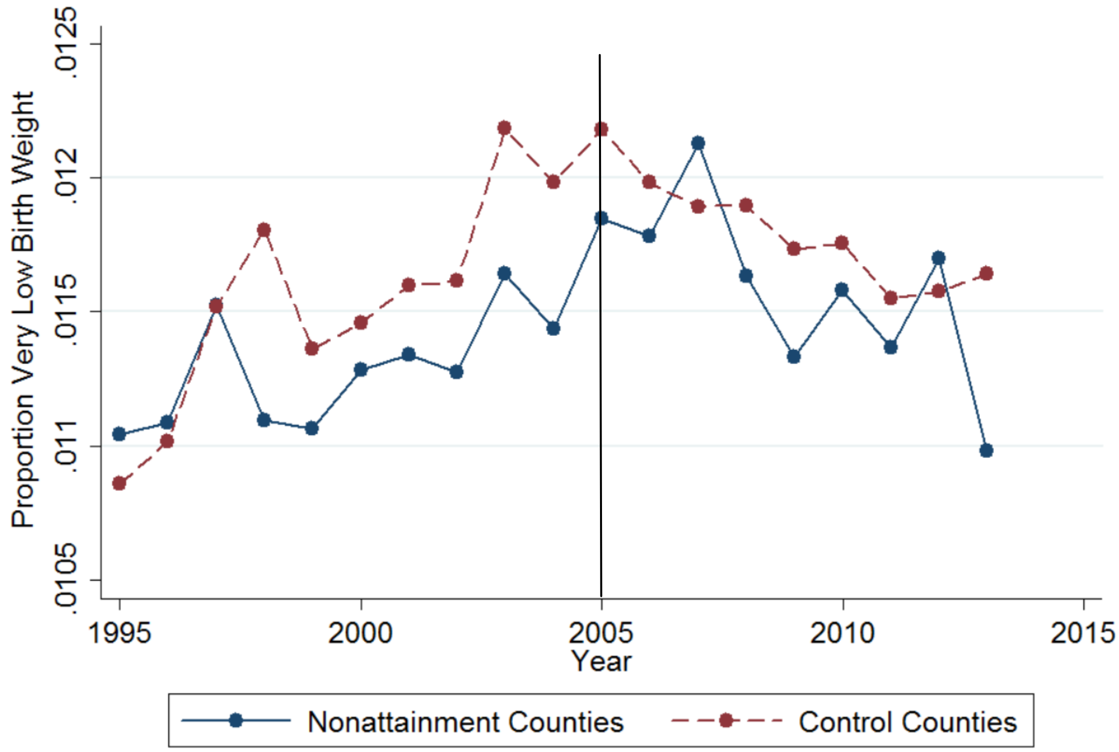


FIGURE 1.3: PROPORTION OF BABIES WITH VERY LOW BIRTH WEIGHT

Note: Nonattainment counties are downwind of power plants. Control counties are other counties in the same states that were not designated nonattainment or partial attainment in December 2004. Very low birth weight is the proportion of babies at the county-year level with a birth weight below 1,500 grams.

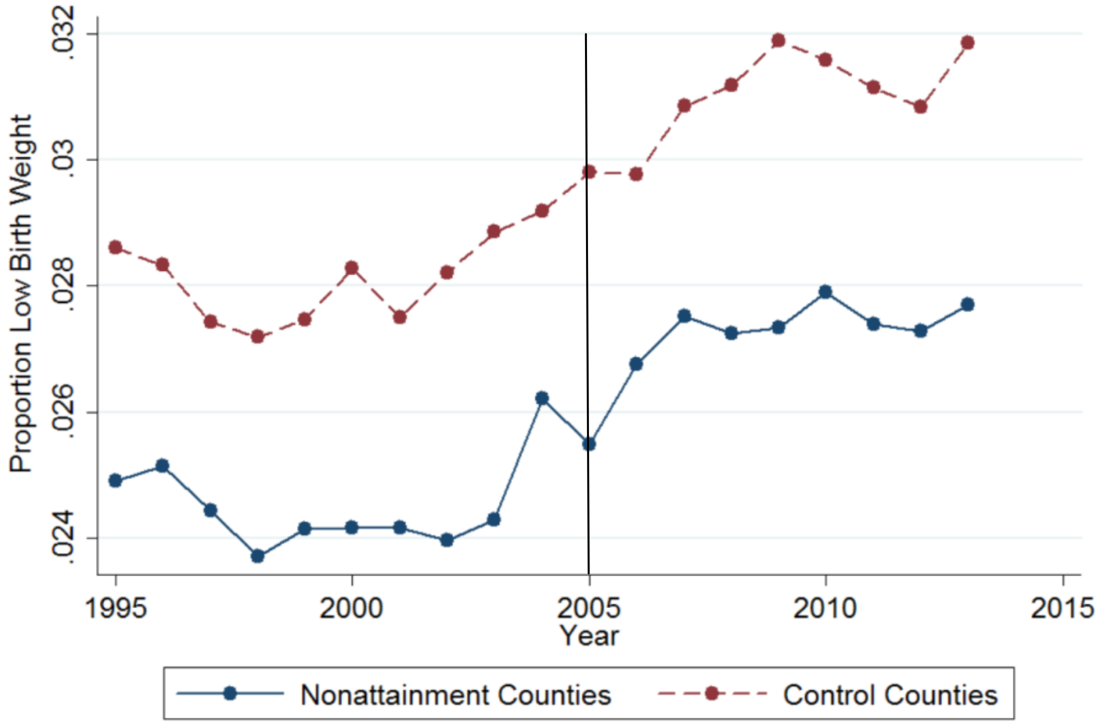


FIGURE 1.4: PROPORTION OF FULL-TERM BABIES WITH LOW BIRTH WEIGHT

Note: Nonattainment counties are downwind of power plants. Control counties are other counties in the same states that were not designated nonattainment or partial attainment in December 2004. Full-term babies have a gestational length equal to or greater than 37 weeks and low birth weight is the proportion of babies at the county-year level with a birth weight below 2,500 grams.

Chapter Two

C-Sections and Lawyers' Fees: The Effects of Contingency Fee Reform on Maternal and Infant Health

2.1 Introduction

2.1.1 Motivation

Medical malpractice fears may alter doctors' choice of procedure in high-risk specialties. Tort reform attempts to alleviate this situation by encouraging doctors to engage in less defensive medicine. On November 23rd, 2004, the state of Nevada enacted the Keep Our Doctors in Nevada (KODIN) initiative, which included tort reforms commonly enacted by states attempting to mitigate a perceived medical malpractice crisis. The American Medical Association had classified 17 other states as being in a similar situation due to both a lack of available malpractice insurers, as well as sky-rocketing insurance premiums (Mello et al., 2003). Figure 2.1 shows the 18 states that were identified as having medical malpractice crises, in addition to 26 states showing concern. The latest crisis occurred in the mid-2000s and saw many states adopt tort reforms in an effort to relieve the liability pressures on doctors. Some of the most widely studied reforms that states adopted are caps on non-economic damages (most commonly known as "pain and suffering"), and the elimination of the "joint and several" liability rule (also known as the "deep pockets" rule). Notably, one reform overlooked in the literature is limiting the contingency fees that lawyers charge their clients in medical malpractice lawsuits.

When lawyers take a case on contingency, they agree to cover all legal costs and, as payment, receive a percentage of the settlement or award if the lawsuit is successful. Prior to the reform, lawyers in Nevada commonly charged a contingency fee of around forty percent of the settlement or award in a medical malpractice case (McMurdo, 2009). With the limit on contingency fees enacted in 2004, lawyers may now only recover 40 percent of the first $50,000; 33.3 percent of the next $50,000; 25 percent of the next $500,000; and 15 percent of any amount exceeding $600,000, whether or not the case is settled in court. For example, if a client is awarded $5.75 million, prior to the reform their lawyer would receive $2.3 million as payment from the client. Once the limit on contingency fees is enacted that same lawyer would receive roughly $900,000. As I will discuss later, prior research has shown composition changes in cases litigated by attorneys once this limit is enacted. With a large potential loss in income, lawyers should now be more eager to litigate serious cases with higher payouts, leaving physicians in high-risk specialties with elevated liability fears. The KODIN initiative provides a unique case study, given that all other tort reforms were already in place with slight variation, excluding the limit on contingency fees newly introduced in Nevada, in addition to no other states having implemented a limit on contingency fees since 1989.[14]

[14]Avraham's (2014) Database of State Tort Law Reforms (5^{th}) lists the tort law reforms enacted in Nevada. This list of reforms and effective dates illustrates that although the KODIN initiative mentions many reforms, all except the limit on contingency fees is previously enacted with slight variation. Avraham details deciphering between reforms that are slightly amended versus new law changes.

When tort reforms are enacted, it is essential that their effects, especially on health outcomes of mothers and newborns, are investigated to ensure policies are serving the public's best interest. Obstetricians and gynecologists (OBGYNs), one of the most frequently sued, have been called into question on whether or not they are altering their behaviour by engaging in defensive medicine (Peckham, 2015). In a recent survey, half of obstetricians admitted to making changes to their practice as a result of the risk or fear of being sued.[15] Of those, seventeen percent reported increasing the number of C-section deliveries due to liability risks (Carpentieri et al., 2015). This paper investigates how limiting contingency fee reform affects physicians' choice of procedure in labour and delivery as well as infant health.

Numerous papers examine the effects of other medical malpractice tort reforms on physician behaviour using data from the 1980s and 1990s. One of the most widely regarded studies finds that the "joint and several" liability rule reduces procedural use of C-sections, whereas a cap on non-economic damages increases them (Currie and MacLeod, 2008). Conversely, Yang et al. (2009) find that caps on non-economic damages lower the rates of C-sections. Although papers may differ on whether tort reforms affect physicians' behaviour, the consensus is that infant health outcomes are usually unaffected by tort reform (see Currie and MacLeod, 2008; Frakes, 2012; Sloan et al., 1995; Yang et al., 2012). The research that follows is the first to examine the impact of contingency fee reform on maternal and infant health outcomes.

The intention of limiting contingency fees is to reduce frivolous cases and alleviate malpractice fears for doctors; however lawyers are now left to focus on more serious cases with higher payouts to recoup lost income. OBGYNs are placed under more scrutiny by lawyers

[15] Studies have shown that physician supply is unchanged before and after tort reforms are enacted (Hyman et al. 2015), thus there is no concern that the supply of obstetricians is altered although there is evidence they do make changes to their practice.

hired on contingency. With the expected loss of a given case increasing, I find OBGYNs perform more C-sections on low income patients who tend to rely on hiring lawyers through contingency, relative to high income patients who are able to hire lawyers on an hourly basis (Youngwood, 1965). Furthermore, there is no observable effect on infant health, illustrating that OBGYNs are practicing defensive medicine, where they choose procedures that are not necessarily in patients' best interests but serve to protect them against possible lawsuits.

2.1.2 Background on Contingency Fees

Contingency fees allow capital constrained individuals to borrow money from a lender (their lawyer) in order to finance litigation with a positively expected benefit (Shrager, 1985). However, Bernstein (1996) finds that contingency fees "encourage attorneys to engage in speculative litigation in the hopes of landing the occasional large jackpot." Anecdotal evidence suggests that, once a limit on contingency fees is put in place, lawyers are no longer eager to take on the same cases they previously did (McMurdo, 2009). Studies agree that once contingency fees are limited frivolous cases (i.e. small payouts) are dropped, which in turn, increases the average payout from medical malpractice cases that are subsequently filed (Avraham, 2007; Helland and Tabarrok, 2003; Danzon and Lillard, 1983).

Helland and Tabarrok (2003) examine the enactment of limiting contingency fees in Florida in 1985. They find that the drop rate of cases increases by approximately 15 percent. However, the most serious cases, involving death and permanent injury, are as much as 16 percentage points *less likely* to be dropped following the enactment of the law. Florida's contingency limits are more relaxed than those of Nevada suggesting that the abovementioned effects would be stronger for the latter.[16] In order to account for the variation in the limits set by different states, Helland and Tabarrok (2003) create an effective tax rate based on the contingency fee limits set out by seven states and find that the more stringent the limits the more likely frivolous cases will be dropped.[17] When examining Figure 2.2, the number of medical malpractice payments made by physicians in Nevada, we see that the number of payments peaked in the early 2000s and then began decreasing. Figure 2.3 displays the percentage change in the different payment ranges for Figure 2.2. Although the data is noisy we see that the largest increases have occurred in the payment range between \$50,000-\$499,999 (inflation adjusted); the smallest payments under \$50,000 have declined over time, whereas the largest payments over \$500,000 increased in the early 2000s but have greatly fallen since 2004. Showing consistency with the drop in cases experienced in other states with contingency fees, it is important to remember that these figures are illustrating the number of payments occurring in a given year, and that the timeline for malpractice cases can take years if taken to court. Moreover, these graphs represent payment ranges for all physicians in Nevada. An industry report by Jury Verdict Research in 2002 found that childbirth negligence cases had the highest median jury award of all medical malpractice cases. The average malpractice award for these cases was \$7.2 million between 1994 and 2000 (Jury Verdict Research, 2002). Therefore, although limiting contingency fees curbs frivolous cases in medical malpractice lawsuits, OBGYNs are even more exposed to serious litigation by lawyers looking to recoup lost income. OBGYNs now faced with the expected loss of a given “contingency fee” case increasing results in greater liability fears, and thus, a greater use of defensive medicine.

[16] Florida’s contingency fee limit allows lawyers to collect 33.3% of the first million dollars recovered, 30% of the second million, and 20% thereafter (with some variations if the case is settled early).

[17] The seven states included in their effective tax rate on contingency fee limits are California, Connecticut, Florida, Illinois, New Jersey, New York, and Wisconsin.

Contingency fees allow individuals who otherwise cannot afford a lawyer to hire legal representation. Lawyers agree to pay any upfront costs and work on a case with the incentive of receiving a portion of the award upon winning the case or settling out of court. Alternatively, if an individual can afford legal representation, they can pay the hourly fee regardless of the result of the case. Since ninety-three percent of medical malpractice cases are settled before going to trial, lawyers do not need to spend many hours in lengthy court battles, thus high income individuals have the opportunity to pay an hourly fee to their lawyer in order to maximize their payout (Diederich Healthcare, 2012). Also, clients can "shop around" and receive estimates from lawyers on how many hours they expect to work on their case, as well as their hourly rate. I argue that high income patients will tend to hire lawyers on an hourly basis, whereas low income patients will tend to hire a lawyer on a contingency fee basis as they are liquidity constrained. Thus, limiting the contingency fee primarily affects the legal representation of low income individuals and not high income individuals.

Like Currie and MacLeod (2008), I assume doctors take liability into account at the time of service delivery in a reduced-form approach which depends on net benefits and costs. Given the patient's condition, a physician would be indifferent between performing and not performing a procedure when the benefit minus expected costs of liability of performing the C-section is equal to not performing the procedure. In the case of the high income patient who would have hired a lawyer on an hourly basis, a change in contingency fee reform does not alter the difference in expected liability and, thus, there is no change to doctors' procedural choices. However, for the low income patient who relies on contingency fee representation, this reform increases expected liability associated with a particular patient for doctors. This can occur due to two reasons: first, doctors have a misperception that low-income patients tend to sue more often than other patients, and second, since low income patients are, in fact, less likely to sue doctors, lawyers may seek out these patients after the reform (McClellan et al., 2012). Given that lawyers are now more focused on serious injury cases with large payouts they may be pursuing low income patients who previously were unlikely to sue.

This paper contributes to the existing literature on tort reform in numerous ways. To my knowledge, it is the first to examine the effect of contingency fee reform on maternal and infant health outcomes. Papers studying contingency fee reform observe the effects on malpractice payouts and time to litigation, but do not move beyond the legal realm to anticipate the reform's impacts on physician procedural choice. Past papers examining physician procedural choice did not include contingency fee reform in their analysis because there was not enough state level variation over their sample period (e.g. Avraham, 2007; Currie and MacLeod, 2008; and Yang et al., 2012). As the most recent state to enact a limit on contingency fees, Nevada provides an opportunity to study the effect of this reform on physician procedural choice using a different empirical approach from previous studies. Second, past papers use Apgar scores to study infant health as they are a reliable predictor of infant mortality (Almond, Chay, and Lee, 2005).[18] This study is able to observe actual infant mortality and does not rely on Apgar scores as the outcome variable for infant health. Moreover, the Linked Birth and Infant Death Records employed are exceptionally detailed, thereby allowing for the examination of potentially heterogeneous effects.

The next section of this paper describes my data, followed by empirical methods in Section 2.3. Section 2.4 presents the results on the impact of the contingency fee reform on maternal and infant health. The paper concludes with a discussion of my findings and their implications in Section 2.5.

[18] An Apgar score is a measure from zero to ten that quickly summarizes the health of a baby. It stands for Appearance, Pulse, Grimace, Activity, and Respiration.

2.2 Data

2.2.1 Vital Statistics

My primary data come from the United States Linked Birth and Infant Death Records for all fifty states and the District of Columbia. These data have virtually all infant deaths under one year of age linked to exceptionally detailed birth certificate data.[19] With this linked dataset, I am able to examine infant mortality (i.e. death within first year of life), as well as physician procedural choices as my outcome variables. Using data from 1995-2012, I group mothers by education to proxy for high and low income households.[20] New research by the Center for Household Financial Stability continues to support that there is a strong correlation between education and income (Boshara et al. 2015). I categorize high school dropouts as "low income" households and mothers who have a college degree or higher as being "high income" households. Since medical doctors are the only attendants that can perform C-sections, I limit my sample to all births attended by a medical doctor. This constitutes around ninety percent of births in the United States.[21] For race, I group all Hispanic and African Americans together as non-white, and all Caucasians as white.[22]

In addition to mother's education and race, other explanatory variables include age indicators, mother's marital status, smoked during pregnancy, and the sex of the baby. Moreover, I incorporate a dummy variable that indicates a patient's "riskiness", defined as a

[19] Around only two percent of infant deaths that occur in the United States cannot be linked to birth certificates.
[20] Since there is very poor information on father's education in birth certificates I do not use it as a proxy for household income.
[21] Around eight percent of birth attendants are midwives.
[22] Around only five percent of mothers identified themselves as "other race" and they were dropped from my sample. For example, Asians and Native Americans are both considered in the "other race" category, but may have very different backgrounds. Also, I estimate my preferred synthetic control method with Hispanic and African American separately, as opposed to the "non-white" variable I present, and find results do not substantially change.

mother suffering from any of the following conditions: diabetes, chronic hypertension, pregnancy hypertension, or eclampsia.[23] These conditions are known prior to labour and may affect physicians' procedural choice. Other dummy variables indicate whether there is at least one previous C-section, whether the pregnancy is a singleton birth, and whether the pregnancy is the first birth for the mother. These variables may affect a physician's decision regarding appropriate care as well as the ultimate birth outcome. For example, a majority of doctors do not want to attend a vaginal birth if the mother has previously had a C-section. In the 1990s, the American College of Obstetricians and Gynecologists (ACOG) recommended that doctors not perform vaginal deliveries after a patient has previously had a C-section. Even though the ACOG's guidelines no longer discouraged vaginal birth after Caesarean (VBAC) since 2010, they still remain low (see Barger et al. 2013). Physician behaviour is also influenced by pricing differences between vaginal and C-section births (Alexander, 2015). Between 1995 and 2008, the Medicaid fee schedule for vaginal and C-section deliveries did not change; after 2008 both fees simultaneously dropped by twenty-two percent.[24]

2.2.2 Tort Reform

I use the fifth edition of the Database of State Tort Law Reforms to characterize the different medical malpractice tort reforms enacted each year in each state. This database contains the most detailed, complete, and comprehensive information on state tort reforms from

[23] Diabetes is a metabolic disease in which the body's inability to produce any or enough insulin causes elevated levels of glucose in the blood. Chronic hypertension is defined as a long-term condition of having blood pressure greater than 140/90 mm Hg. Pregnancy hypertension is the development of new hypertension in a pregnant woman after 20 weeks gestation without the presence of protein in the urine or other signs of pre-eclampsia. Eclampsia is a condition in which one or more convulsions occur in a pregnant woman suffering from high blood pressure, often followed by coma and posing a threat to the health of both mother and baby.
[24] See Table A2.1 for the average annual Medicaid fee schedule for vaginal and C-section deliveries in Nevada.

1980 to 2012.[25] It has become the gold standard in empirical tort reform research by providing a review of original legislation and case law with exact text and effective dates. Popular tort reforms have been analyzed in medical malpractice research (see Dubay et al., 1999; Kessler and McClellan, 1996; Avraham et al., 2012; Iizuka, 2013). In this study state-year level indicator variables are created to account for the presence of caps on non-economic damages, the elimination of the "joint and several" liability rule, caps on punitive damages, and limiting contingency fees. I control for these variables to better estimate the causal impact of contingency fee reform on physician procedural choice. Specifically, while using the synthetic control method (discussed in the next section) I ensure other major tort reforms present in Nevada (caps on punitive damages and non-economic damages, as well as the "joint and several" rule) are also present in the states used to create an appropriate counterfactual for Nevada. Therefore, changes in C-section use can be attributed to the Nevada contingency fee reform, rather than the other reforms enacted a few years earlier.

2.3 Empirical Methods.

2.3.1 Difference-in-Differences Models

I first estimate standard difference-in-differences (DiD) models as a motivating example, and second, use synthetic control methods to evaluate the effect of contingency fee tort reform on physician procedural choice and infant health outcomes. DiD models rely on choosing an appropriate comparison group. In this instance, I choose Texas as my comparison group. Texas and Nevada simultaneously experienced a medical malpractice crisis and enacted the same tort reforms, with exception to the limit on contingency fees. On October 1st, 2002, Nevada enacted

[25] See Avraham's (2014) Database of State Tort Law Reforms (5th) for more information on the tort reform dataset.

the “joint and several” rule and a cap on non-economic damages, while Texas enacted the same reforms in July and September 2003, respectively. The effect of these other reforms on physician procedural choice should not be of concern since both states enacted them at a similar time with the same malpractice climate; thus any difference between Texas and Nevada in the following years should occur due to Nevada’s additional contingency fee reform adopted in November 2004. For comparison, Table 2.1 includes summary statistics from the Linked Birth and Infant Death Records categorized by mother’s education for Nevada and Texas.

Using linear probability models, I estimate the following DiD equation:

$$\text{(6)} \qquad Y_{it} = \beta_0 + \beta_1 \text{NEVADA}_i + \sum_{n=2}^{N} \beta_n \text{YEAR}_t + \delta \text{REFORM}_{it} + \gamma C_{it} + \varepsilon_{it}$$

where Y_{it} represents the outcome of interest for individual *i* in year *t*. My outcomes of interest are whether or not a C-section is performed on the mother, and also whether or not the infant passes away within the first year. The treatment group is represented by an indicator variable, NEVADA_i, for all patients in Nevada; REFORM_{it} is a dummy for each individual that equals one if the individual is in the treatment group (Nevada) after the reform is enacted (essentially an interaction term of being in Nevada during the reform); YEAR_t is a full set of year dummies; and C_{it} are individual characteristics. The individual characteristics include: whether or not the mother is married, a teenager, forty years of age or older, non-white, smoked during pregnancy, had a previous C-section, had a baby boy, had her first birth, had a singleton birth, and if she had any risk factors prior to delivery. Since there is only one treated and one control state the standard errors are not clustered at the state level due to the limited number of clusters; thus the statistical significance may be overstated (see Bertrand et al., 2004; Cameron and Miller, 2015). Each model will be estimated separately by low and high educated patients, consistent with the theoretical underpinnings discussed in Section 2.1.2.

2.3.2 Synthetic Control Models

When performing case studies, such as described above, it is imperative to find an adequate comparison between the exposed and unexposed units of a policy intervention. Typically, there is a high degree of ambiguity about how comparison units are chosen; using inappropriate comparisons may lead to erroneous conclusions. Although Texas was experiencing the same medical malpractice environment as Nevada, using the synthetic control method creates a data-driven procedure to construct a more precise comparison group (See Abadie and Gardeazabal, 2003; and Abadie et al., 2010, 2011, 2015). The synthetic control method provides a systematic way to choose comparison units by allowing for a weighted combination of many units to comprise the most appropriate counterfactual. When comparison units are not sufficiently similar to the treated unit the variation in outcomes may be due to the difference in their characteristics, rather than the policy intervention or event of interest (Geddes, 2003; George and Bennett, 2005; King, Keohane, and Verba, 1994). With the synthetic control method the similarities between the affected and unaffected units in terms of pre-intervention outcomes and other predictors of post-intervention outcomes are observed and maximized.

In the absence of randomization, there is no one state that acts as a perfect comparison for another. The main idea behind the synthetic control approach is that a weighted combination of states will provide a better counterfactual than any one state alone. Suppose that there are J states, where $i=1$ refers to Nevada, the treated state. Borrowing from the statistical matching literature, I refer to the set of potential controls as the 'donor pool', that is, all the states that do not have a limit on contingency fees for medical malpractice.[26] The synthetic control method

[26] The following states are excluded from the 'donor pool' since they have already enacted contingency fee tort reform: California, Connecticut, Delaware, Florida, Hawaii, Illinois, Indiana, Maine, Massachusetts, Michigan, New Hampshire, New Jersey, New York, Oklahoma, Tennessee, Utah, Wisconsin, and Wyoming.

identifies a linear combination of the other $i=2$ to J states with weights, $W=(w_2,\dots w_J)$ such that $w_i \geq 0$ and $w_2+\dots+w_J=1$, that best reproduces Nevada during the pre-reform period (1995-2004), both in terms of average C-section rates (Y) and a list of observed controls (Z) that potentially affect the use of C-sections. The identification of the effect of the reform is achieved by comparing the post-reform *observed* average C-sections in Nevada, Y_1, and its synthetic equivalent (synthetic Nevada), $Y_S = \Sigma w_i Y_i$, $i=2$ to J. If it is established that over extended periods of time Nevada and the "synthetic" Nevada have similar behaviour, then any discrepancy in average C-sections following the reform is interpreted as a product of the reform itself.

2.4 Results

Tables 2.2 and 2.3 show the results from conducting a standard DiD using linear probability models for C-sections and infant mortality, respectively. All coefficients and standard errors are multiplied by 100. Table 2.2 reports the coefficient and robust standard errors for both high school dropout patients and patients with at least a college degree. The main variable of interest, REFORM_{it}, illustrates that there is a statistically significant effect on C-section rates for high school dropout patients, but not for patients with at least a college degree. Based on a Nevada pre-reform C-section rate of 0.21 for high school dropout patients, the reform's coefficient, 0.99, translates into a five percent increase in C-sections for those patients. Table 2.3 shows no statistically significant effect of the reform on infant mortality for both high school dropouts, and college and higher patients. As stated earlier, Texas is used as my comparison group in the standard DiD model, however the strong assumption of parallel paths for Texas and Nevada creates concern for the precision of those estimates. The standard DiD models are presented as a baseline for my preferred method using synthetic controls.

With synthetic controls, I am able to construct a more precise control group from the donor pool of available states. Table 2.4 displays the weight of each state used in the synthetic control group. A weight of zero is assigned to all other states in the donor pool. “Synthetic Nevada” consists of a weighted combination of Colorado, District of Columbia, Oregon, and Texas for high school dropout mothers. Colorado, Louisiana, North Dakota, and Texas make up the synthetic control for mothers with a college degree or higher. Table 2.4 also displays the root mean squared prediction error (RMSPE) during the pre-policy period for each synthetic group. The RMSPE for high school dropouts and at least a college degree is 0.008 and 0.004, respectively. This illustrates that the synthetic controls strongly match to Nevada and provide a reliable counterfactual (Abadie et al., 2010). Table 2.5 compares the C-section predictor variables using synthetic control methods and highlights how well the synthetic control group is able to accurately reproduce the pre-policy characteristics of Nevada.

When examining the effects of limiting contingency fees on C-section rates with a more accurate control for Nevada (“Synthetic Nevada”), in Figure 2.4, we begin to see an increase in C-sections for “low income” patients right before the policy is enacted. This is consistent with Helland and Tabarrok’s (2003) observation that lawyers anticipate the limit on contingency fees, thus filing more cases prior to the policy change in order to receive larger payments. In May 2003, eighty percent of voters said they would support limiting contingency fees. This clearly signaled to lawyers that the reform will be voted into legislation. This increased enthusiasm to pursue medical malpractice cases prior to the reform’s enactment may cause greater liability pressure on OBGYNs before November 23rd, 2004, thereby influencing physicians to perform more C-sections prior to the actual enactment of the reform.[27]

On average, the C-section rate for high school dropout patients increases by 2.8 percentage points after the reform in Nevada. This translates to an average increase of almost ten percent in C-sections for high school dropout patients. In comparison to the standard DiD, the synthetic control method finds a twice as large percentage increase in C-section rates for high school dropouts. When examining the effect of the reform on "high income" patients, we find the same overall effect as in the standard DiD; there is no statistically significant change. Figure 2.8 shows Nevada slightly deviating from "Synthetic Nevada", but then converging back, illustrating that the reform had a much stronger effect on "low income" patients in comparison to "high income".

Figure 2.4 and 2.5 include a polynomial trend line with 95 percent confidence intervals to effectively display the statistically significant difference between Nevada and its counterfactual. The standard errors used from the trend line to create the confidence interval are conservative; they assume that the estimated weights from "Synthetic Nevada" are correct. In addition to the traditional variation in standard errors the synthetic control method additionally estimates state weights which may be wrong. To evaluate the significance of my estimates and to ensure that my results are not driven by chance, I run placebo tests similar to Abadie and Gardeazabal (2003), Bertrand et al. (2004), and Abadie et al. (2010). These placebo tests involve iteratively applying the synthetic control method used on Nevada to each state in the donor pool. If the placebo tests create positive gaps of magnitude similar to high school dropouts in Nevada, then

[27] Anecdotal evidence suggests that physicians are very sensitive to lawsuits and may practice more defensive medicine if a colleague in their practice is sued or they have a previous lawsuit filed against them.

my analysis does not provide significant evidence of an increase in C-sections due to the limit on contingency fees.

Figure 2.6 displays the estimated gaps from the synthetic control method for the states in the donor pool as well as Nevada. The solid black line denotes the gap estimated for Nevada and the gray lines illustrate the estimated gap for high school dropout average C-section rates between each state in the donor pool and its respective synthetic control. Figure 2.6 shows that the Nevada gap varies around zero, illustrating that the synthetic control method has done a relatively good job of fitting the Nevada data in the pre-reform period. Moreover, in the post-reform period, the estimated gap between high school dropout C-section rates in Nevada and "Synthetic Nevada" is notably larger relative to the distribution of gaps for the 24 states in the donor pool.

From Figure 2.6 we can see that some of the states in the control group have large gaps even in the pre-reform period. This illustrates that the synthetic control method is unable to create an accurate counterfactual and thus gaps in the post-reform period are due to a lack of fit, rather than by the reform's effect. In Figure 2.7 I display the same placebo tests but this time exclude states whose pre-reform RMSPE is twice the pre-reform RMSPE of Nevada. By excluding these states, we are able to focus on the states that are well fitted prior to the reform. Since there are 19 control states, the chance of estimating a gap of Nevada's magnitude under a random permutation would be 1 in 20, which adheres to the 5 percent level used in traditional statistical significance tests.

For sensitivity analysis, I re-examine each group by first limiting my sample to women delivering their first child, and second, I observe only singleton births, as multiple births are more likely to receive a C-section. In both cases, the graphs look similar to Figures 2.4 and 2.5, however the impact on the rate of C-sections for low educated mothers is slightly stronger. With the removal of deliveries that would have likely been a C-section regardless of the reform, the percentage increase in C-sections from first births and singleton births is around 12 percent, as opposed to the 9.8 percent increase from the full sample. Third, I examine the C-section rate for women that have had a previous C-section. In this instance, we are aware that doctors generally do not like to perform a VBAC and would take extra precaution if a woman has already had a C-section. Figure 2.8 displays the average C-section rate for low educated women that have previously had a C-section. Here, we see that their rates of C-section are very high and increasing over time. In anticipation of the enactment of the reform, and right after, there is an increase in the number of C-section deliveries (an overall average of six percent) for these women. This further illustrates OBGYNs apprehension to perform a VBAC during a time of heightened malpractice pressures. Although the C-section rate for high educated women that have previously had a C-section is also high and increasing over time no large gap exists after the reform. Figure 2.9 illustrates on average only a one percent increase in the C-section rate for women with a previous C-section with at least a college degree. The differential increase for women with previous C-sections by education illustrates that this tort reform is affecting women based on socio-economic factors, and not on basic health-risk factors. When looking at the effect of different tort reforms on C-section rates, Currie and MacLeod (2008) find that high and low risk moms should be unaffected. In this instance, however, women with a previous C-section are considered at a higher health risk for a vaginal delivery and thus there should be no differential effect in C-section rates for these women by education. Nevertheless, it is present due to the financial nature of the contingency fee reform.

After examining the effect of contingency fee tort reform on physician procedural choice, I also examine its impact on infant mortality. I find no statistically significant impact on infant mortality rates (IMR) after the enactment of the contingency fee reform, which demonstrates that OBGYNs are successfully engaging in defensive medicine. Figure 2.10 and 2.11 both display the difficulty in finding a close synthetic control for infant mortality. Since infant mortality is a very rare occurrence the trend is noisy. We can see that IMR is slightly higher for low educated mothers, ranging between 5 and 6 deaths per 1000 live births; in comparison, the IMR is between 3 and 4 deaths per 1000 live births for mothers with a college degree or higher.[28] Both the synthetic control method and the standard DiD show that the enactment of the contingency fee reform did not have a statistically significant effect on infant mortality.

2.5 Conclusion

Limiting contingency fees for medical malpractice lawsuits is intended to lower liability concerns for doctors. Evidence suggests that lawyers target more serious lawsuits involving death and serious injury, which leaves OBGYNs more susceptible to a major lawsuit than prior to the reform. In a recent survey 85 percent of OBGYNs admitted to being sued. Around 3500 physicians from the US answered this annual survey, and 37 percent believed the best way to discourage lawsuits is to completely ban lawyers from taking cases "on contingency" (Peckham, 2015). Evidently, physicians do believe that contingency fees affect medical malpractice lawsuits. On the other hand, offering contingency fees allows low income, liquidity constrained individuals the opportunity to *afford* legal representation.

[28] A five year rolling average is used to display infant mortality rates because the trend is very noisy.

With the initiation of limited contingency fees in Nevada, I find that OBGYNs perform more C-sections on low income patients, as proxied by high school dropout patients. High income patients, who are more likely to be able to afford to pay lawyers an hourly fee, do not experience an increase in comparison to their synthetic control group. I examine C-sections because there is consensus amongst the medical community that they are unlikely to provoke lawsuits, thus OBGYNs fearful of being sued may, on the margin, perform more C-sections (Lake, 2012). The World Health Organization (WHO, 2009) states that both "very low and very high rates of cesarean section can be dangerous".

Optimal rates of C-sections, initially announced by the WHO to be around 15 percent, are encouraged to prevent infant death; however I do not find a decrease in infant mortality rates due to the enactment of contingency fee reform. Plotting the trend of infant mortality for high school dropout mothers, we observe the number of infant deaths per 1000 live births to range between 5 and 6 over the sample period. This suggests that the increase in C-section rates for low income patients is, in fact, a case of defensive medicine, where physicians choose procedures that are not necessarily in patients' best interests but serve to protect physicians against possible lawsuits. Not only does tort reform alter physician procedural choice, but it does so in heterogeneous ways, illustrating that unintended consequences of policy interventions can lead to unnecessary surgery for more vulnerable patients.

2.6 References

Abadie, A., A. Diamond, and J. Hainmueller. 2010. "Synthetic Control Methods for Comparative Case Studies: Estimating the Effect of California's Tobacco Control Program." *Journal of the American Statistical Association* 105(490): 493–505.

Abadie, A., A. Diamond, and J.Hainmueller. 2011. "Synth: An R Package for Synthetic Control Methods in Comparative Case." *Journal of Statistical Software* 42(13):1–17.

Abadie, A., A. Diamond, and J. Hainmueller. 2015. "Comparative Politics and the Synthetic Control Method." *American Journal of Political Science* 59(2): 495–510.

Abadie, A., and J. Gardeazabal. 2003. "The Economic Costs of Conflict: A Case Study of the Basque Country."*American Economic Review* 93(1): 112–32.

Alexander, D. 2015. "Does Physician Compensation Affect Procedure Choice and Patient Health? Evidence from Medicaid C-section Use", Center for Health and Wellbeing Working Paper. Available at http://scholar.princeton.edu/dalexand/data-1.

Almond, D., K. Chay, and D. Lee. 2005. "The Costs of Low Birth Weight." *Quarterly Journal of Economics* 120(3):1031–83.

American College of Obstetricians and Gynecologists. 2010. "ACOG Practice bulletin no. 115: Vaginal birth after previous cesarean delivery." *Obstetrics and Gynecology* 116(2): 450.

Avraham, R. 2007. "An Empirical Study of the Impact of Tort Reforms on Medical Malpractice Settlement Payments." *Journal of Legal Studies* 36(S2): S183-S229.

Avraham, R. 2014. "Database of State Tort Law Reforms 5th Ed." University of Texas School of Law: Law and Economics Research Paper No.e555.

Avraham, R., L. S. Dafny, and M. M. Schanzenbach. 2012. "The Impact of Tort Reform on Employer-Sponsored Health Insurance Premiums." *Journal of Law, Economics, and Organization* 28(4): 657-686.

Barger, M. K., J. T. Dunn, S. Bearman, M. DeLain, and E. Gates. 2013. "A survey of access to trial of labour in California hospitals in 2012." *BMC Pregnancy Childbirth* 3(13):83.

Bernstein, D. E. 1996. "Procedural Tort Reform: Lessons from Other Nations." *Regulation* 19(1):71-81. Available at http://object.cato.org/sites/cato.org/files/serials/files/regulation/1996/1/v19n1-8.pdf.

Bertrand, M., E. Duflo, and S. Mullainathan. 2004. "How Much Should We Trust Differences in-Differences Estimates?" *Quarterly Journal of Economics* 119(1): 249-275.

Boshara, R., W. R. Emmons, and B. J. Noeth. 2015. "The Demographics of Wealth**:** How Age, Education and Race Separate Thrivers from Strugglers in Today's Economy, Essay No. 2: Education and Wealth." Centre for Household Financial Stability. Federal Reserve Bank of St. Louis.

Cameron, A. C., and D. L. Miller. 2015. "A Practitioner's Guide to Cluster-Robust Inference." *Journal of Human Resources* 50(2): 317-372.

Carpentieri, A. M., J. J. Lumalcuri, J. Shaw, and G. F. Joseph Jr. 2015. "Overview of the 2015 American Congress of Obstetricians and Gynecologists' Survey on Professional Liability." American College of Obstetricians and Gynecologists Clinical Review (Nov/Dec Issue).

Currie, J., and W. B. MacLeod. 2008. "First do no harm? Tort reform and birth outcomes." *Quarterly Journal of Economics* 123(2): 795–830.

Danzon, P. M., and L. A. Lillard. 1983. "Settlement Out of Court: The Disposition of Medical Malpractice Claims." *Journal of Legal Studies* 12: 345-377.

Dubay, L., R. Kaestner, and T. Waidmann. 1999. "The Impact of Malpractice Fears on Cesarean Section Rates." *Journal of Health Economics* 18: 491-522.

Geddes, B. 2003. *Paradigms and Sand Castles: Theory Building and Research Design in Comparative Politics*. Ann Arbor: University of Michigan Press.

George, A. L., and A. Bennett. 2005. *Case Studies and Theory Development in the Social Sciences*. Cambridge MA: MIT Press.

Gower, J. 2013. "2013 Medical Malpractice Payout Analysis." Diederich Healthcare. Available at http://www.diederichhealthcare.com/the-standard/2013-medical-malpractice-payout analysis/

Helland, E., and A. Tabarrok. 2003. "Contingency Fees, Settlement Delay, and Low-Quality Litigation: Empirical Evidence from Two Datasets." *Journal of Law, Economics, & Organization* 19(2): 517-542.

Hyman, D. A., C. Silver, B. Black, and M. Paik. 2015. "Does Tort Reform Affect Physician Supply? Evidence from Texas." *International Review of Law and Economics* 42: 203-218.

Frakes, M. 2012. "Defensive medicine and obstetric practices." *Journal of Empirical Legal Studies* 9 (3): 457–481.

Iizuka, T. 2013. "Does Higher Malpractice Pressure Deter Medical Errors?" *Journal of Law and Economics* 56: 161-188.

Jury Verdict Research. 2002. *Medical Malpractice: Verdicts, Settlements and Statistical Analysis*. Horsham, Penn.: LRP Publications.

Kessler, D., and M. McClellan. 1996. “Do Doctors Practice Defensive Medicine?” *Quarterly Journal of Economics* 111: 353-390.

King, G., R. O. Keohane, and S. Verba. 1994. *Designing Social Inquiry: Scientific Inference in Qualitative Research*. Princeton, NJ: Princeton University Press.

Lake, N. 2012. “Labour, Interrupted: The rise in the use of C-sections.” *Harvard Magazine*. Nov/Dec Issue: 21-26.

McClellan, F. M., A. A. White, R. L. Jimenez, and S. Fahmy. 2012. “Do Poor People Sue Doctors More Frequently? Confronting Unconscious Bias and the Role of Cultural Competency.” *Clinical Orthopaedics and Related Research* 470(5): 1393–1397.

McMurdo, D. 2009. “$2.3 million or $800,000 the question in court.” Review Journal. Available at http://www.reviewjournal.com/news/23-million-or-800000-question-court.

Mello, M. M., D. S. Studdert, and T. A. Brennan. 2003. “The New Medical Malpractice Crisis”. *New England Journal of Medicine* 348(23):2281-2284.

National Center for Health Statistics. Linked Birth and Infant Death, 1995-2012, as compiled from data provided by the 57 vital statistics jurisdictions through the Vital Statistics Cooperative Program.

National Practitioner Data Bank. 2014. Payment Year by Malpractice Payment Range. Generated using the Data Analysis Tool at http://www.npdb.hrsa.gov/analysistool.

Peckham, C. 2015. “Medscape Malpractice Report 2015: Why Most Doctors Get Sued.” WebMD Health Professional Network. Available at http://www.medscape.com/features /slideshow/public/malpractice-report-2015.

Shrager, D. 1985. “The Hammer for the Public Interest.” *American Bar Association Journal* 71: 38-40.

Sloan, F., S. S. Entman, B. A. Reilly, C. A. Glass, G. B. Hickson, and H. H. Zhang. 1995. “Tort liability and obstetricians' care levels.” Duke University, Department of Economics, Working Papers: 95-107.

World Health Organization, UNFPA, UNICEF, and AMDD. 2009. *Monitoring Emergency Obstetric Care: A Handbook*. Paris: World Health Organization.

Yang Y. T., D. S. Studdert, S. V. Subramanian, M. M. Mello. 2009. “Relationship Between Malpractice Litigation Pressure and Rates of Cesarean Section and Vaginal Birth After Cesarean Section.” *Medical Care* 47(2):234–242.

Yang Y. T., D. S. Studdert, S. V. Subramanian, M. M. Mello. 2012. "Does Tort Law Improve the Health of Newborns, or Miscarry? A Longitudinal Analysis of the Effect of Liability Pressure on Birth Outcomes." *Journal of Empirical Legal Studies* 9(2):217–245.

Youngwood, A. 1965. "The Contingent Fee. A Reasonable Alternative?" *The Modern Law Review* 28(3):330-335.

Table 2.1: Summary Statistics for Nevada and Texas, 1995-2012

Variables	High School Dropout Mothers		College & Higher Mothers	
	Nevada	Texas	Nevada	Texas
C-section	0.262	0.272	0.347	0.360
	(0.440)	(0.445)	(0.476)	(0.480)
infant death	0.006	0.006	0.003	0.004
	(0.076)	(0.075)	(0.058)	(0.061)
married	0.392	0.474	0.885	0.915
	(0.488)	(0.499)	(0.319)	(0.280)
non-white	0.748	0.841	0.184	0.306
	(0.434)	(0.366)	(0.387)	(0.461)
teenager	0.261	0.298	0.000	0.000
	(0.439)	(0.457)	(0.018)	(0.027)
forty and older	0.016	0.014	0.041	0.036
	(0.127)	(0.116)	(0.198)	(0.187)
smoke during pregnancy	0.119	0.077	0.020	0.015
	(0.323)	(0.267)	(0.139)	(0.120)
previous C-section	0.134	0.131	0.128	0.140
	(0.341)	(0.337)	(0.334)	(0.347)
risky patient	0.047	0.078	0.066	0.088
	(0.212)	(0.268)	(0.248)	(0.283)
first birth	0.290	0.323	0.349	0.361
	(0.454)	(0.468)	(0.477)	(0.480)
singleton baby	0.978	0.979	0.950	0.953
	(0.146)	(0.145)	(0.217)	(0.212)
baby boy	0.511	0.510	0.515	0.513
	(0.500)	(0.500)	(0.500)	(0.500)
observations	123555	1761553	77680	1234239

Note: Standard deviation in parenthesis

Table 2.2: Standard Difference-in-Difference Effect of Contingency Fee Reform on C-Sections, Nevada and Texas (1995-2012)

C-Section	High School Dropout		College & Higher	
reform	0.990	***	-0.358	
	(0.208)		(0.297)	
Nevada	-1.627	***	0.426	**
	(0.138)		(0.215)	
baby boy	1.527	***	2.155	***
	(0.053)		(0.071)	
previous C-section	72.579	***	69.317	***
	(0.075)		(0.085)	
risky patient	10.329	***	11.642	***
	(0.118)		(0.138)	
married	0.064		-1.656	***
	(0.057)		(0.140)	
smoke during pregnancy	1.208	***	3.835	***
	(0.108)		(0.304)	
first birth	12.793	***	15.931	***
	(0.075)		(0.083)	
singleton birth	-41.617	***	-43.775	***
	(0.234)		(0.178)	
teenager	-4.016	***	-12.660	***
	(0.074)		(1.362)	
forty and older	8.485	***	10.374	***
	(0.262)		(0.195)	
non-white	-0.987	***	4.448	***
	(0.080)		(0.081)	
constant	50.544	***	52.243	***
	(0.271)		(0.285)	
R-squared	0.321		0.291	
observations	1885108		1311919	

Note: Coefficients and standard errors multiplied by 100. Linear probability models include year dummies. Robust standard errors in parenthesis. A *** or ** indicates statistical significance at 99% or 95%, respectively.

Table 2.3: Standard Difference-in-Difference Effect of Contingency Fee Reform on Infant Mortality, Nevada and Texas (1995-2012)

Infant Mortality	High School Dropout		College & Higher	
reform	0.023		-0.027	
	(0.045)		(0.044)	
Nevada	-0.031		-0.005	
	(0.031)		(0.033)	
baby boy	0.109	***	0.056	***
	(0.011)		(0.011)	
previous C-section	-0.010		-0.091	***
	(0.017)		(0.015)	
risky patient	0.003		0.006	
	(0.021)		(0.021)	
married	-0.087	***	-0.181	***
	(0.012)		(0.023)	
smoke during pregnancy	0.295	***	0.104	**
	(0.028)		(0.049)	
first birth	-0.056	***	0.009	
	(0.015)		(0.012)	
singleton birth	-2.223	***	-1.715	***
	(0.082)		(0.057)	
teenager	0.173	***	-0.072	
	(0.016)		(0.209)	
forty and older	0.398	***	0.167	***
	(0.059)		(0.036)	
non-white	-0.106	***	0.144	***
	(0.018)		(0.013)	
constant	2.822	***	2.158	***
	(0.088)		(0.067)	
R-squared	0.0023		0.0039	
observations	1885108		1311919	

Note: Coefficients and standard errors multiplied by 100. Linear probability models include year dummies. Robust standard errors in parenthesis. A *** or ** indicates statistical significance at 99% or 95%, respectively.

Table 2.4: State Weights & Root Mean Squared Prediction Error for Synthetic Nevada

High School Dropout		**College & Higher**	
State	Weight	State	Weight
Colorado	0.41	Colorado	0.135
District of Columbia	0.001	Louisiana	0.001
Oregon	0.259	North Dakota	0.092
Texas	0.331	Texas	0.772
RMSPE	0.008	RMSPE	0.004

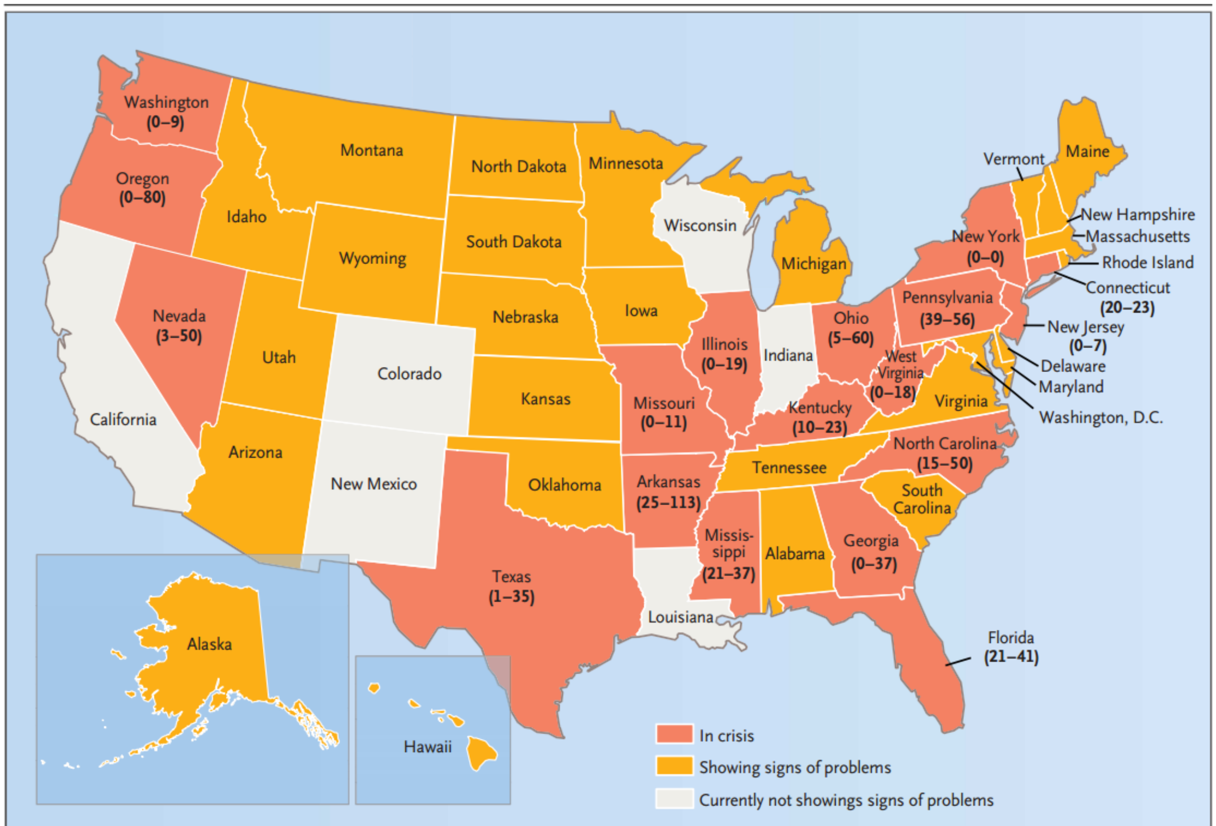
Note: The rest of the states in the 'donor pool' have a weight of zero.

Table 2.5: Predictor Means from Synthetic Control Method

Predictor Variables	**High School Dropout**		**College & Higher**	
	Nevada	Synthetic	Nevada	Synthetic
non-white	0.695	0.690	0.143	0.208
baby boy	0.510	0.511	0.514	0.514
risky patient	0.030	0.071	0.039	0.072
married	0.419	0.493	0.905	0.947
smoke during pregnancy	0.153	0.161	0.025	0.018
singleton baby	0.978	0.978	0.952	0.957
teenager	0.293	0.326	0.000	0.000
forty and older	0.012	0.010	0.040	0.035
previous C-section	0.106	0.107	0.107	0.121
cap on NED (2004)	1.000	0.741	1.000	0.999
cap on NED (2003)	1.000	0.410	1.000	0.227
joint (2004)	1.000	1.000	1.000	1.000
joint (2003)	1.000	1.000	1.000	1.000
cap on punitive damages (1995-2004)	1.000	1.000	1.000	1.000

Note: NED stands for non-economic damages; joint (2003/2004) signifies the limitation of the "joint and several" liability rule in 2003 and 2004, which is when both reforms are active in Nevada before the KODIN initiative took effect. The cap on punitive damages was enacted during the entire pre-reform period, 1995-2004.

Figure 2.1: American Medical Association's Classification of States in a Medical Malpractice Crisis

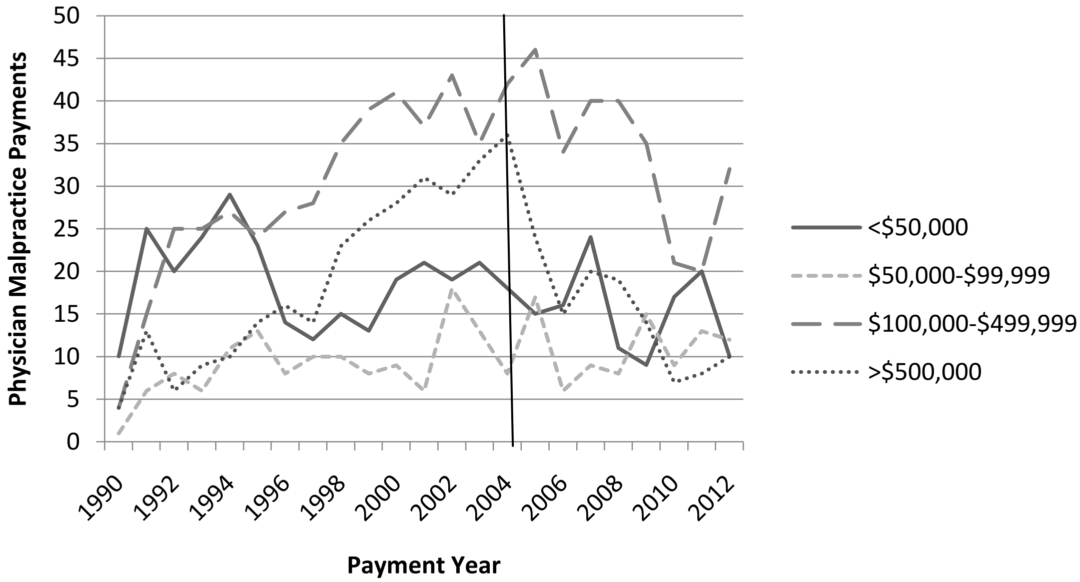


Ranges of Percentage Increases in Premiums between 2001 and 2002 for a Standard Professional Liability Insurance Policy ($1 Million per Incident, $3 Million per Year) for an Obstetrician–Gynecologist, among Insurance Companies in States That Are "in Crisis" According to the American Medical Association.

Data are from the American Medical Association.

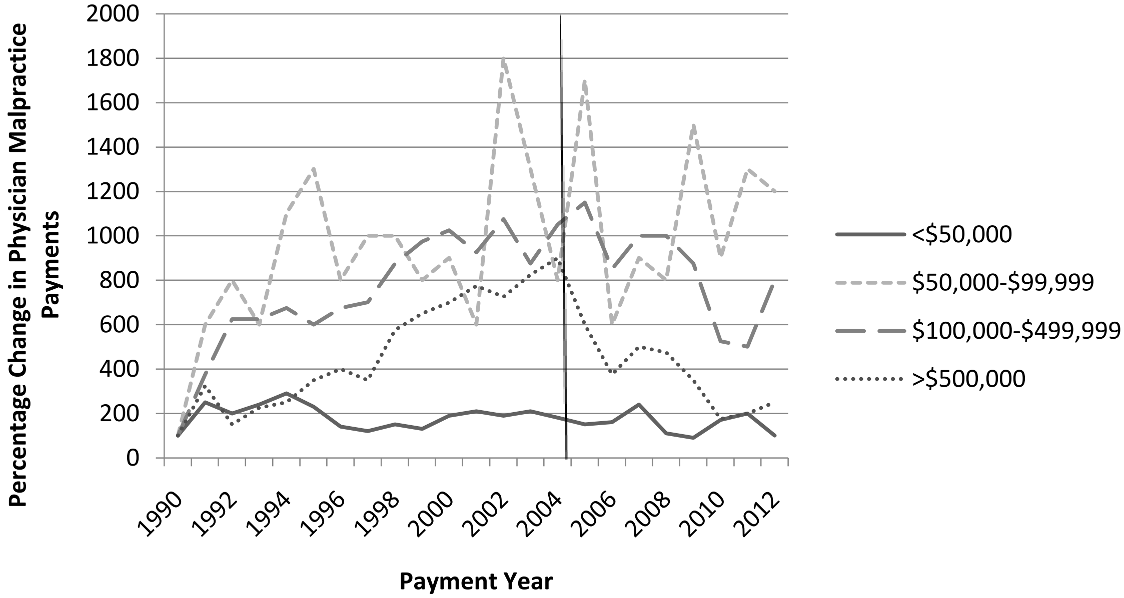
Source: Mello et al. (2003)

Figure 2.2: Physician Malpractice Payments by Payment Range in Nevada



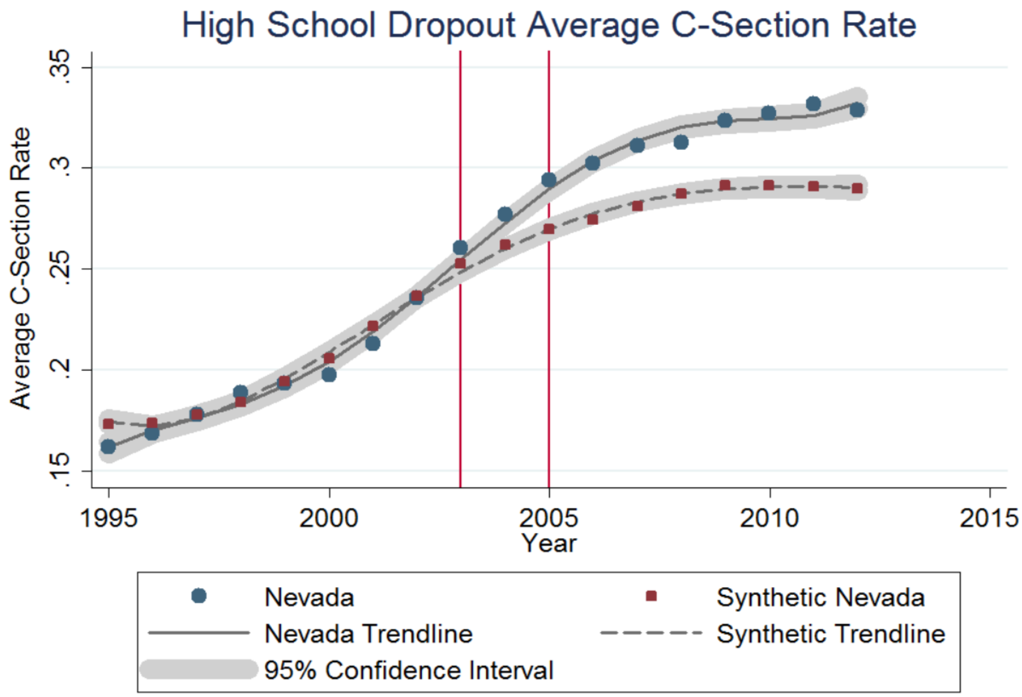
Note: The physician malpractice payments (inflation adjusted) come from the National Practitioner Data Bank: Adverse Action and Medical Malpractice Reports (1990-2012). The solid vertical line represents when the limit on contingency fees was enacted in Nevada (November 23rd, 2004).

Figure 2.3: Percentage Change in Physician Malpractice Payments by Payment Range in Nevada



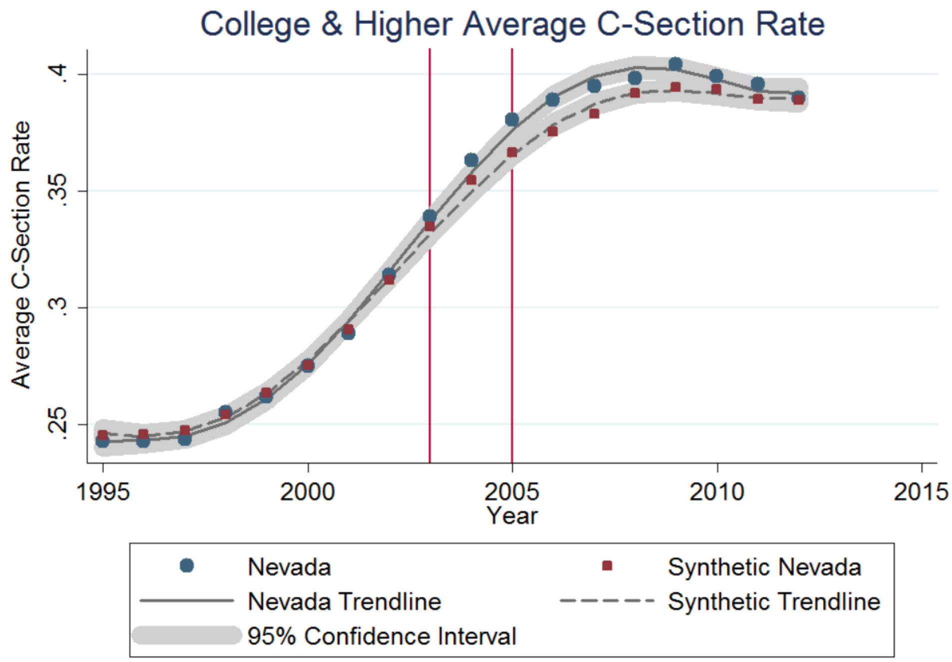
Note: The physician malpractice payments (inflation adjusted) come from the National Practitioner Data Bank: Adverse Action and Medical Malpractice Reports (1990-2012). The solid vertical line represents when the limit on contingency fees was enacted in Nevada (November 23rd, 2004).

Figure 2.4: High School Dropout Average C-Section Rate



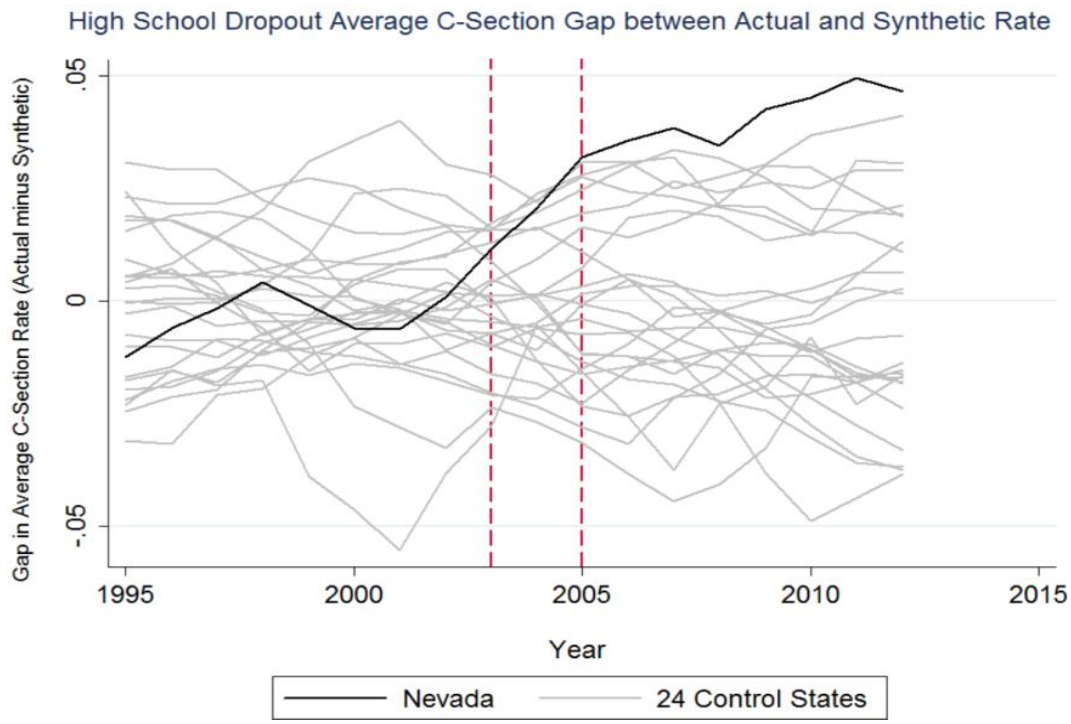
Note: The first vertical line represents May 2003 when eighty percent of voters in Nevada said they would support limiting contingency fees. The second vertical line represents when the limit on contingency fees was enacted in Nevada (November 23rd, 2004).

Figure 2.5: College and Higher Average C-Section Rate



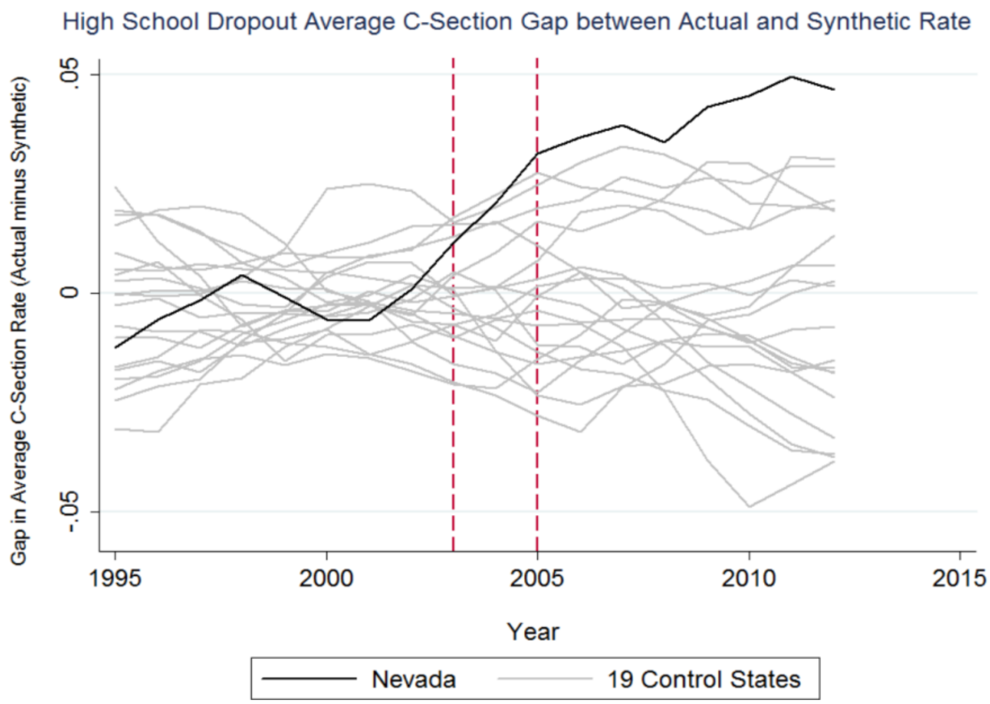
Note: The first vertical line represents May 2003 when eighty percent of voters in Nevada said they would support limiting contingency fees. The second vertical line represents when the limit on contingency fees was enacted in Nevada (November 23rd, 2004).

Figure 2.6: High School Dropout Average C-Section Gap between Actual and Synthetic Rate (25 States)



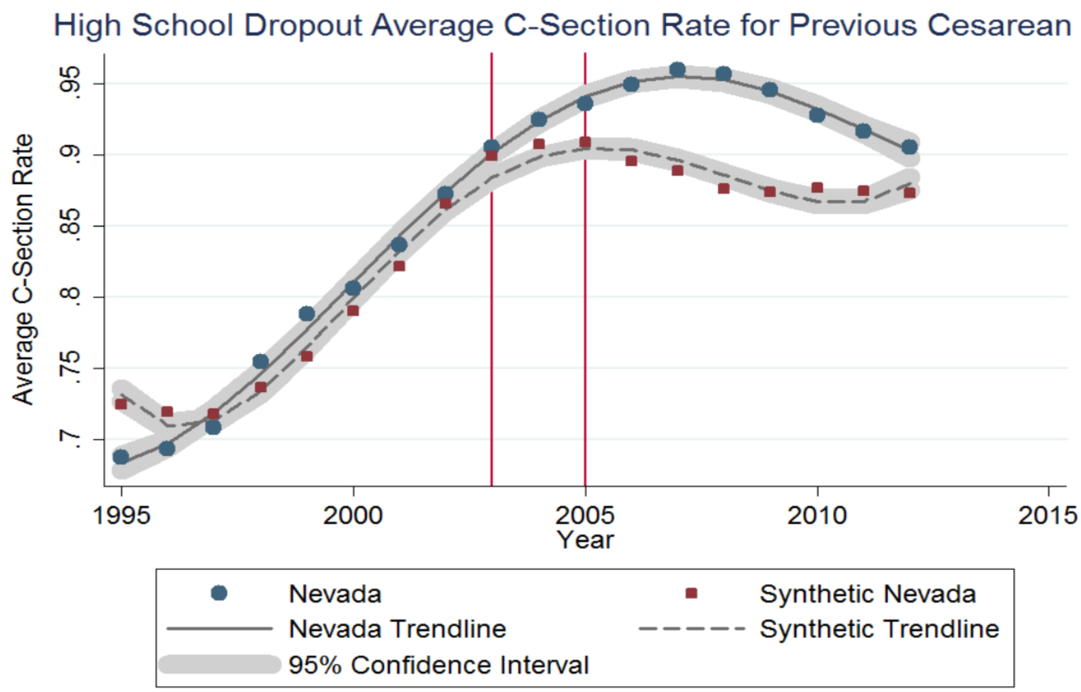
Note: The first vertical line represents May 2003 when eighty percent of voters in Nevada said they would support limiting contingency fees. The second vertical line represents when the limit on contingency fees was enacted in Nevada (November 23rd, 2004).

Figure 2.7: High School Dropout Average C-Section Gap between Actual and Synthetic Rate (20 States)



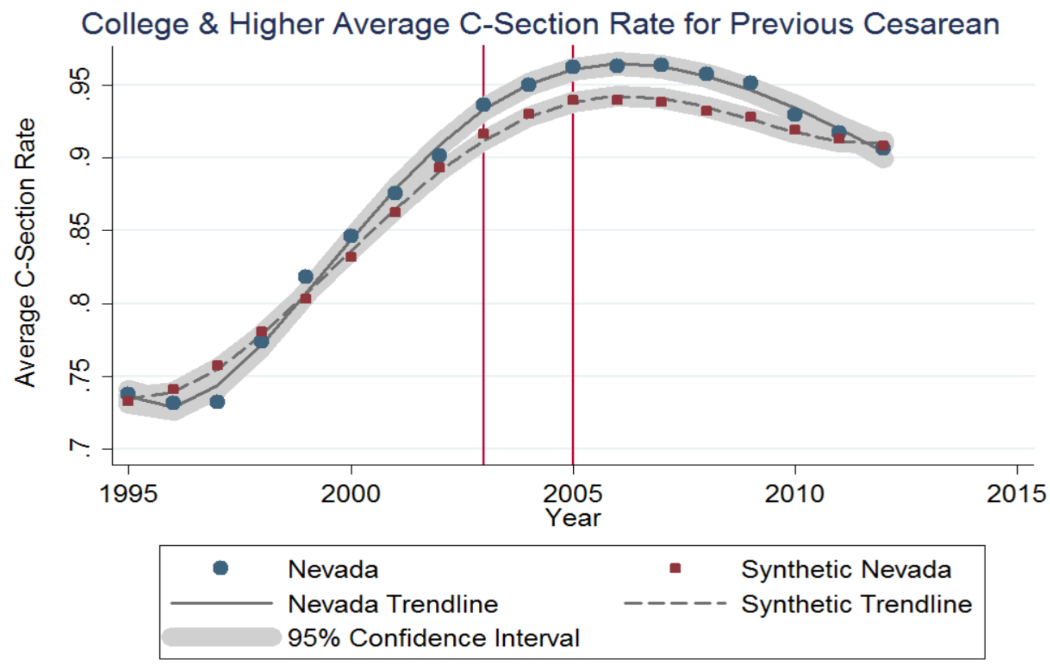
Note: The first vertical line represents May 2003 when eighty percent of voters in Nevada said they would support limiting contingency fees. The second vertical line represents when the limit on contingency fees was enacted in Nevada (November 23rd, 2004).

Figure 2.8: High School Dropout Average C-Section Rate for Previous Cesarean



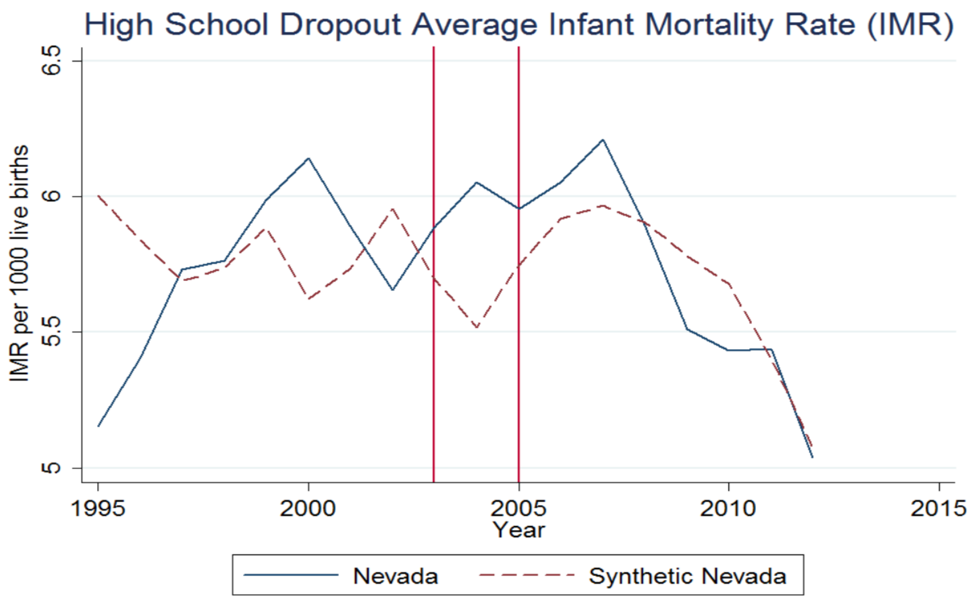
Note: The first vertical line represents May 2003 when eighty percent of voters in Nevada said they would support limiting contingency fees. The second vertical line represents when the limit on contingency fees was enacted in Nevada (November 23rd, 2004).

Figure 2.9: College and Higher Average C-Section Rate for Previous Cesarean



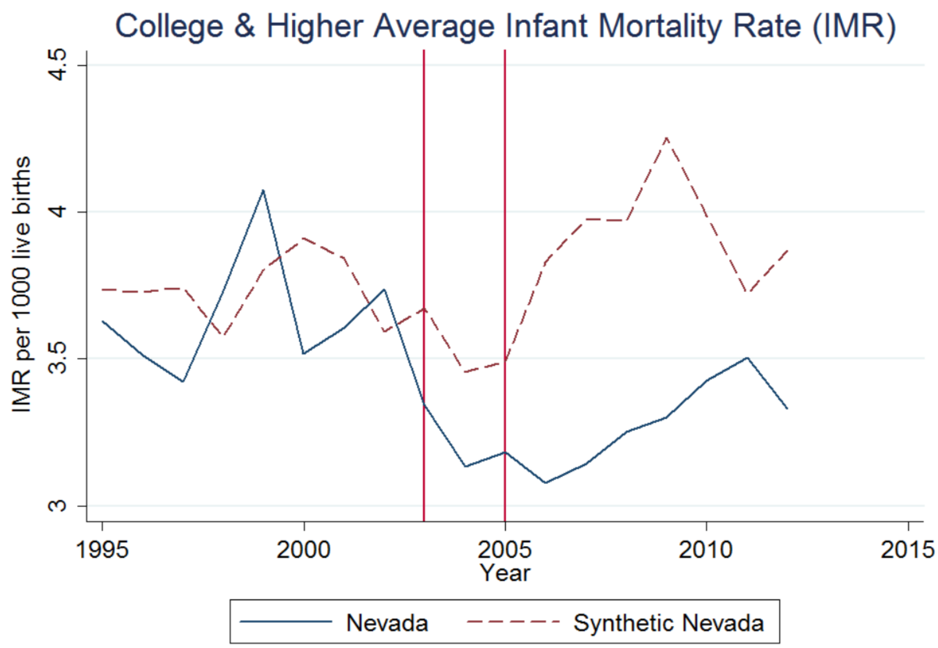
Note: The first vertical line represents May 2003 when eighty percent of voters in Nevada said they would support limiting contingency fees. The second vertical line represents when the limit on contingency fees was enacted in Nevada (November 23rd, 2004).

Figure 2.10: High School Dropout Average Infant Mortality Rate



Note: The first vertical line represents May 2003 when eighty percent of voters in Nevada said they would support limiting contingency fees. The second vertical line represents when the limit on contingency fees was enacted in Nevada (November 23rd, 2004).

Figure 2.11: College and Higher Average Infant Mortality Rate



Note: The first vertical line represents May 2003 when eighty percent of voters in Nevada said they would support limiting contingency fees. The second vertical line represents when the limit on contingency fees was enacted in Nevada (November 23rd, 2004).

Appendix 2.1

Table A2.1: Raw Average Annual Medicaid Physician Fee Schedule for Nevada

Year	Vaginal Delivery	C-Section Delivery	Price Difference
1995	$ 1032.23	$ 1219.87	$ 187.64
1996	1032.23	1219.87	187.64
1997	1032.23	1219.87	187.64
1998	1032.23	1219.87	187.64
1999	1032.23	1219.87	187.64
2000	1032.23	1219.87	187.64
2001	1032.23	1219.87	187.64
2002	1032.23	1219.87	187.64
2003	1032.23	1219.87	187.64
2004	1032.23	1219.87	187.64
2005	1032.23	1219.87	187.64
2006	1032.23	1219.87	187.64
2007	1032.23	1219.87	187.64
2008	956.96	1130.92	173.96
2009	806.42	953.01	146.59
2010	806.42	953.01	146.59
2011	806.42	953.01	146.59
2012	806.42	953.01	146.59

Note: Monthly data is provided by Alexander (2015).

Chapter Three

A Re-Examination of the Effects of Tort Reforms on Obstetrical Procedures and Health Outcomes

3.1 Introduction

Numerous studies have been conducted regarding medical malpractice fears altering physicians' choice of procedure, especially in high-risk specialties. Tort reforms attempt to alleviate this situation by reducing physicians' defensive medicine practices. While Currie and MacLeod's (2008) renowned paper on this subject has been widely cited and remains the central economic reference on the effect of tort reforms on health outcomes, it focused on the effect of tort reforms in the 1990s. Since then the American Medical Association classified 18 states as being in a medical malpractice "crisis" due to both a lack of available malpractice insurers as well as sky-rocketing insurance premiums, and an additional 26 states as showing concerns (Mello et al., 2003). The latest crisis saw many states adopt tort reforms to relieve liability pressures on physicians.[29]

[29]Appendix 3.1 provides explanations on the four most studied medical malpractice tort reforms.

A substantial amount of states had adopted tort reforms since then and it is worth investigating how tort reforms affect obstetrical procedures and health outcomes in the early twenty-first century. Obstetricians and gynecologists (OBGYNs), one of the most frequently sued specialties, have been questioned on whether they alter their behaviours by engaging in defensive medicine (Peckham, 2015). In a recent survey half of obstetricians admitted to making changes to their practice as a result of the risk or fear of being sued. Of those, seventeen percent reported increasing the number of C-section deliveries due to liability risks (Carpentieri et al., 2015).

This paper investigates how tort reforms affect physicians' choice of procedure in labour and delivery as well as health outcomes in the early twenty-first century. I find that caps on non-economic damages have a much smaller effect on C-section procedures than what Currie and MacLeod (2008) found in the past. Their largest estimate came from the "joint and several" liability rule, wherein they find a large negative and statistically significant effect on C-section rates. Updating their work, I do not find the "joint and several" liability rule statistically significant during our sample period. Thus, tort reforms that helped mitigate past malpractice crises may not be as effective as they once were. In addition, I find further evidence that obstetrical procedures are influenced by tort reforms.

This paper provides a more current and comprehensive analysis of the effect of tort reforms on obstetrical procedures and health outcomes than previous works. This paper also advances current literature by examining infant mortality; past papers use Apgar scores to study infant health, as they are a reliable predictor of infant mortality (Almond, Chay, and Lee, 2005).[30] This study uses actual infant mortality data and does not rely on Apgar scores as the

[30] An Apgar score is a measure from zero to ten that summarizes the health of a baby. It stands for Appearance, Pulse, Grimace, Activity, and Respiration.

outcome variable for infant health. Moreover, although the consensus is that infant health outcomes are unaffected by tort reform (see Currie and MacLeod, 2008; Frakes, 2012; Sloan et al., 1995; Yang et al., 2012), I find the collateral source rule improves infant health.

The next section describes the data used, followed by a discussion of the empirical methods in Section 3.3. Section 3.4 presents the results on the impact of tort reforms. The paper ends with a conclusion in Section 3.5.

3.2 Data

3.2.1 Vital Statistics

My primary data come from a ten percent random sample of the United States Linked Birth and Infant Death Records for all fifty states and the District of Columbia from 1995-2012 (N=5,693,477).[31] I examine whether the patient is given a C-section, induction, had a "preventable" complication, or a breech delivery. I define a "preventable" complication as a patient with meconium, or precipitous labour.[32] Both could potentially be preventable, whereas a breech birth, for instance, is not caused by a physician's procedural choices. I also examine the incidence of low birth weight, and infant mortality.

I categorize patient's "riskiness", defined as a mother suffering from any of the following conditions: diabetes, chronic hypertension, pregnancy hypertension, or eclampsia.[33] These

[31] These data have virtually all infant deaths under one year of age linked to detailed birth certificate data. Around only two percent of infant deaths that occur in the United States cannot be linked to birth certificates.
[32] Meconium is when the baby has had its first stool still inside the mother's womb and this can cause serious health problems if left untreated. Precipitous labour is defined as expulsion of the fetus within less than 3 hours of commencement of contractions. A breech position is when the baby is feet first facing the vagina as opposed to head first. A breech position makes vaginal delivery dangerous.
[33] Diabetes is a metabolic disease in which the body's inability to produce any or enough insulin causes elevated levels of glucose in the blood. Chronic hypertension is defined as a long-term condition of having blood pressure greater than 140/90 mm Hg. Pregnancy hypertension is the development of new hypertension in a pregnant woman after 20 weeks gestation without the presence of protein in the urine or other signs of pre-eclampsia. Eclampsia is a

conditions are known prior to labour and may affect physicians' procedural choice. Since only medical doctors can perform C-sections, I limit my sample to births attended by a medical doctor, which constitutes around ninety percent of births in the United States.[34]

The Vital Statistics data are detailed and thus allow us to control for many factors. I account for mother's education by creating indicator variables for high school dropouts, as well as those with a college degree or higher. I also account for the differences in health for Caucasian, Hispanic, and African American women.[35] In addition to mother's education and race, other explanatory variables include age, mother's marital status, smoking during pregnancy, and the sex of the baby.

Other dummy variables indicate whether there is at least one previous C-section, whether the pregnancy is a singleton birth, and whether the pregnancy is the first birth for the mother. These variables may affect a physician's decision regarding appropriate care as well as the ultimate health outcomes.[36]

3.2.2 Tort Reform

I use the fifth edition of the Database of State Tort Law Reforms to characterize the different medical malpractice tort reforms enacted each year in each state. This database

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condition in which one or more convulsions occur in a pregnant woman suffering from high blood pressure, often followed by coma and posing a threat to the health of both mother and baby.

[34] Around eight percent of birth attendants are midwives.

[35] Around only five percent of mothers identified themselves as "other race" and they were dropped from our sample. For example, Asians and Native Americans are both considered in the "other race" category, but may have very different backgrounds.

[36] For example, many physicians do not prefer a vaginal birth if the mother has previously had a C-section. In the 1990s, the American College of Obstetricians and Gynecologists (ACOG) recommended that physicians not perform vaginal deliveries after a patient has previously had a C-section. Even though the ACOG's guidelines no longer discouraged vaginal birth after Caesarean (VBAC) since 2010, VBACs remain relatively less common (see Barger et al. 2013).

contains the most detailed, complete, and comprehensive information on state tort reforms.[37] In this study state-year level indicator variables are created to account for the presence of caps on punitive damages (PD), caps on non-economic damages (NED), the elimination of the "joint and several" liability (JSL) rule, and the collateral source rule (CSR). Table 3.1 displays the means for all my data categorized by births, "risky" patients, and the abovementioned tort reforms.

3.3 Empirical Methods

I use linear probability models to examine the effect of tort reforms on obstetrical procedures and health outcomes. With such a large dataset, I include county fixed effects, as well as state specific time trends. My model can be expressed as:

(1) $$Y_{it} = \beta_0 + \beta_1 TORT_{st} + \beta_2 X_{it} + \beta_3 YEAR + \beta_4 STATE * TIME + \beta_5 COUNTY + \varepsilon_{it}$$

Where Y_{it} represents the various outcomes of interest for individual *i* in year *t*: C-section, induction, preventable complications, breech position, low birth weight, and infant mortality (i.e. death within first year of life). The main variables of interest, $TORT_{st}$, are the various tort reform for state *s* in year *t* mentioned in the previous section. The X_{it} vector includes controls for the mother's socioeconomic characteristics, as well as for the labour and delivery, mentioned in Section 3.2.1.[38] I also control for the month and day of the week of delivery since research has shown that babies born on weekends experience worse health outcomes (Palmer et al., 2015).

$YEAR$ is simply a vector of year indicators, whereas $STATE * TIME$ are state-specific linear time trends that allow each state to be on different trajectories as opposed to the year

[37] It has become the gold standard in empirical tort reform research by providing a review of original legislation and case law with exact text and effective dates. See Avraham's (2014) Database of State Tort Law Reforms (5th) for more information on the tort reform dataset. Appendix A provides an explanation of the most prevalent tort reforms used in medical malpractice research (see Dubay et al., 1999; Kessler and McClellan, 1996; Avraham et al., 2012; Iizuka, 2013).

[38] I account for race, mother's education, age, and marital status. I also control for mother's "riskiness" at the time of labour, if it is a singleton birth, the first birth of the mother, the mother previously had a C-section, smoked during the pregnancy, and the child's sex.

indicators that are the same across states. Moreover, the county fixed effects allow for the control of geographic variation that occurs from differences in access to medical services and physician practice patterns (Newhouse and Garber, 2013). Lastly, standard errors are clustered at the state level to account for the variation in tort reforms.

In addition to estimating the specification in equation (1) with all four tort reforms simultaneously, I also estimate the effect of each reform separately with the same controls mentioned above. I also re-estimate equation (1) but separated by those patients considered "risky" and "non-risky". These estimates identify the effect of tort reform on physicians' procedural choice when their discretion is questionable (in non-risky cases) versus when it is not (risky cases). As a robustness check I also remove large states one at a time to ensure that results are not driven by a few large states.

3.4 Results

Table 3.2 provides the main results from equation (1), where panel (a) is the main regression with all four tort reforms in the same model, whereas panel (b) is listing the effects of each tort reform estimated separately without the others.[39] In the first column of panel (a), examining the effect of tort reforms on C-sections, I find that caps on punitive damages, as well as caps on non-economic damages has statistically significant effects; there is a roughly three percent decrease and a two percent increase in the probability of C-section, respectively. Interestingly, caps on non-economic damages have a smaller effect than it did in previous

[39] Coefficients are multiplied by 100 for consistency with Currie and MacLeod's (2008) work.

decades.[40] Thus, tort reforms that helped mitigate past malpractice crises may not be as effective today.

Currie and MacLeod's (2008) largest estimate came from the "joint and several" liability rule, wherein they found a large negative statistically significant effect on C-sections. Updating their work, I find the "joint and several" liability rule is not statistically significant during my sample period.[41] It is likely that the elimination of the "joint and several" liability rule in the 1990s makes the enactment of the same tort reform in the early 21st century ineffective. Lawyers understand that going after the "deepest pocket" is no longer appropriate and, instead, sue defendants for the proportional amount of malpractice; the "joint and several" liability rule has become somewhat of a formality.[42]

The effect of tort reforms on induction (column 2) and breech (column 4) are all statistically insignificant which is expected.[43] Conversely, caps on punitive damages and caps on non-economic damages statistically effect preventable complications (column 3). Column 5 and 6 examine the effect of tort reforms on infant health. Here we find that the collateral source rule has a negative and statistically significant effect on both low birth weight and infant mortality; while having no statistically significant effect on maternal delivery procedures.[44] As a

[40] Currie and MacLeod's (2008) coefficient for caps on non-economic damages, 1.20, is twice as large as my coefficient of 0.60. With a 29.8 percent probability of C-section between 1995 and 2012, the implied percentage effect of capping non-economic damages is two percent, down from the five percent increase Currie and MacLeod found.

[41] While Currie and MacLeod found a seven percent decrease in the probability of C-section, I find an increase of 0.2 percent that is statistically insignificant.

[42] Forty states at the end of my sample period have this tort reform enacted.

[43] Deciding to induce a pregnant woman into labour usually occurs when the woman has reached 42 weeks gestation or has a serious complication such as preeclampsia, which is unlikely to be caused by the physician's decisions. Also, a breech position is considered a complication that is "not preventable" by a physician, thus physicians would not be motivated or influenced by these tort reforms.

[44] There is a small 1.8 percent and large 10 percent decrease in low birth weight and infant mortality, respectively. It is noted that the ten percent decline in the infant mortality is due to a very small mean consisting of 6 deaths in every 1000 live births, thus the large decline is misleading.

robustness check large states are individually removed one at a time with no substantial change to my results in Table 3.2 panel (a).

When examining panel (b) of Table 3.2 we observe that, although the corresponding coefficients for each tort reform are not the same in comparison to panel (a), they are relatively similar in that the signs do not change, the estimates are fairly similar in magnitude, and, for the most part, the same reforms are still significant except for the case of caps on punitive damages.[45]

Table 3.3 follows the same methods as Table 3.2 panel (a), however the data have been sub-grouped by patient "riskiness".[46] Based on Table 3.3 we observe that the overall effects of tort reform are occurring via non-risky patients. This follows the hypothesis that physicians have little discretion or procedural choice when it comes to risky patients, but are influenced by tort reforms for those patients on the margin. An interesting estimate worth noting is that the "joint and several" liability reform is never statistically significant in the previous table but in Table 3.3 it is not only statistically significant but the estimate is going in the opposite direction for risky C-section versus non-risky C-section. This implies that physicians who will now be responsible for their proportional negligence are 3.2 percent more likely to provide C-sections for their risky patients than prior to the reform.

3.5 Conclusion

This paper aims to examine the effect of tort reforms on obstetrical procedures and health outcomes in the early twenty-first century. Numerous papers examine the effects of tort reforms

[45] Anecdotal evidence suggests that punitive damage caps do not play as large a role as other tort reforms specifically in medical malpractice cases involving physicians because punitive damages are meant to punish those found guilty of wilful or intentional harm.

[46] Patient "riskiness" is defined as any patient having diabetes, chronic hypertension, pregnancy hypertension, or eclampsia at the time of labour. See footnote 33 for a description of these conditions.

on physician behaviour using data from the 1980s and 1990s. However, since then the United States experienced a medical malpractice "crisis" in the early 21^{st} century, which saw many states adopt tort reforms to alleviate this issue. Using current data, I observe that tort reforms are not as effective as they once were. I also find solid evidence that physicians' procedural choices are affected by tort reforms.

3.6 References

Almond, D., K. Chay and D. Lee. 2005. "The Costs of Low Birth Weight." *Quarterly Journal of Economics* 120(3):1031–83.

American College of Obstetricians and Gynecologists. 2010. "ACOG Practice bulletin no. 115: Vaginal birth after previous cesarean delivery." *Obstetrics and Gynecology* 116(2): 450.

Avraham, R. 2007. "An Empirical Study of the Impact of Tort Reforms on Medical Malpractice Settlement Payments."*Journal of Legal Studies* 36(S2): S183-S229.

Avraham, R. 2014. "Database of State Tort Law Reforms 5th Ed." University of Texas School of Law: Law and Economics Research Paper No.e555.

Barger, M. K., J. T. Dunn, S. Bearman, M. DeLain, and E. Gates. 2013. "A survey of access to trial of labour in California hospitals in 2012." *BMC Pregnancy Childbirth* 3(13):83.

Carpentieri, A. M., J. J. Lumalcuri, J. Shaw, and G. F. Joseph Jr. 2015. "Overview of the 2015 American Congress of Obstetricians and Gynecologists' Survey on Professional Liability." American College of Obstetricians and Gynecologists Clinical Review (Nov/Dec Issue).

Currie, J., and W. B. MacLeod. 2008. "First do no harm? Tort reform and birth outcomes." *Quarterly Journal of Economics* 123(2): 795–830.

Dubay, L., R. Kaestner, and T. Waidmann. 1999. "The Impact of Malpractice Fears on Cesarean Section Rates." *Journal of Health Economics* 18: 491-522.

Frakes, M. 2012. "Defensive medicine and obstetric practices." *Journal of Empirical Legal Studies* 9 (3): 457–481.

Iizuka, T. 2013. "Does Higher Malpractice Pressure Deter Medical Errors?" *Journal of Law and Economics* 56: 161-188.

Kessler, D., and M. McClellan. 1996. "Do Doctors Practice Defensive Medicine?" *Quarterly Journal of Economics* 111: 353-390.

Mello, M. M., D. S. Studdert, and T. A. Brennan. 2003. "The New Medical Malpractice Crisis." *New England Journal of Medicine* 348(23): 2281-2284.

National Center for Health Statistics. Linked Birth and Infant Death, 1995-2012, as compiled from data provided by the 57 vital statistics jurisdictions through the Vital Statistics Cooperative Program.

Newhouse, J. P., and A. M. Garber. 2013. "Geographic Variation in Medicare Services." *New England Journal of Medicine* 368: 1465-1468.

Palmer, W., A. Bottle, and P. Aylin. 2015. "Association between day of delivery and obstetric outcomes: observational study." *British Medical Journal* 351: h5774.

Peckham, C. 2015. "Medscape Malpractice Report 2015: Why Most Doctors Get Sued." WebMD Health Professional Network. Available at http://www.medscape.com/features/slideshow/public/malpractice-report-2015.

Sloan, F., S. S. Entman, B. A. Reilly, C. A. Glass, G. B. Hickson, and H. H. Zhang. 1995. "Tort liability and obstetricians' care levels." Duke University, Department of Economics, Working Papers: 95-107.

Yang Y. T., D. S. Studdert, S. V. Subramanian, and M. M. Mello. 2012. "Does Tort Law Improve the Health of Newborns, or Miscarry? A Longitudinal Analysis of the Effect of Liability Pressure on Birth Outcomes." *Journal of Empirical Legal Studies* 9(2):217–245.

Table 3.1: Means of Key Variables by Law in Effect at Time of Birth or Risk Group

	All States	Risky Patients	PD Cap Present	NED Cap Present	JSL Reform Present	CSR Reform Present
(a) Outcomes						
C-Section	0.298	0.457	0.303	0.306	0.301	0.296
Induction	0.216	0.377	0.228	0.212	0.213	0.213
Preventable Complication	0.067	0.061	0.067	0.063	0.065	0.068
Breech	0.049	0.071	0.049	0.054	0.050	0.048
Low Birth Weight (< 2500 grams)	0.083	0.167	0.086	0.081	0.081	0.080
Infant Mortality	0.006	0.006	0.006	0.006	0.006	0.006
(b) Demographic Variables						
Male	0.512	0.518	0.512	0.512	0.512	0.512
Singleton Birth	0.965	0.938	0.965	0.965	0.965	0.964
First Child	0.331	0.360	0.329	0.332	0.330	0.328
Previous C-Section	0.129	0.157	0.129	0.133	0.131	0.129
Risky Patient	0.085	1.000	0.089	0.083	0.084	0.084
Smoked During Pregnancy	0.096	0.092	0.103	0.076	0.089	0.089
Hispanic	0.232	0.196	0.206	0.302	0.270	0.250
African American	0.160	0.180	0.179	0.133	0.144	0.130
High School Dropout	0.208	0.171	0.204	0.222	0.218	0.201
College Degree or Higher	0.269	0.275	0.270	0.270	0.262	0.281
Teenager	0.110	0.078	0.113	0.106	0.110	0.099
Forty and Older	0.025	0.045	0.023	0.026	0.025	0.027
Married	0.633	0.658	0.628	0.629	0.631	0.640
Observations	5693477	484859	3255721	2547267	4319588	3654498
(c) Tort Reform Measures						
PD cap	0.498		1.000	0.557	0.529	0.500
NED cap	0.403		0.451	1.000	0.486	0.476
JSL Reform	0.737		0.783	0.889	1.000	0.767
CSR Reform	0.632		0.635	0.746	0.657	1.000
Number of State-Time Observations	918		457	370	677	580

Notes: PD= Punitive damages; NED= Non-economic damages; JSL= Joint and several liability; CSR= Collateral source rule. "Risky" patient is defined as a patient that has diabetes, chronic hypertension, pregnancy hypertension, or eclampsia.

Table 3.2: Effects of Tort Reforms on Obstetrical Procedures and Health Outcomes

Procedures	C-section		Induction	Preventable Complications		Breech	Low Birth Weight		Infant Mortality	
				(a) Overall effects, four laws entered						
Any PD cap	-0.98	*	0.24	0.78	*	0.15	-0.01		0.02	
	(0.50)		(0.84)	(0.45)		(0.40)	(0.07)		(0.02)	
Any NED cap	0.60	*	0.69	-0.38	*	0.50	0.09		-0.02	
	(0.32)		(0.73)	(0.23)		(0.82)	(0.09)		(0.02)	
JSL reform	0.06		-1.17	-0.40		-0.49	-0.01		0.02	
	(0.34)		(1.12)	(0.29)		(0.49)	(0.11)		(0.03)	
CSR reform	0.63		-0.04	-0.18		-0.16	-0.15	**	-0.06	***
	(0.41)		(0.63)	(0.23)		(0.21)	(0.07)		(0.02)	
R-squared	0.297		0.061	0.006		0.039	0.138		0.004	
Observations						5693477				
	(b) Effects with tort laws entered separately (each cell from a separate regression model)									
Any PD cap	-0.74		0.14	0.58		0.13	-0.01		0.01	
	(0.55)		(0.85)	(0.44)		(0.41)	(0.07)		(0.02)	
Any NED cap	0.55	**	0.38	-0.42	*	0.36	0.08		-0.02	
	(0.27)		(0.76)	(0.27)		(0.71)	(0.08)		(0.02)	
JSL reform	0.35		-0.75	-0.50		-0.22	-0.0002		-0.1	
	(0.31)		(0.85)	(0.31)		(0.24)	(0.06)		(0.03)	
CSR reform	0.56		-0.30	-0.26		-0.21	-0.14	**	-0.06	***
	(0.47)		(0.48)	(0.20)		(0.23)	(0.05)		(0.02)	

Notes: Coefficients and standard errors multiplied by 100. Linear probability model includes month, year, and county fixed-effects, and state specific time trends. Standard errors are clustered at the state level. "Preventable" complications are when meconium occurs or precipitous labour. Low birth weight is defined as any baby being born weighing less than 2,500 grams. * Significant at the 10% level; ** Significant at the 5% level; *** Significant at the 1% level.

Table 3.3: Effects of Tort Reform Subgrouped by Patient Riskiness

	Non-Risky C-Section	Risky C-Section	Non-Risky Preventable Complications	Risky Preventable Complications	Non-Risky Low Birth Weight	Risky Low Birth Weight	Non-Risky Infant Mortality	Risky Infant Mortality
Any PD cap	-0.97 *	-0.85	0.79 *	0.66	0.06	-0.55	0.03	-0.15
	(0.50)	(0.65)	(0.47)	(0.41)	(0.08)	(0.37)	(0.03)	(0.09)
Any NED cap	0.65 **	0.13	-0.38	-0.39	0.13	-0.36	-0.03	0.08 *
	(0.31)	(0.46)	(0.24)	(0.31)	(0.08)	(0.42)	(0.02)	(0.05)
JSL reform	-0.06	0.96 **	-0.41	-0.34	-0.004	-0.02	0.01	0.11
	(0.35)	(0.40)	(0.29)	(0.44)	(0.13)	(0.35)	(0.04)	(0.07)
CSR reform	0.61	0.96	-0.23	0.42	-0.18 **	0.06	-0.06 ***	-0.05
	(0.46)	(0.61)	(0.25)	(0.27)	(0.08)	(0.24)	(0.02)	(0.07)
R-squared	0.298	0.218	0.006	0.009	0.133	0.118	0.005	0.002
Observations	5208618	484859	5208618	484859	5208618	484859	5208618	484859

Notes: Coefficients and standard errors multiplied by 100. Linear probability model includes month, year, and county fixed-effects, and state specific time trends. Standard errors are clustered at the state level. "Preventable" complications are when meconium occurs or precipitous labour. Low birth weight is defined as any baby being born weighing less than 2,500 grams. "Risky" patient is defined as a patient that has diabetes, chronic hypertension, pregnancy hypertension, or eclampsia. * Significant at the 10% level; ** Significant at the 5% level; *** Significant at the 1% level.

Appendix 3.1

Description of Common Medical Malpractice Tort Reforms:

Punitive damages refer to damages awarded for the purpose of punishment, to deter intentional or reckless behaviour or actions motivated by malice. Punitive damages are neither economic nor non-economic damages, as they are not awarded to compensate any loss. Tort reforms are enacted to cap this amount.

Non-economic damages refer to compensation for subjective, non-monetary losses such as pain, suffering, inconvenience, emotional distress, loss of society and companionship, loss of consortium, and loss of enjoyment of life. Tort reforms are enacted to cap this amount.

"Joint and several" liability rule ("deep pockets rule") is a theory of recovery that permits a plaintiff to recover full damages from any defendant regardless of their proportional fault. It's known as the "deep pockets rule" because a plaintiff would most probably choose to go after the defendant with the "deepest pocket". Tort reforms are enacted to either impose that liability be based on the defendant's individual fault, or the joint and several rule can be applied if the defendant is responsible for at least fifty percent of the damage caused.

Collateral source rule: prohibits the admission of evidence that the plaintiff or victim has received compensation from some source other than the damages sought against the defendant. Tort reforms are enacted to remove this rule so that courts may offset awarded damages if the victim is receiving compensation from other sources.

Conclusion

My work examines the effects of several policy interventions on the health of women and children. In particular, this thesis consists of three essays, each examining different government regulations. First, I examine the effect of a reduction in coal-fired power plant emissions on infant health outcomes of downwind counties. Second, I analyze how limiting lawyers' contingency fees affects physicians' decision to perform C-sections on women and, ultimately, its effect on infant mortality. The third, and final, paper investigates whether or not medical malpractice tort reforms have altered physicians' decision to take part in defensive medicine.

Chapter 1 examines the Clean Air Interstate Rule (CAIR) which mandated the reduction of power plant emissions in the eastern United States. This policy improved air quality in neighbouring downwind counties, greatly reducing exposure to a specific form of pollution—fine particulate matter. I investigate the impact of this reduction exposure on birth outcomes using data from the U.S. Natality Detail Files. I find that female babies experience improvements in premature birth and low/very low birth weight status which are driven by the reduction in prematurity. I also focus on full-term babies to better isolate the impact of prematurity from fetal growth on birth weight. Consistent with recent work, I find that full-term male babies experience an increase in birth weight, demonstrating an improvement in intrauterine growth due to lower exposure to fine particulates. Finally, I find a reduction in infant mortality for babies whose mothers were categorized as "high-risk" pregnancies, suggesting that reduced exposure may lead to improved birth outcomes among those most at risk.

Chapter 2 analyzes a limit on contingency fees for lawyers in medical malpractice cases enacted in Nevada. Generally, such limits are thought to change the composition of liability cases as they induce lawyers to drop more frivolous cases in favour of ones involving death and serious injury. Inadvertently, obstetricians faced a greater fear of litigation. Applying synthetic control methods, I find a 2.8 percentage point increase in the C-section rates of high school dropout patients, translating to a ten percent increase after the reform. There is no statistically significant difference in C-section rates after the enactment of the reform on patients with at least a college degree, and further, no statistically significant effect on infant mortality. Limiting contingency fees in medical malpractice cases induces obstetricians to engage in defensive medicine by performing more C-sections on low income patients, illustrating that tort reform can alter physician procedural patterns, albeit in heterogeneous ways.

Chapter 3 continues with the theme of government regulated policy intervention by examining the effect of popular medical malpractice tort reforms on maternal and infant health. Numerous papers examined the effects of tort reform on physician behaviour using data from the 1990s. However, a medical malpractice "crisis" in the early 21st century saw many US states adopt tort reforms to alleviate this issue. Using data from 1995 to 2012 I observe that tort reforms are not as effective as they once were. However, I find evidence that physicians' procedural choices are affected by tort reforms. Not only are C-section rates and "preventable" complications affected by tort reforms, but I also observe that tort reforms influence physicians' decisions with non-risky patients.

This thesis provides evidence that infant and maternal health is sensitive to government regulated policy intervention. Changes in the physical environment (i.e. pollution), as well as the legal environment (i.e. medical malpractice tort reform), have strong effects on infant and maternal health. It is, thus, imperative that policy interventions continue to be researched, especially for the most vulnerable members of society: newborn babies.