**IMPACTS OF MEDICAID EXPANSION ON
THE LIABILITY INSURANCE INDUSTRY**

A Dissertation
Submitted to
the Temple University Graduate Board

In Partial Fulfillment
of the Requirements for the Degree
DOCTOR OF PHILOSOPHY

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August 2020

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ABSTRACT

This dissertation studies the impact of Medicaid expansion on the liability insurance industry. Within the three chapters, the first two chapters focus on the medical liability insurance industry, and the third chapter focuses on the auto insurance industry.

Chapter 1, “Medicaid Expansion and Medical Liability Costs”, examines the impact of health insurance expansion on medical liability costs using the case of the Affordable Care Act’s (ACA) Medicaid expansion. Medicaid expansion has increased the demand for medical services, but in doing so it may also have increased physicians’ liability in medical practice. By studying malpractice costs to insurers, medical practitioners, and hospitals in the U.S. for the period 2010–2018, we find insurers operating in states with Medicaid expansion experienced significantly higher medical liability costs than those in non-expansion states. While insurers in expansion states did increase premiums, the increase was not enough to fully offset rising costs. Moreover, we find that tort reforms did not mitigate ACA-induced malpractice liability costs. We show this is because Medicaid expansion increased malpractice costs mainly by increasing claim frequency while tort reforms generally focus on reducing claim severity. We further find little evidence that hospitals paid higher malpractice insurance premiums, self-insurance, or incurred higher out-of-pocket medical liability losses after Medicaid expansion. Taken together, our results imply that it is medical practitioners and malpractice insurers who bear the rising medical liability costs.

Chapter 2, “Medicaid Expansion and Medical Liability Insurance Prices” extends the first chapter to study the impact of Medicaid expansion on medical liability insurance

prices for three specialties, internal medicine, general surgery, and obstetrics-gynecology (OB-GYN). As Medicaid expansion increased medical liability costs to insurers, they may react by increasing medical malpractice insurance prices. By studying counties in expansion states and non-expansion states and bordering counties with different Medicaid expansion status over the years from 2010-2018, we find that Medicaid expansion leads to significantly higher medical liability insurance prices two years after the expansion on average and the impact is strongest for internal medicine and general medicine but less so for OB-GYN. Our finding suggests that the expansion of health insurance could increase liability costs to medical practitioners.

Auto insurance provides coverage of healthcare for injured drivers even for those without traditional health insurance coverage. The expansion of public health insurance provides low-income injured drivers with an additional source of coverage for medical bills. This may change drivers' incentives for using auto insurance and the ultimate payments made by auto insurers. In Chapter 3, "Public Health Insurance Expansion and Auto Insurance: The Case of Medicaid Expansion", we first use a simple theoretical model to illustrate how obtaining public health insurance mitigates the incentive of insured drivers to engage in claims buildup. We then empirically test how the Affordable Care Act (ACA)'s Medicaid expansion changed the medical costs covered by auto insurance. By studying private passenger auto insurers in expansion states and non-expansion states between 2010 and 2018, we find that Medicaid expansion led to significantly lower auto insurance losses and premiums. We further show that the results were driven by the decreasing losses and premiums for third-party liability insurers but not in the states with no-fault insurance.

This Dissertation is dedicated to my parents and my grandparents.

ACKNOWLEDGMENTS

At the outset of this dissertation and the end of my journey as a Ph.D. student, I would like to extend my appreciation to those who have helped me during the last four years at Temple University. I would not be in this position I am now without their support.

First of all, I would like to express my deepest gratitude to my dissertation committee chair, Dr. Martin Grace. As my advisor and mentor, he has taught me more than I could ever give him credit for. His profound knowledge in Risk Management and Insurance (RMI), Economics, and Law exposed me to various research topics and helped me develop my dissertation topic. He encouraged me to be an independent researcher while he was always there giving me timely help and advice. I cannot remember how many times that I knocked his office door and asked if he had a minute for a quick meeting, which usually turned out to be a long discussion until all my concerns were resolved. Pursuing a Ph.D. degree is not easy, but having a patient, enthusiastic, and humorous advisor like Dr. Grace makes my Ph.D. journey full of joy.

My sincere appreciation also goes to my dissertation committee members who provided me with extensive personal and professional guidance. I would like to thank Dr. Hua Chen for trusting and working with me since I was a simple-minded first-year student. Dr. Chen's rigorous attitude when we worked on projects showed me the right path to do research. He also made every possible effort to support me to achieve my goals and get through the stressful time when I was on the job market. I would like to thank Dr. Cameron Ellis for bringing me to the world of public policy research and for giving me constructive suggestions to each of my dissertation chapter. I also benefited a lot from brownbag seminars, reading groups, and research group meetings that he organized. During my years at Temple, Dr. Mary Weiss always saw my potential in doing unique research. Her encouragement largely boosted my confidence and inspired me to be a researcher like her. I am also thankful for her going through almost unbelievable details of each version of my dissertation. Moreover, I am grateful to Dr. Catherine Maclean who agreed to be my outside dissertation member and came up with many important suggestions.

I have received a lot of help from other colleagues in the Risk, Insurance, and Healthcare Management department. A series of research seminars offered by Dr. David Cummins introduced me to RMI research in multiple subfields and helped me gain presentation and analytical skills that are essential for Ph.D. students. The Ph.D. coordinator, Dr. Randy Dumm helped me prepare my job market materials and gave me support when I searched for jobs. I am very grateful for all his help. I would like to thank the department Chair Dr. Rob Drennan for his financial support and for his rigorous training when I worked as his teaching assistant. I am also thankful for Professor Storm Wilkins who generously allowed me to observe her teach and shared her teaching philosophy with me. The way she engages students in the class sets a role model for me.

In addition, I have been very grateful for the interdisciplinary research environment that the Fox School of Business provided. Through well-designed Ph.D. courses and school-wide events, I got a chance to know scholars in other research areas and obtained insightful advice from them. Dr. Sudipta Basu from Accounting always gave me stimulating feedback during young scholar forums and yearly research competitions. Dr. Rajiv Banker from Accounting guided me to think out of boxes and worked with me on multiple interdisciplinary research projects. Dr. Oleg Rytchkov from Finance helped me build my econometrics foundation of my research and gave me helpful advice before my job interviews. In addition, I would like to acknowledge the help of all staff members from the research office especially Lisa Fitch for her kindness.

Outside Temple, a special thanks goes to my advisor Dr. Jason Barr at Rutgers University, Newark for bringing me as an undergraduate student to the academia in 2014 and keeping supporting me since then. He is my first coauthor of my first publication. The four golden rules in academia he summarized and gave to me have been guiding and motivating me all the way. I am also grateful for Dr. Gene Lai from the University of North Caroline, Charlotte. He introduced me to the world of RMI research. He gave me continuous support by coming to each of my presentation at the ARIA meeting and witnessed each important step during my Ph.D. journey. I am further thankful for Dr. Jun Wang at Baruch College-the City University of New York for giving me the chance to teach there and helping me find my enthusiasm in teaching.

My life outside research is enriched by many friends and cohorts. I have received a lot of help in coursework and research from great school mates Sabrina Du, Juan Zhang, and Xuesong You and senior students especially Ying Peng and Yingrui Lu. I enjoyed our trips together to different conferences and our conversations in the cubicle. My Ph.D. journey would be less enjoyable without them. I would also thank my house-mates Alex Rawji, Leanne Susan, Kristin Peterson, and Christine Lai for giving me the feeling of home and supporting me during the pandemic. As M.D., Alex and Leanne shared their experience as medical practitioners with me and provided me with very helpful institutional background when I worked on my first two chapters of dissertation about medical liability.

Finally, I would like to thank my parents, Zhongcheng Luo and Xuemei Deng, and my grandparents, Huarong Deng and Jinxiu Zhong for their endless love and support. They are priceless gift to me. I would like to thank my uncle Haizhi Deng, aunt Dongli Tu, their parents, Huanian Deng and Youlan Xiao, and my little cousin Charles Deng, for giving me a lovely and caring family in New York. Also, my boyfriend, Suerfu, thanks for bringing me so much happiness. I am blessed to have him in my life.

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CHAPTER 1

MEDICAID EXPANSION AND MEDICAL LIABILITY COSTS

1.1 Introduction

Medical liability arises from interactions between physicians and patients. Given physicians' capacity constraints, new demanders for healthcare might strain available medical resources, thus increasing the risk of malpractice. While this is a sensible supposition, the evidence of such a relationship is scarce. In this paper, we explore the effect of health insurance expansion on medical liability costs using the case of Medicaid expansion from the Affordable Care Act (ACA). We find that insurers operating in states with Medicaid expansion experienced significantly higher malpractice costs than those in non-expansion states, and this negative impact was not mitigated by tort reform.

Medical malpractice claims are common. Nearly half (49.2%) of physicians aged 55 and older were sued during their careers (Guardado, 2017a). The overall costs associated with medical liability, including defensive medicine, are estimated to be $55.6 billion per year (Mello et al., 2010). As a result, there have been at least three waves of reforms attempting to limit liability for medical injuries. Nevertheless, evidence shows a recent increase in medical liability costs. For instance, West Virginia witnessed a 219% increase in medical liability insurance losses since 2014 (Mcvey, 2019). A similar increase also occurred in Washington state, where the loss ratio in the medical liability insurance market peaked in 2017 (Kreidler, 2018). Our paper investigates whether these increases were driven by Medicaid expansion and asks the question of whether the increases are ameliorated by tort reforms.

The ACA has no provision related to medical malpractice, but it may drive up medical liability costs substantially. With over 20 million new insureds, physician visits, and health service utilization have largely increased (Chirba and Noble, 2013; Auerback, Heaton, and Brantley, 2014). However, physician supply grew at a much lower rate (Kirch et al., 2012; Dall et al., 2018). The mismatch of changes in physician demand and supply might exacerbate the existing physician shortage in the U.S. (Huang and Finegold, 2013; Dall et al., 2018; Courtemanche et al., 2019a). A direct consequence is that physicians spend less time with each patient. Evidence from the 2018 Survey of America's Physicians shows that 80% of physicians are at capacity or are overextended and that 78% of physicians (sometimes, often or always) experience feelings of burnout (The Physicians Foundation, 2018). This capacity constraint affects not only the newly insured but also all other patients, potentially causing medical liability costs to increase significantly after Medicaid expansion.

We also explore the interaction between health insurance reforms and state tort systems. The liability system is a function of the health insurance environment (Kessler and McClellan, 2002b) and Medicaid expansion has changed the environment significantly. While we expect that Medicaid expansion increases medical liability costs, tort reforms, in contrast, are designed to limit the liability or censor the right tail of the award distribution. Evidence exists that some reforms, such as caps on non-economic damages, have reduced medical malpractice claim losses and pressures (e.g., Born, Viscusi, and Baker, 2009; Grace and Leverty, 2013; Paik, Black, and Hyman, 2017; Bertoli and Grembi, 2019). In this paper, we investigate whether insurers in expansion states with a specific tort reform experienced lower medical liability costs than their counterparties in states without specific tort reform.

To proxy medical liability costs, we mainly use medical malpractice insurance claim losses and associated costs incurred to insurers and insured physicians in each state. As a type of professional liability insurance, medical malpractice insurance provides coverage to medical practitioners for liability arising from medical services that result in a patient's injury or death. A majority of physicians are required to have minimum levels of malpractice insurance to practice in a state, to qualify for state programs that assist them with claims, or by their employer.[1] Even without such requirements, most physicians carry malpractice insurance to avoid risking their personal assets. We expect that if Medicaid expansion increases medical liability exposures, insurers will experience higher losses and then increase premiums. In addition to buying insurance, some large hospitals may retain their malpractice risk through self-insurance and/or covering uninsured losses using their own capital. In Section 7, we examine the impact of Medicaid expansion on medical liability costs borne by hospitals and do not find hospitals' costs increased.

Our medical malpractice insurance data is from the National Association of Insurance Commissioners (NAIC), which collects extensive financial data from insurers required to file annual reports in the U.S. As the primary source of insurer data, the NAIC

[1] Malpractice insurance is a requirement for practicing medicine in the following states: Colorado, Connecticut, Kansas, Massachusetts, New Jersey, Rhode Island, and Wisconsin. The minimum levels of insurance vary greatly, ranging from $100,000 to $1 million in coverage per claim and from $300,000 to $3 million in total coverage each year. Another seven states, i.e., Indiana, Louisiana, Nebraska, New Mexico, New York, Pennsylvania, and Wyoming, require a minimum amount of insurance coverage to participate in state programs that assist them with claims. These programs include either caps that limit damages that can result from a malpractice claim, or a patient compensation fund which is a state effort to cover certain patient injuries and to provide supplemental malpractice insurance to physicians. For other states, many physicians still face requirements to obtain malpractice insurance in certain situations. For example, many hospitals require physicians with visiting privileges to obtain malpractice insurance. Some healthcare insurance plans require any doctor who participates in their coverage to have malpractice insurance. See https://smallbusiness.chron.com/doctors-required-malpractice-insurance-60552.html

provides the most accurate measures of medical malpractice insurance revenues and losses. Our identification strategy is based on a difference-in-difference (DID) analysis that compares the difference in medical liability costs in Medicaid expansion states before and after the expansion with that in non-expansion states. We first study the average expansion effect on medical liability costs and then investigate the time-varying effects using an event study framework.

We find that, during our sample period from 2010 to 2018, medical malpractice insurers' losses incurred (i.e., indemnity payments to claimants) in Medicaid expansion states increased significantly, about 20.5% higher than those in non-expansion states. The increase in total losses, including losses incurred and defense and cost containment expenses, in expansion states was 21.7% higher than that in non-expansion states. Event study results further show that malpractice insurance losses in expansion states grew significantly each year after the expansion and the largest impact was seen in the second year.

We also find that insurers in expansion states raised premiums by an average of 15.6% in response to the rising costs. The magnitude of the yearly impact kept increasing in the first three years of expansion and showed some variations after that. When it comes to insurers' profitability, our results show that insurers' loss ratios, defined as total losses divided by premiums earned, did not change significantly on average, but did increase (profit decreasing) after the first year of expansion. This suggests that the premium increase in expansion states was not large enough to offset the higher losses. Our results are consistent with observations from insurance practitioners (Auden and Glombicki, 2019), who suggest that the medical liability insurance market experienced underwriting losses after 2015 and that the profitability issue worsened.

It is noteworthy that the percentage increase in malpractice insurance losses incurred (or total losses) is much larger than the percentage increase in the number of Medicaid enrollees. On average, Medicaid expansion increased the proportion of residents with insurance coverage by about 5% (Courtemanche et al., 2019b). This indicates that in addition to a pure scale effect, i.e., the one-to-one increase in malpractice costs in response to an increase in the number of Medicaid enrollees, there exists a significant spillover effect from new Medicaid enrollees to all existing patients.

Moreover, we do not find evidence that tort reforms can mitigate the ACA-induced medical liability claim losses in our sample period. We conjecture this is because tort reforms mainly work on decreasing claim severity by limiting larger payouts rather than reducing claim frequency. If Medicaid expansion increased claim frequency but did not affect severity "too" much, tort reforms might have little effect. We do find some evidence to support this argument. We show that an insurer's portion of medical malpractice business in expansion states, measuring its exposure to malpractice liability risk driven by Medicaid expansion, is positively associated with its malpractice claim frequency, but it does not affect the average claim severity significantly.

To the best of our knowledge, two papers are most relevant to our study. The first paper by Auerback, Heaton, and Brantley (2014) employs a micro-simulation model and forecast that the implementation of the ACA would increase medical malpractice claim costs by 3.4% on average in 2016. The estimated claim losses vary by state. Costs are predicted to increase within a range of 0.4% in Wisconsin to 7.8% in New Mexico. We provide empirical evidence showing that the ACA-induced medical liability losses seem to be larger than the predictions using simulation.

Another contemporary study by Heaton and Flint (forthcoming) uses state-level insurance loss ratio data during 2010-2016 and finds that Medicaid expansion reduces auto liability and workers' compensation loss ratios by 6–11%, but does not significantly affect the loss ratio of other lines such as medical malpractice insurance. Our paper goes beyond Heaton and Flint in a few significant ways. First, they use state-level aggregate data so their results do not reflect changes at the state-firm level. We provide a more granular analysis in our paper to account for firm heterogeneity and to minimize aggregation bias. We also know that tort reforms affect firms differently based on their place in the loss distribution so a firm-level analysis is more appropriate given our attempt to examine tort reforms' potential mitigation of any cost increases due to the expansion. Second, they focus on the analysis of the loss ratio without studying the two important determinants of the loss ratio, i.e., insurance losses and premiums. Their finding of no significant change in the loss ratio does not mean Medicaid expansion has no impact on insurers' premiums and losses. In contrast, we examine all three variables from malpractice insurers' and insureds' perspective. We also investigate malpractice costs borne by hospitals. Thus we provide a more detailed and comprehensive analysis of how Medicaid expansion affected major players in the medical liability market. Third, in addition to the average impact of Medicaid expansion on medical malpractice costs, we also conduct an event study to investigate the post-expansion yearly impact. While on average Medicaid expansion did not affect the loss ratio, consistent with Heaton and Flint's findings, we find the loss ratio increased significantly starting from the second year of expansion. Fourth, we investigate the interplay of Medicaid expansion and state tort reforms, which is not studied in Heaton and

Flint. Finally, we explore the channel(s) through which Medicaid expansion affects medical liability costs. Heaton and Flint were not able to do this because using aggregate data makes it "impossible to delineate whether the changes in losses came through a reduction in the volume of claims (claim frequency) or the size of the average claim (severity)".[2]

Our contributions to the ACA literature are three-fold. First, we empirically examine the impact of Medicaid expansion on the medical liability system. We provide a comprehensive analysis of how the expansion affects medical malpractice insurance losses, premiums, and loss ratios. Understanding these questions sheds some light on the degree to which the extension of other public health insurance programs may influence the medical liability system. Second, we examine the interaction between Medicaid expansion and tort systems and provide a way of assessing whether the increase in medical liability costs is due to changes in claim frequency or changes in severity. In doing so, we can show that tort reforms will likely have little influence on the growth of these liability costs. Therefore, policymakers should focus on policies designed to increase the medical services workforce to alleviate this issue. Third, we look at hospitals' loss experience after Medicaid expansion and find that hospital losses did not increase, which suggests that physicians' malpractice is the main reason for the increase in liability costs. This is evidence of a physician capacity constraint.

The remainder of this paper is organized as follows. In Section 2, we provide background information on the ACA Medicaid expansion, the medical liability system, and tort reforms. We describe the data in Section 3 and discuss our empirical methodologies in

[2] See Heaton and Flint (forthcoming) page 19.

Section 4. We present the baseline results in Section 5 and explore the underlying mechanism through which Medicaid expansion affects medical malpractice costs in Section 6. We discuss the medical liability costs borne by hospitals in Section 7. Concluding remarks are given in Section 8.

1.2 Institutional Background and Literature Review

1.2.1 The Affordable Care Act Medicaid Expansion

The U.S. had a significant uninsured population over the past forty years (Frean et al., 2017). Before the ACA, public health insurance programs such as Medicare and Medicaid only covered people older than 65, disabled, or low-income parents (as low as 50% of the family poverty level (FPL) in some states). Low-income childless adults were ineligible for Medicaid in almost every state. The ACA provides states the option to expand Medicaid eligibility to cover more uninsured. The state-by-state Medicaid expansion, starting in 2014, expanded coverage to households with income up to 138% of the FPL so that more low-income households are qualified for free or low-cost health care. By the end of 2018, 31 states had adopted and implemented Medicaid expansion and over 15 million enrollments were from the new adult eligibility group.[3]

A substantial body of research exists to study the impact of Medicaid expansion on insurance coverage, access to care, utilization, and health status. See Mazurenko et al. (2018) for a comprehensive review. These studies demonstrate a significant increase in insurance coverage (Frean et al., 2017), enhanced healthcare affordability (Decker, Lipton, and Sommers, 2017; Goldman et al., 2018), improved access to medication and services

[3] Our sample period is from 2010 to 2018. After 2018, five more states adopted Medicaid expansion. The remaining fourteen states have not adopted Medicaid expansion yet. We report the status of each state regarding whether and if so, when they adopted the ACA Medicaid expansion in Appendix C Table C1.

(Barbaresco et al., 2015; Wherry and Miller, 2016; Martin et al., 2017; Miller and Wherry, 2019), and better health outcomes and survival rates (Barbaresco et al., 2015; Gao, 2017; Swaminathan et al., 2018) in expansion states compared to non-expansion states.

The improvement in healthcare access after Medicaid expansion also indicates a steep increase in the demand for medical services and practitioners. In contrast, because it takes more than a decade to educate and train a physician, the supply of physicians grows more slowly (Kirch et al., 2012; Dall et al., 2018). Given that a physician shortage already exists (Bodenheimer and Pham, 2010), the ACA seems likely to make it worse (Sargen et al., 2011; Huang and Finegold, 2013). The shortage of physicians caused delays in care by increasing wait times for appointments by 2.6% (Miller and Wherry, 2017). Also, ambulance response times are slower by 24% on average (Courtemanche et al., 2019a). It is within this context that we study the extent that Medicaid expansion affects medical liability costs.

1.2.2 Medical Liability System

Two major goals of the medical liability system are to compensate patients injured by medical negligence or intentional actions and to deter medical providers from such behaviors (Kessler, 2011; Stamm et al., 2018). Because of the high probability of being involved in a medical malpractice claim over a career, a majority of physicians purchase medical malpractice insurance.

Medical liability insurers are at the forefront of medical malpractice claims. When a patient files a claim, liability insurers represent medical providers to investigate, defend, and settle claims. If the negotiation between patients and insurers fails, patients can file a formal legal complaint. According to a survey by the American Medical Association

(Guardado, 2017b), from 2006 to 2015 among 90,473 healthcare professional liability closed claims investigated, 23.3% were settled, 7% were decided at trial, and the rest were dropped. These claims often involve a very long settlement process, leading to a significant time lag between the date of an injury and the date a claim is paid. In 2015, the average indemnity payment for trials was $1,121,815 and $341,015 for settlements. The average defense and cost containment expense for trials was $226,741 and $78,906 for settled claims. Although the average expense for dropped, dismissed, or withdrawn claims is low ($30,475), these claims account for 68.2% of all claims and more than one-third of total expenses incurred to insurers (Guardado, 2017b).

Like all other insurance products, medical malpractice insurance premiums are based on the expected value of future losses and expenses. Insurers use historical data to forecast future losses and expenses and determine the premiums which largely vary across states and specialties. In addition to historical loss information, current economic conditions, market competition, and policy uncertainties, such as changes in the tort system and healthcare system, may also affect insurers' premium estimations. The medical malpractice insurance market has occasionally experienced crises since the 1970s, during which claim payments, as well as defense and investigation costs, increased rapidly, causing sharply ascending insurance premiums. The deterioration in the market led many states to institute tort reforms. The rationale is that limits on liability could limit the size of court awards, which could in turn reduce costs for insurers, and restrain premium increases over time.

1.2.3 Tort Reforms

There have been several widely adopted tort reforms, including caps on non-economic damages (CN), caps on punitive damages (CP), joint and several liability reform (JS), and collateral source reform (CS). Non-economic damages, such as pain, suffering, and emotional distress, are subjective and difficult to value, so differences in awards are often hard to justify. For this reason, 22 states place caps on non-economic damages. Similarly, punitive damages exist to punish a defendant for intentional or malicious misconduct and to deter similar future misconduct. Because punitive damages are often demanded in civil lawsuits and the size of such damage awards grew significantly, 30 states enacted reforms to place a cap on punitive damages. Collateral source reforms adopted in 35 states changes the damage award rules to account for all collateral sources of payment to reduce overpayments to plaintiffs. Plaintiffs may receive compensation from workers' compensation, health insurance, or disability insurance in addition to the compensation from physicians' liability insurance. If other sources have compensated the plaintiff, the proceeds paid by medical liability insurers would be reduced by that amount. Finally, joint and several liability reform, adopted in 39 states, changes the responsibility shared by multiple defendants. Under the common law rule, joint and several liability allowed a plaintiff to collect all of the damages from any defendant, regardless of the defendant's contribution to the fault. Reforms either abolish this doctrine or require each party to pay according to its responsibility for the harm.[4]

A considerable literature covers the influence of tort reforms on medical malpractice losses and malpractice insurers' profitability. The general consensus finds that tort reforms, especially caps on non-economic damages, reduce medical malpractice

[4] We report the status of each state in terms of the tort reforms in Appendix C Table C1. There are some states which adopted these tort reforms but ruled them unconstitutional before 2010, the start of our sample period. We regard these states as non-tort reform states.

awards, reduce losses incurred to medical malpractice insurers, and improve insurer profitability (Viscusi and Born, 1995, 2005; Kessler and McClellan, 2002; Born, Viscusi, and Baker, 2009; Grace and Leverty, 2013).

Since 2003, the nationwide medical malpractice insurance market has experienced decreasing losses and premiums. This trend held for about a decade but reversed recently. We investigate whether the ACA Medicaid expansion contributes to this reversal. We also explore the effectiveness of tort reforms during the post-expansion period by comparing insurers' medical liability costs in states adopting specific tort reforms with their costs in states without such tort reforms.

1. 3 Data

To examine the effect of Medicaid expansion on medical liability costs, we utilize medical malpractice insurers' data, tort reforms, and state demographic data from various sources to compile a dataset of firm-state-year observations from 2010 to 2018.

Our data about Medicaid expansion is from the Kaiser Family Foundation.[5] The ACA Medicaid expansion officially started on January 1, 2014. In our sample, we exclude three states (California, Minnesota, and Connecticut) and Washington D.C., which exercised early expansion options and had newly eligible enrollees before 2014. We exclude Massachusetts and Vermont which implemented Medicaid expansion in 2014 but had no newly eligible enrollees since then. We also exclude five states (Pennsylvania, Indiana, Alaska, Montana, and Louisiana) that expanded Medicaid coverage later in our sample period. Our final sample includes 21 expansion states that implemented Medicaid expansion in 2014 and 19 non-expansion states (including 5 states that adopted Medicaid

[5] See https://www.kff.org/medicaid/issue-brief/status-of-state-medicaid-expansion-decisions-interactive-map/

expansion after 2018 and 14 states that have not adopted it yet).[6] We discuss details about our main sample in Appendix A. We also create alternative samples with a narrower or broader treatment group and report the robustness results in Section 8. The robustness results remain similar to those in our main analysis.

Our source of the firm-state-year medical liability insurance data is from the Exhibit of Premiums and Losses (State Page) from insurer filings with the NAIC. In this exhibit, insurers provide their losses incurred and premiums earned data by line for each calendar year in each state where they operate. *Premiums earned* are premiums collected by insurers for the portion of policies for which coverage has been provided. *Losses incurred* are indemnity payments that have been made and estimated to be made in the future as a result of medical malpractice events occurring in the current year. In addition to losses incurred, we also consider defense and cost containment expenses, which are expenses incurred during the process of claims settlement which can include costs for investigating claims, court costs, and expenses paid to defense attorneys and expert witnesses. We call the sum of losses incurred and defense and cost containment expenses as an insurer's *total losses*. The *loss ratio* is defined as the total losses divided by net premiums earned, and it is used to measure an insurer's profitability. A low loss ratio indicates high profitability. To ensure that our sample consists of insurers actively participating in the medical malpractice insurance market, we exclude observations with premiums earned in a state less than or equal to $10,000 and those with losses less than or equal to $500.[7]

[6] Our treatment group includes New Jersey and Washington, two early expansion states. They used the early expansion option to shift people from existing public insurance programs into Medicaid but did not enroll any new participant until 2014 (Sommers et al., 2013; Sommers et al., 2014; Nikpay et al., 2015). For this reason, we keep these two states in our sample but regard them as expanding Medicaid coverage in 2014.
[7] Although medical malpractice insurance price varies across specialty and states, insurers with less than or equal to $10,000 premiums earned in a state are likely to have at most one to two policies in place in that state and thus are deemed as inactive in the market. We exclude observations with losses incurred less than

Several studies have investigated the disposition of malpractice claims and find the majority of the claims filed with insurers are settled before trial (Danzon, 2000; Guardado, 2017b). One main advantage of using malpractice claim data from insurers, rather than from the court, is that it includes claim losses from both settlements and judgments. In addition, medical malpractice claims take on average four to five years from occurrence to payment (Nordman, Cermak, and Mcdaniel, 2004). Some medical liability claims that occurred after Medicaid expansion are thus potentially yet to close. Another advantage of using malpractice loss incurred data from insurers is that it contains not only claim losses that have been paid but also include estimates for claims that incurred in the current year but are not yet closed. In comparison, two other major databases, the National Practitioner Data Bank (NPDB) and the Medical Professional Liability (MPC) Closed Claim Comparative data, consist of only closed claims.[8] Using the NAIC data is less likely to underestimate the ACA-driven medical malpractice costs.

We recognize that the NAIC data does not include medical liability costs from healthcare providers and institutions who choose to retain the risk or self-insure and thus do not file financial data with the NAIC. Nevertheless, because many self-insurance plans are combined with an excess insurance policy that covers extreme losses above a specific level[9], the losses covered by the excess insurance is included in the NAIC data (Nordman, Cermak, and Mcdaniel, 2004). Also, in Section 7 we provide additional evidence on the impact of Medicaid expansion on medical liability costs borne by hospitals.

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or equal to $500, which are likely due to reporting errors or accounting issues. The observations that we exclude from the sample account for only 0.06% of total premiums earned in the market.

8 The National Practitioner Data Bank (NPDB) is available at https://www.npdb.hrsa.gov/. The MPC closed claim comparative reviews claims closed between 2006 and 2015. For an overview of MPL CCC data, see https://hub.tmlt.org/tmlt-blog/claims-by-specialty-mpl-association-2006-2015-national-closed-claim-data.

9 This would be equivalent to a hospital having an insurance policy with a very large deductible. The hospital retains the risk below the deductible.

We use a set of firm-level and state-level control variables that are commonly used in the insurance and ACA literature (see e.g., Grace and Leverty, 2013; Courtemanche et al., 2019a). Since we make no causal claims about these control variables, we do not develop specific hypotheses about them. Firm-level control variables include firm size, liquidity, leverage, organizational form, and group affiliation status. These data are obtained from the NAIC database as well. *Firm Size* is measured by the natural logarithm of an insurer's total admitted assets. Leverage and liquidity are included to capture an insurer's financial strength. *Liquidity* is measured by the cash and short-term investments scaled by total admitted assets. *Leverage* is defined as total liabilities scaled by surplus. We also include two dummy variables to control for an insurer's organizational form and affiliation status. The dummy variable, *Stock*, is equal to 1 if an insurer is a stock insurer and 0 for mutual, risk retention group, or other organizational forms. The dummy variable, *Group*, is equal to 1 if the firm is a member of an insurance group and 0 for single unaffiliated insurers.

We also include state-level variables reflecting state economic, social, or legal environments. The data for tort reforms comes from the database of State Tort Law Reforms (Avraham, 2019; DSTLR 6th). This database tracks tort reforms from 1980 to 2018. We include four tort reform dummy variables, i.e., *caps on non-economic damages (CN), caps on punitive damages (CP), joint and several reforms (JS), and collateral source reform (CS)*, to indicate whether a state has adopted a particular tort reform or not in a given year. We focus on these four tort reforms because they are the most influential ones and often considered in prior studies of medical malpractice insurance markets (e.g., Born, Viscusi, and Baker, 2009; Born and Karl, 2013; Grace and Leverty, 2013).[10]

We include the *number of lawyers* (per capita), the *number of healthcare employees* (per capita), and the *number of insurance employees* (per capita) to control for the capacity/power of each relevant group. We include *unemployment rate* and *personal income* (per capita) to reflect the economic status of a given state in a specific year. We also use the ratio of the population reported in *poor and fair health status* to control for average health quality at the state level. [11]

Table 1.1 presents the summary statistics for our data. On average, an insurer earns medical malpractice insurance premiums of $3.07 million in a state in a given year. The average losses incurred is $1.65 million and it is $2.33 million for total losses. The average loss ratio is about 132%, indicating that medical malpractice insurers on average experienced underwriting losses in our sample period. On average, insurers own total assets of $2,402.846 million. It is noteworthy that losses incurred, total losses, premiums earned, loss ratios, and firm size are highly skewed, so we use log-transformation for these variables in our regression analysis. Our sample insurers allocate about 10.7% of their assets to cash and short-term investments, and their liability is about half of their surplus. Among our sample, 74.9% of the observations are stock insurers and 76.1% of them belong to an insurance group.

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[10] The tort system is stable for most of the states in our sample period. During our sample period, only eight states adopted or struck down these four tort reforms. Specifically, North Carolina and Tennessee adopted caps on non-economic damage reform in 2012; South Carolina and Tennessee adopted caps on punitive damage reform in 2012; Pennsylvania adopted joint and several liability reform in 2011. In contrast, Mississippi, Missouri, and Utah struck down caps on non-economic damage reform in 2013; Arkansas and Missouri abolished caps on punitive damage in 2012 and 2015, respectively.

[11] The number of lawyers in each state is obtained from the American Bar Association. The number of healthcare employees, the number of insurance employees and the unemployment rate in each state are from the Bureau of Labor Statistics. The personal income data is from the Bureau of Economic Analysis. The ratio of population in poor and fair health status is from the Risk Factor Surveillance System.

Table 1.1 Summary Statistics

VARIABLES	Mean	St. Dev.	25%	50%	75%
Expansion (dummy)	0.323	0.468	0	0	1
Losses Incurred (million)	1.651	10.178	0.024	0.153	0.760
Log (Losses Incurred)	11.851	2.331	10.105	11.936	13.541
Total Losses (million)	2.330	14.09	0.042	0.244	1.102
Log (Total Losses)	12.293	2.267	10.644	12.404	13.912
Premiums Earned (million)	3.066	17.438	0.088	0.371	1.434
Log (Premiums Earned)	12.861	1.933	11.382	12.822	14.176
Loss Ratio (%)	131.748	609.963	32.176	57.577	97.115
Log (Loss Ratio)	4.071	1.083	3.502	4.070	4.586
Firm Size (million)	2,402.846	7116.511	78.171	268.51	737.311
Log (Firm Size)	19.457	2.020	18.174	19.408	20.419
Leverage	0.514	0.213	0.396	0.564	0.665
Liquidity	0.107	0.156	0.025	0.054	0.116
Stock	0.749	0.434	0	1	1
Group	0.761	0.426	1	1	1
No. of Insurance Employees (per capita)	0.008	0.002	0.006	0.007	0.009
No. of Healthcare Employees (per capita)	0.055	0.01	0.048	0.054	0.062
No. of Lawyers (per capita)	0.003	0.001	0.003	0.003	0.004
Personal Income (per capita)	0.013	0.016	0.004	0.008	0.014
Unemployment Rate	0.006	0.002	0.005	0.006	0.008
Poor or Fair Health Status	0.162	0.030	0.138	0.158	0.183
Caps on Non-Economic Damage (CN)	0.476	0.499	0	0	1
Caps on Punitive Damage (CP)	0.663	0.473	0	1	1
Collateral Source Reform (CS)	0.639	0.480	0	1	1
Joint and Several Reform (JS)	0.803	0.398	1	1	1
No. of Observations	18,517	18,517	18,517	18,517	18,517

1.4 Research Design

1.4.1 DID Analysis for the Average Impact of Medicaid Expansion

To investigate the impact of the ACA Medicaid Expansion on medical liability costs, we use a difference-in-difference (DID) approach to compare medical malpractice insurance outcomes in expansion and non-expansion states before and after Medicaid expansion. The first identification strategy uses a binary DID model as shown in equation (1.1),

$$Y_{ist} = \beta_0 + \beta_1 Expansion_{st} + \beta_2 X_{ist} + \alpha_t + \delta_i + \varphi_s + \varphi_s \times t + e_{ist} \qquad (1.1)$$

where

Y_{ist} represents insurer i's medical malpractice insurance premiums earned, losses incurred, total losses, or loss ratio in state s in year t.

$Expansion_{st}$ is a dummy variable that is equal to 1 if state s implemented Medicaid expansion in year t, and 0 otherwise.

X_{ist} is a vector of control variables at the firm-level and state-level.

α_t controls for the year fixed effect.

δ_i controls for the firm fixed effect.

φ_s controls for the state fixed effect.

t is a continuous trend variable. $\varphi_s \times t$ controls the state-specific linear trend.

e_{ist} are idiosyncratic errors.

The estimated coefficient β_1 provides the estimated mean difference in the medical malpractice outcome variable in expansion and non-expansion states during the post-expansion period as compared to the mean difference before expansion, controlling for firm characteristics, state demographic and economic covariates, tort systems, and firm, state, and year fixed effects. Since the medical liability insurance market has experienced underwriting cycles over time (Baker, 2004) and each state might show a different trend in the cycle, we follow Born, Karl, and Montesinos-Yufa (2018) to include a state-specific linear trend to control for this effect in this market.

As stated earlier, a state's Medicaid expansion has improved access to health care and thus may cause a possible surge in demand for medical services. Capacity constraints could create great challenges for physicians and might increase the number of medical malpractice claims. In this regression, we hypothesize that β_1 is positive when the dependent variable is losses incurred or total losses. When the dependent variable is premiums earned, β_1 might be positive if insurers increased premiums accordingly to compensate for the rising costs. Nevertheless, in the face of rate regulation, market competition, and the uncertainty about future healthcare reforms, insurers may not have responded to the ACA immediately by raising premiums, so we do not have a prediction for the sign of β_1 in this case. Neither do we have a prediction for β_1 when the dependent variable is the loss ratio because it depends on whether the loss increase is offset by the premium increase.

It is noteworthy that the tort system is stable for most of the states during our sample period (see footnote 9), so the impact of the tort system in these states is mainly captured by the state fixed effects. The coefficient of tort reform dummy variables only reflects the average performance of insurers in a few states that newly adopted or abrogate a certain tort reform during our sample period in comparison to all other states.

1.4.2 Event Study Analysis for the Dynamic Impact of Medicaid Expansion

To better understand the dynamic impact of Medicaid expansion on medical liability costs, we use an event-study. As more Medicaid eligible patients enter the health care system, we may see the impact of Medicaid expansion varies over time. To investigate the treatment effect dynamics, we use the following specification,

$Y_{ist} = \beta_0 + \beta_1 Treat_{s,t=-4} + \beta_2 Treat_{s,t=-3} + \beta_3 Treat_{s,t=-2} + \beta_4 Treat_{s,t=0} +$

$$\beta_5 Treat_{s,t=1} + \beta_6 Treat_{s,t=2} + \beta_7 Treat_{s,t=3} + \beta_8 Treat_{s,t=4} + \beta_9 X_{ist} + \alpha_t + \delta_i + \varphi_s + \varphi_s \times t + e_{ist}. \quad (1.2)$$

In this equation, we define a set of dummy variables indicating the periods before and after the ACA Medicaid expansion was adopted in each state. For Medicaid expansion states, $Treat_{s,t=-4}$ is equal to 1 if the observation in expansion states is four years prior to the adoption of Medicaid expansion and 0 otherwise. Since all expansion states in our sample started Medicaid expansion in 2014, $Treat_{s,t=-4}$ is equal to 1 for observations in expansion states in year 2010. For non-expansion states, $Treat_{s,t=-4}$ always equals 0. We define $Treat_{s,t=-3}$, $Treat_{s,t=-2}$, $Treat_{s,t=0}$, $Treat_{s,t=1}$, $Treat_{s,t=2}$, $Treat_{s,t=3}$, and $Treat_{s,t=4}$ similarly, where $t = 0$ refers to the expansion year, i.e., year 2014. The year before the Medicaid expansion (year 2013) is regarded as the base year, so $Treat_{s,t=-1}$ is omitted in the regression. This event study framework disentangles the timing of the policy change and can help us explore the variation in the impact of Medicaid expansion over time.

In addition, the event study framework can help us assess the parallel trend assumption underlying the DID analysis. DID analysis is valid only if, in the absence of Medicaid expansion, the medical malpractice outcome variables for insurers in expansion states and non-expansion states follow the same trend. While this assumption cannot be tested directly, we can test whether the trend of such variables was different between expansion and non-expansion states before the expansion took place. If the outcome difference between the treatment group and the control group in other pre-treatment years is not significantly different from that in the base year, our test is passed. In other words, the tests for differential pre-treatment trends (i.e., falsification tests) are provided by evaluating whether the coefficients on the "treatment" variables in the pre-treatment years (β_1, β_2, and β_3) are significantly different from zero. This event study framework helps evaluate whether the control group is a valid counterfactual for the treatment group (Grecu, Dave, and Saffer, 2019).

1.4.3 Tort Reforms and Medicaid Expansion

While we expect that the implementation of the ACA Medicaid expansion would increase insurers' medical malpractice claim costs in expansion states, tort reforms censor the right tail of the award distribution (Lieber, 2014). Many studies have shown that following the enactment of tort reforms, medical malpractice insurers incur lower losses with improved profitability (Viscusi and Born, 1995, 2005; Kessler and McClellan, 2002; Born, Viscusi, and Baker., 2009; Grace and Leverty, 2013). Born, Karl, and Montesinos-Yufa (2018) further demonstrate that the presence of a damage cap alleviates the severity of market conditions during periods of crises.

It is within this context that we consider the interaction between the ACA healthcare reform and tort reforms. We hypothesize that medical liability insurers in states with certain tort reforms are less vulnerable to the ACA-induced malpractice risk than their counterparties in states without such tort forms. Our identification strategy is to use a triple DID model. In Equation (1.3), we include four interaction terms between the dummy variable, $Expansion_{st}$, and the tort reform dummies. As many of the states adopted multiple tort reforms, including interaction terms for all four reforms, might lead to multicollinearity concerns (Avraham and Schanzenbach, 2010). We, therefore, build additional four regressions as shown in Equation (1.4), each including the interaction between $Expansion_{st}$ and one tort reform dummy separately.

$$Y_{ist} = \beta_0 + \beta_1 Expansion_{st} \times CN_{st} + \beta_2 Expansion_{st} \times CP_{st} + \beta_3 Expansion_{st} \times JS_{st} + \beta_4 Expansion_{st} \times CS_{st} + \beta_5 X_{ist} + \alpha_t + \delta_i + \varphi_s \times + e_{ist} \quad (1.3)$$

$$Y_{ist} = \beta_0 + \beta_1 Expansion_{st} \times Tort\ Reform_{st}(CN_{st}, CP_{st}, CS_{st}, or\ JS_{st}) + \beta_2 X_{ist} + \alpha_t + \delta_i + \varphi_s + \varphi_s \times t + e_{ist} \quad (1.4)$$

In this part of the analysis, we further exclude seven states, i.e., Arkansas, Mississippi, Missouri, North Carolina, South Carolina, Tennessee, and Utah, which either adopted or abolished the tort reforms that we consider during our sample period due to potential for self-selection bias.[12] This bias may exist in states which adopted tort reforms after the ACA was signed into law in 2010 as the states adopted tort reforms because they experienced or expected to experience higher medical liability losses. After removing these seven states, the tort reform dummy variables by themselves are time-invariant and thus are excluded from the regression. If the coefficient of the interaction term between $Expansion_{st}$ and a tort-reform dummy is significantly negative, we can conclude that the negative impact of Medicaid expansion is mitigated by that tort reform.

1.5 Baseline Results

1.5.1 Average Impacts of Medicaid Expansion

Table 2 reports the results for the binary DID estimation in Equation (1). Standard errors are clustered by state. We use four dependent variables: premiums earned (per capita), losses incurred (per capita), total losses (per capita), and the loss ratio. These variables are log-transformed.

We find that, on average, a medical malpractice insurer's losses incurred (total losses) in expansion states increased by 20.5% (21.7%) after Medicaid expansion as

[12] Pennsylvania adopted joint and several liability reform in 2011. It has been excluded from our sample because it is one of the late expansion states.

compared to those operating in non-expansion states. The percentage increase in premiums earned in expansion states relative to the increase in non-expansion states was 15.6%. The loss ratio increased (profits lowered) by 6.2% on average in expansion states, though this result is not statistically significant.

On average, Medicaid expansion increased health insurance coverage by 12% for low-income adults and by about 5% for all residents over the post-expansion period (Courtemanche et al., 2019b; Miller and Wherry, 2019). We note that the percentage increase in coverage is much lower than the increase in losses incurred or total losses due to Medicaid expansion. This result indicates that, in addition to a pure scale effect which increases losses incurred (total losses) proportionally with the number of new Medicaid enrollees, there is a significant spillover effect from these newly enrolled to other patients. Recent studies (e.g., Huang and Finegold, 2013; Dall et al., 2017; Courtemanche et al., 2019a) show that the U.S. is facing an exacerbating physician shortage. Given the capacity constraint, the additional demand for medical services driven by Medicaid expansion may scatter physicians' attention among a much larger pool of patients, potentially leading to more medical errors not just among the newly Medicaid insured but also among other patients.

Regarding firm characteristics, we find that firm size is significantly, positively associated with an insurer's loss incurred, total losses, and premiums earned in its medical liability line. The impact of leverage and liquidity is mixed in terms of its significance level in these regressions. The organizational form and group affiliation status seem not to have a significant impact on losses and premiums, but group insurers have a higher loss ratio.

Table 1.2 Medicaid Expansion and Medical Liability Costs (Average Effect)

VARIABLES	(1) Log (Losses Incurred)	(2) Log (Total Losses)	(3) Log (Premiums Earned)	(4) Log (Loss Ratio)
Expansion	0.205**	0.217***	0.156***	0.062
	(0.078)	(0.077)	(0.049)	(0.055)
Stock	-0.003	-0.005	-0.055	0.033
	(0.117)	(0.109)	(0.082)	(0.069)
Group	0.060	0.024	-0.118	0.144**
	(0.092)	(0.095)	(0.080)	(0.059)
Liquidity	0.263	0.302**	0.125	0.158*
	(0.157)	(0.149)	(0.100)	(0.091)
Log (Firm Size)	0.155***	0.183***	0.165***	0.012
	(0.051)	(0.049)	(0.029)	(0.033)
Leverage	0.330*	0.256	0.291**	-0.011
	(0.171)	(0.168)	(0.123)	(0.106)
Personal Income	13.178	5.001	-4.295	8.842
	(8.472)	(8.928)	(9.651)	(11.443)
No. of Healthcare Employees	-40.479*	-28.432	-5.932	-21.583
	(20.722)	(23.166)	(14.562)	(16.682)
No. of Insurance Employees	-35.089	-48.424	-40.530	-8.583
	(94.993)	(93.161)	(56.012)	(60.936)
No. of Lawyers	-77.098	-82.936	40.334***	-119.469***
	(60.200)	(50.138)	(14.775)	(43.953)
Poor or Fair Health Status	1.205	0.578	1.605	-1.100
	(2.343)	(2.409)	(1.047)	(1.732)
Unemployment Rate	0.787	0.210	-1.955	2.083
	(2.072)	(2.272)	(1.555)	(1.390)
Caps on Non-Econ Damages	-0.040	-0.069	-0.050	-0.019
	(0.100)	(0.086)	(0.073)	(0.049)
Caps on Punitive Damages	0.040	0.089	-0.019	0.104
	(0.155)	(0.146)	(0.071)	(0.147)
Constant	9.652***	9.371***	9.434***	4.709***
	(1.386)	(1.339)	(0.841)	(0.822)
Observations	18,517	18,517	18,517	18,517
R-Squared	0.538	0.569	0.652	0.178
Firm FE	YES	YES	YES	YES
State FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
State-Specific Linear Trend	YES	YES	YES	YES

This table reports regression results for the DID model in Equation (1). Columns (1) to (4) report the results with the dependent variables: medical liability insurance losses incurred, total losses, premiums earned, and loss ratio (%) respectively. All the dependent variables are log-transformed. Alaska, California, Connecticut, Indiana, Louisiana, Massachusetts, Minnesota, Montana, Pennsylvania, and Vermont are excluded from our sample. Standard errors are clustered at the state level and are reported in parentheses. *** (**, *) indicates significance at the 1% (5%, 10%) level. Firm-level control variables include firm size, leverage, liquidity, stock, and group. State-level control variables include unemployment rate (%), personal income (per capita), population reported with poor of fair health status (%), the number of insurance employees (per capita), the number of healthcare employees (per capita), the number of lawyers (per capita), and tort reform dummy variables. The dummy variables for collateral resource reform and joint and several reforms are omitted because they are time-invariant.

When it comes to state-level controls, we find that insurers operating in a state with more employees in the healthcare sector (per capita) tend to have lower losses incurred in their malpractice liability lines of business. This result is marginally significant at the 10% level, so it provides partial support to our capacity constraint argument. In comparison, insurers operating in states with more lawyers (per capita) tend to have higher premiums earned and lower loss ratios. We do not find impacts of other state-level control variables.

1.5.2 Dynamic Impacts of Medicaid Expansion

Table 1.3. presents regression results of the event study in Equation (2). We can see that in the pre-treatment period, none of the treatment variable coefficients is significantly different from zero in any of the regressions from Columns (1) to (4) and the magnitude is small. This means that the difference in outcome variables between expansion and non-expansion states two (three, or four) years prior to expansion is not significantly different from the difference one year prior to expansion. In other words, we do to find any trend differential in the pre-treatment period between expansion and non-expansion states.

In comparison, we see significant treatment effects of Medicaid expansion on losses incurred, total losses, and premiums earned in the post-treatment period. This effect lasts for five years till the end of our sample period, with time-varying magnitudes. Take the total losses regression as an example. Medical malpractice insurers' total losses in

Table 1.3 Medicaid Expansion and Medical Liability Costs (Yearly Effects)

VARIABLES	(1) Log (Losses Incurred)	(2) Log (Total Losses)	(3) Log (Premiums Earned)	(4) Log (Loss Ratio)
$Treat_{s,t=-4}$	0.091	0.035	0.004	0.019
	(0.108)	(0.109)	(0.072)	(0.084)
$Treat_{s,t=-3}$	0.032	-0.009	-0.024	0.005
	(0.079)	(0.081)	(0.054)	(0.059)
$Treat_{s,t=-2}$	-0.008	-0.036	-0.059	0.018
	(0.093)	(0.089)	(0.051)	(0.062)
$Treat_{s,t=0}$	0.148*	0.160**	0.111**	0.056
	(0.075)	(0.076)	(0.044)	(0.060)
$Treat_{s,t=1}$	0.276***	0.291***	0.145**	0.152**
	(0.097)	(0.091)	(0.059)	(0.059)
$Treat_{s,t=2}$	0.195**	0.240**	0.149**	0.106*
	(0.090)	(0.091)	(0.056)	(0.061)
$Treat_{s,t=3}$	0.172*	0.222**	0.127**	0.120*
	(0.093)	(0.090)	(0.057)	(0.068)
$Treat_{s,t=4}$	0.225**	0.256**	0.117	0.160**
	(0.101)	(0.101)	(0.077)	(0.066)
Observations	18,517	18,517	18,517	18,517
R-squared	0.538	0.569	0.652	0.178
Firm Controls	YES	YES	YES	YES
State Controls	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
State FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
State-specific Linear Trend	YES	YES	YES	YES

This table reports the regression results for the event study in Equation (2). Column (1) to (4) report the results with the following dependent variables: medical liability insurance losses incurred, total losses, premiums earned and loss ratio (%). All the dependent variables are log-transformed. Alaska, California, Connecticut, Indiana, Louisiana, Massachusetts, Minnesota, Montana, Pennsylvania, and Vermont are excluded from our sample. Standard errors are clustered at the state level and are reported in parentheses. *** (**, *) represents significance at the 1% (5%, 10%) level. Firm-level control variables include firm size, leverage, liquidity, stock, and group. State-level control variables include unemployment rate (%), personal income (per capita), population reported with poor of fair health status (%), the number of insurance employees (per capita), the number of healthcare employees (per capita), the number of lawyers (per capita), and tort reform dummy variables.

expansion states increased by 16% in the first year of expansion (i.e., year 2014), compared to those operating in non-expansion states. The marginal impact kept increasing to 29.1%

in 2015, dropped to 24% in 2016 then to 22.2% in 2017, and bounced back to 25.6% in 2018. In the meantime, insurers in expansion states witnessed premium increases of 11.1%, 14.5%, 14.9%, 12.7%, and 11.7%, respectively, in the five years after expansion, though the last year's premium increase was not statistically significant. The percentage increases in premiums earned were much smaller than those in total losses, resulting in significant increases in the loss ratio in expansion states since the second year.

To better visualize the time-varying treatment effects, we plot the yearly impacts of Medicaid expansion on medical malpractice losses incurred, total losses, premiums earned, and loss ratios in Figures 1-4, respectively, with 95% confidence intervals. The x-axis denotes the year relative to the expansion year and the y-axis displays the size of the treatment coefficients from Equation (2). For all outcome variables examined, we do not find trend differentials in the pre-expansion period that violate the parallel trend assumption. Instead, we find significant treatment effects in the post-expansion period.

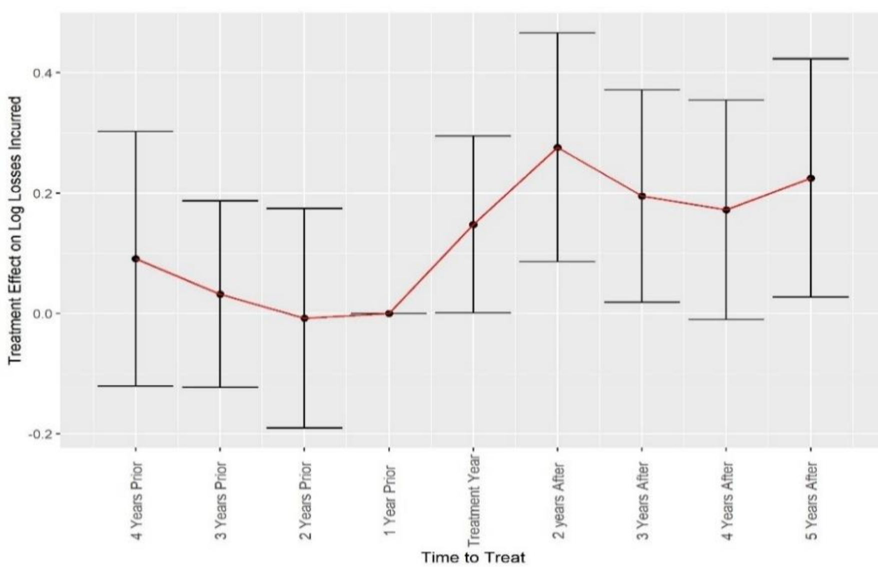

Figure 1.1 Yearly Impacts of Medicaid Expansion on Medical Malpractice Insurance Losses Incurred

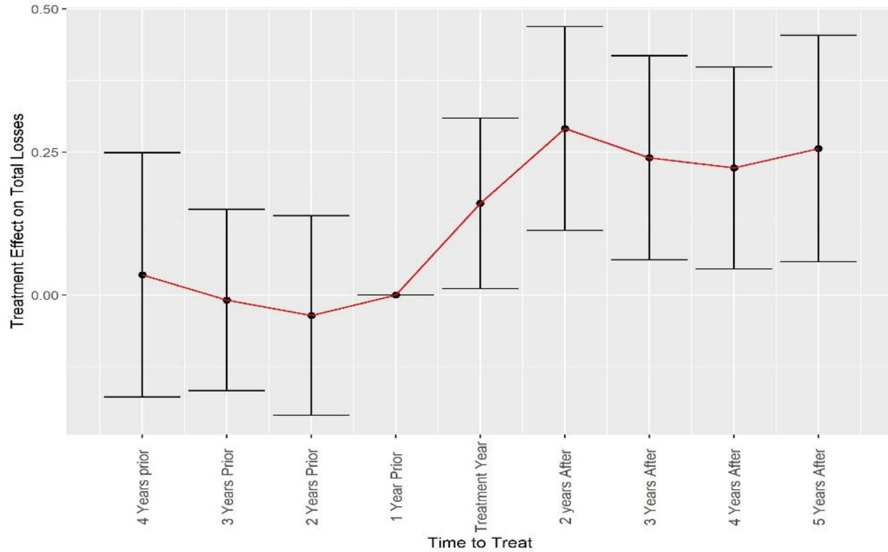

Figure 1.2 Yearly Impacts of Medicaid Expansion on Medical Malpractice Insurance Total Losses

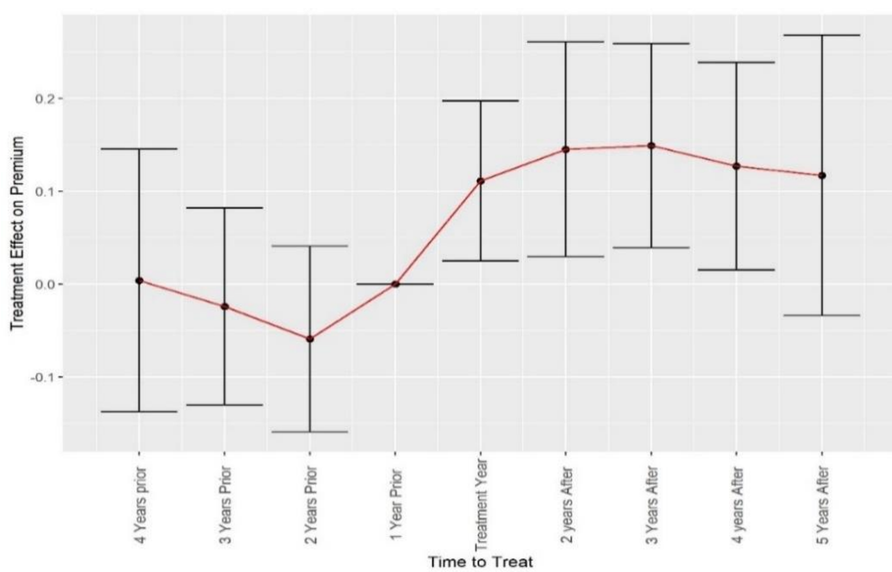

Figure 1.3 Yearly Impacts of Medicaid Expansion on Medical Malpractice Insurance Premium Earned

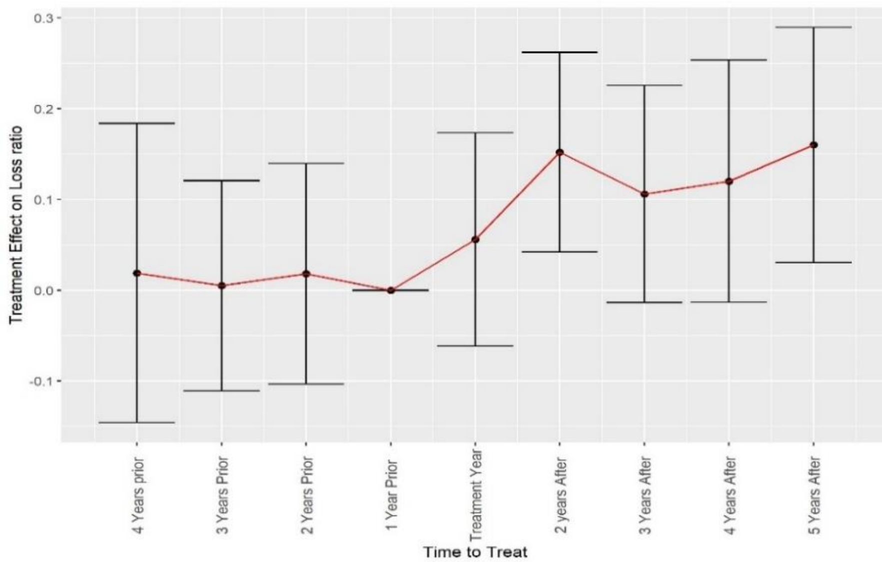

Figure 1.4 Yearly Impacts of Medicaid Expansion on Medical Malpractice Insurance Loss Ratio

1.5.3 Interaction between Tort Reforms and Medicaid Expansion

Next, we study the joint impacts of the health care reform and tort reforms. Table 1.4 shows the results of the triple DID estimation with losses incurred, total losses, premiums earned, and loss ratios as the dependent variable, respectively. In Column (1) where we consider four tort reforms jointly, we find the interaction terms between $Expansion_{st}$ and tort reform dummies have very high variance inflation factors (VIFs), indicating the possible existence of multicollinearity. Therefore, we also present the results in Columns (2)-(4) when only one tort reform dummy variable is included at one time.[13]

In general, the interaction terms between $Expansion_{st}$ and the tort reform dummies are not significant, except for $Expansion_{st} \times JS_{st}$ in the losses incurred and total losses regressions. However, since nearly 80% of expansion states have adopted the joint

[13] The multicollinearity issue might also exist in the regression in column (4) when we include both $Expansion_{st}$ and $Expansion_{st} \times JS_{st}$ because near 80% of expansion states have adopted the joint and several liability reform. The correlation between the two variables is 0.85.

Table 1.4 Medicaid Expansion, Tort Reforms, and Medical Liability Costs

	(1)	(2)	(3)	(4)	(5)
Dependent Variable: Log (Losses Incurred)					
Expansion	0.163	0.242**	0.265***	0.272**	0.116
	(0.127)	(0.099)	(0.096)	(0.122)	(0.097)
Expansion*CN	-0.003	-0.003			
	(0.110)	(0.105)			
Expansion*CP	-0.051		-0.045		
	(0.116)		(0.105)		
Expansion*CS	-0.036			-0.038	
	(0.120)			(0.121)	
Expansion*JS	0.168**				0.156*
	(0.077)				(0.086)
R-squared	0.547	0.547	0.547	0.547	0.547
Dependent Variable: Log (Total Losses)					
Expansion	0.168	0.279***	0.290***	0.306**	0.098
	(0.124)	(0.102)	(0.094)	(0.120)	(0.098)
Expansion*CN	-0.044	-0.041			
	(0.111)	(0.109)			
Expansion*CP	-0.048		-0.049		
	(0.112)		(0.109)		
Expansion*CS	-0.052			-0.052	
	(0.105)			(0.121)	
Expansion*JS	0.225***				0.206**
	(0.081)				(0.091)
R-squared	0.577	0.577	0.577	0.577	0.577
Dependent Variable: Log (Premiums Earned)					
Expansion	0.146*	0.142**	0.224***	0.226***	0.082
	(0.075)	(0.070)	(0.060)	(0.061)	(0.109)
Expansion*CN	0.075	0.050			
	(0.068)	(0.082)			
Expansion*CP	-0.132**		-0.117		
	(0.062)		(0.072)		
Expansion*CS	-0.045			-0.079	
	(0.039)			(0.062)	
Expansion*JS	0.116*				0.100
	(0.062)				(0.102)
R-squared	0.659	0.659	0.659	0.659	0.659
Dependent Variable: Log (Loss Ratio)					
Expansion	0.022	0.136*	0.070	0.080	0.019
	(0.105)	(0.072)	(0.084)	(0.082)	(0.099)
Expansion*C	-0.111	-0.085			

N					
	(0.077)	(0.079)			
Expansion*CP	0.077		0.063		
	(0.096)		(0.086)		
Expansion*CS	-0.003			0.029	
	(0.103)			(0.080)	
Expansion*JS	0.106				0.104
	(0.089)				(0.100)
R-squared	0.180	0.180	0.180	0.180	0.180
Observations	15,460	15,460	15,460	15,460	15,460

This table reports the regression results for the triple DID model in Equations (3) and (4). Alaska, California, Connecticut, Indiana, Louisiana, Massachusetts, Minnesota, Montana, Pennsylvania, and Vermont are excluded from our sample. We also exclude seven other states (Arkansas, Mississippi, Missouri, North Carolina, South Carolina, Tennessee, and Utah), which newly adopted or struck down one of the tort reforms during our sample period. Standard errors are clustered at the state level and reported in parentheses. *** (**, *) represents significance at the 1% (5%, 10%) level. Firm-level control variables include firm size, leverage, liquidity, stock, and group. State-level control variables include unemployment rate (%), personal income (per capita), population reported with poor of fair health status (%), the number of insurance employees (per capita), the number of healthcare employees (per capita), and the number of lawyers (per capita). Firm fixed effects, state fixed effects, year fixed effects, and state-specific linear trends are included in the regression.

and several reform, multicollinearity exists between $Expansion_{st}$ and $Expansion_{st} \times JS_{st}$. It is possible that the significance of $Expansion_{st} \times JS_{st}$ only reflects the impact of Medicaid expansion itself. Therefore, we do not find evidence to support our hypothesis that the negative impacts of Medicaid expansion on losses incurred and total losses are lessened by any of the four tort reforms. We do not find that tort reforms alleviated the impact of Medicaid expansion on premiums earned and loss ratios either.

1.5.4 Summary of Results

To summarize, we find that medical malpractice insurers experienced significantly higher losses incurred and total losses in expansion states after Medicaid expansion was implemented than their counterparties in non-expansion states. Insurers raised premiums accordingly, but the increase in premiums did not fully cover the increase in losses, leading to an increase in loss ratios. These results are consistent with the national trend, i.e., the medical malpractice insurance industry started to experience negative profitability in insurance underwriting since 2014 (NAIC, 2018). Contrary to our initial prediction, we do not find that tort reforms mitigate the ACA-driven medical liability losses.

1.6 Medicaid Expansion and Medical Liability Costs: Frequency and Severity

In this section, we explore the mechanism(s) through which Medicaid expansion increased an insurer's medical liability costs and try to explain the reason why tort reforms seem not to function well in mitigating the negative impact of Medicaid expansion.

Medical liability losses are a function of claim frequency and severity. Medicaid expansion could increase medical malpractice losses through either of these two channels. In comparison, major tort reforms tend to reduce claim severity by cutting large payouts rather than changing prevailing practice patterns and proactively deterring malpractice claims from occurring (Frakes and Jena, 2016). Claims with large payouts are rare events. Thus, we conjecture if the ACA Medicaid expansion leads to more medical malpractice claims, but the majority of these claims do not have large payouts, then tort reforms would not necessarily have an impact on these claims.[14]

To test our hypothesis, we investigate Medicaid expansion's impact on the frequency and severity of medical malpractice claims. The NAIC reports an insurer's losses incurred (monetary value) in its medical malpractice line of business in each state. However, it only reports the total number of claims filed with this insurer nationwide instead of the number of claims in each state. For this reason, we propose a proxy to examine Medicaid expansion's impact on claim frequency and severity.

As we have shown, Medicaid expansion potentially increases an insurer's exposure

[14] For instance, many states set the caps on non-economic damages (punitive damages) at $500,000, while 74.9% of the indemnity payments is lower than this threshold and thus not affected by the caps (Guardado, 2017b).

to medical liability risk, but this effect is only applicable in expansion states. For insurers with existing medical malpractice business in expansion states, their exposure to malpractice risk due to Medicaid expansion is zero in the pre-expansion period but would increase as more states implemented the expansion policy. In comparison, insurers with no existing medical malpractice business in expansion states would be less affected by Medicaid expansion. We hypothesize that the more an insurer's medical malpractice line of business is from expansion states before Medicaid expansion was implemented, the more it is exposed to malpractice risk caused by Medicaid expansion, and the higher claim frequency and/or severity the firm might experience after Medicaid expansion.

To test this hypothesis, we first define a variable, $Business\ Exposure_{it}$, that measures an insurer's exposure to malpractice risk due to Medicaid expansion in year t. It is defined as

$$Business\ Exposure_{it} = \frac{\sum_s Premiums\ Earned\ 2013_{is} \times Expansion_{st}}{Premiums\ Earned\ 2013_i} \quad (1.5)$$

where we use the percentage of insurer i's medical malpractice insurance premiums earned in state s in 2013, one year before Medicaid expansion was implemented, to measure its existing malpractice business in a given state s and multiply it with the dummy variable, $Expansion_{st}$, and eventually, aggregate this multiplication across states at the firm level.

We then run the following two regressions

$$y_{it} = \beta_0 + \beta_1\ Business\ Exposure_{it} + \beta_2 X_{it} + \alpha_t + \delta_i + e_{it}, \quad (1.6)$$

where the dependent variable can be losses incurred, claim frequency (i.e., total number of claims), or average claim severity (i.e., losses incurred divided by the total number of claims) for insurer i in year t. A significantly positive β_1 in Equation (5) indicates that an insurer's losses incurred, claim frequency, or average claim severity is driven by its business exposure to Medicaid expansion states. This estimation is similar to the triple DID regression used in the recent ACA literature, e.g., Courtemanche et al. (2019a, 2019b), where the authors interact the pre-ACA uninsured rate in 2013 with the DID variable when they study the impact of Medicaid expansion on insurance coverage.

Table 1.5. presents regression results for Equation (6). The firm-level control variables used here are the same as those used in Table 2. We find that an insurer's losses incurred increases significantly with its malpractice business exposure to expansion states. This result is consistent with our previous findings that Medicaid expansion increased insurers' losses incurred in expansion states. We also find that an insurer's malpractice business exposure to expansion states positively contributes to its claim frequency but does not have a significant impact on its average claim severity. These results explain why insurers' medical liability costs increased significantly in expansion states after Medicaid expansion. They also help explain why tort reforms, which are generally severity-focused, seem not to function well in alleviating this negative impact of Medicaid expansion.

Table 1.5 Impacts of Medicaid Expansion on Medical Malpractice Claim Frequency and Severity

VARIABLES	(1) Log (Losses Incurred)	(2) Log (Claim Frequency)	(3) Log (Avg. Claim Severity)
Business Exposure	0.537***	0.399**	0.138
	(0.167)	(0.160)	(0.200)
Firm Controls	YES	YES	YES
Firm FE	YES	YES	YES
Year FE	YES	YES	YES
R-squared	0.078	0.110	0.040
No. of Obs.	2048	2,048	2,048

This table reports the results for the regression in model (1.5) using an insurer's losses incurred, claim frequency, and average claim severity as dependent variables. All dependent variables are log-transformed. Alaska, California, Connecticut, Indiana, Louisiana, Massachusetts, Minnesota, Montana, Pennsylvania, and

Vermont are excluded from our sample. To save space, we only report the coefficients of Business Exposure. Standard errors are clustered at the firm level and are reported in parentheses. *** (**, *) represents significance at the 1% (5%, 10%) level. Firm-level control variables include firm size, leverage, liquidity, stock, and group.

1.7 Further Discussions: Medical Liability Costs Borne by Hospitals

In our prior analysis, we study the impact of Medicaid expansion on medical liability costs from the perspective of liability insurers using the NAIC data. One limitation of the NAIC data is that it does not have information on medical malpractice claim losses from entities that retain their risk or use self-insurance and thus do not report to the NAIC. In this section, we complement our main analysis by investigating whether Medicaid expansion increased medical malpractice losses borne by hospitals.

In recent years, many hospitals, especially large ones, have begun self-insuring part or all of their professional liability risk through self-insurance plans. All Medicare-certified institutional providers are required to submit an annual cost report to the Centers for Medicare and Medicaid Services (CMS). The cost reports contain provider information such as facility characteristics, utilization data, and financial statements. One item in the cost report is the medical liability cost of hospitals. It includes the total amount of malpractice premiums paid, the total amount of self-insurance paid, and the total amount of paid losses. Malpractice premiums paid are premiums paid to liability insurers. Self-insurance paid is funds paid to a self-insurance plan. Total losses paid are medical malpractice losses of a hospital that are not covered by insurers or self-insurance plans. This type of cost is an out-of-pocket cost to hospitals. Using those data, we could estimate whether hospitals in the expansion states experienced higher medical liability costs than those in non-expansion states.

Like our main analysis, we use data from 2010 to 2018 but at the hospital level. We exclude hospitals that do not report any positive value in the three malpractice cost items. In the sample period, on average, malpractice premiums paid account for 75.1% of the total liability costs borne by hospitals. In comparison, 12.4% of the total costs consist of self-insurance plans, and the remaining 12.5% is (out-of-pocket) losses paid by hospitals. This cost sharing demonstrates that buying commercial medical liability insurance is still the major way for hospitals to manage medical liability risk.

To test the impact of Medicaid expansion on hospitals' malpractice liability costs, we continue to use the binary DID model. Dependent variables are log-transformed hospital costs, including malpractice premiums paid, self-insurance paid, and losses paid. We include hospital income and hospital total beds as the hospital control variables (both are log-transformed). State control variables are the same as those used in the main analysis. We also include hospital fixed effects, state fixed effects, year fixed effects, and a state-specific linear trend. We conduct the analysis using the sample as we discuss above.

To save space, we only report the coefficient of our variable of interest, $Expansion_{st}$, from the main sample analysis in Table 1.6. Results from alternative samples are presented in Section 8. Our results show that hospitals in expansion states, on average, did not pay significantly higher medical malpractice premiums to liability insurers or self-insurance programs after Medicaid expansion took place than those in non-expansion states. Hospitals in expansion states did not incur higher out-of-pocket medical liability losses, either. Taken together, the results from the insurers' and the hospitals' perspective suggest that it is medical malpractice insurers and physicians, rather than hospitals, who bear rising medical liability costs after Medicaid expansion.

Table 1.6 ACA Medicaid Expansion and Medical Malpractice Costs Borne by Hospitals

VARIABLES	(1) Log (Premiums Paid)	(2) Log (Self-Insurance Paid)	(3) Log (Losses Paid)
Expansion	-0.040	-0.195	0.047
	(0.137)	(0.123)	(0.233)
Observations	25,525	25,525	25,525
R-squared	0.753	0.766	0.762
Hospital Controls	YES	YES	YES
State Controls	YES	YES	YES
Hospital FE	YES	YES	YES
State FE	YES	YES	YES
Year FE	YES	YES	YES
State-Specific Linear Trend	YES	YES	YES

This table reports the regression results of the impact of Medicaid expansion on medical liability costs borne by hospitals using the DID models. Columns (1) to (3) report the results with the following dependent variables: medical liability insurance premiums paid, self-insurance premiums paid, and losses paid by hospitals respectively. All dependent variables are log-transformed. Standard errors are clustered at the state level and are reported in parentheses. *** (**, *) represents significance at the 1% (5%, 10%) level. We include two hospital-level control variables: hospital income and total beds, both of which are log-transformed. State-level control variables include unemployment rate (%), personal income (per capita), population reported with poor or fair health status (%), the number of insurance employees (per capita), the number of healthcare employees (per capita), the number of lawyers (per capita), and tort reform dummy variables. We also include hospital fixed effects, state fixed effect, year fixed effects and state-specific linear trends.

1.8 Robustness Check

In our main analysis, we exclude five states (California, Connecticut, Massachusetts, Minnesota, and Vermont) which had large numbers of Medicaid enrollees before 2014 and five late expansion states (Alaska, Indiana, Montana, Pennsylvania, and Louisiana) which expanded Medicaid after 2014 but before 2018. We keep two early expansion states (New Jersey and Washington) in the sample but regard them as expanding Medicaid coverage in 2014. As a robustness check, we build two alternative samples. In the first alternative sample, we further exclude New Jersey and Washington from the main

Table 1.7 Medicaid Expansion and Medical Liability Costs (Alternative Samples)

Variables	(1) Log (Losses Incurred)	(2) Log (Total Losses)	(3) Log (Premiums Earned)	(4) Log (Loss Ratio)
Alternative Sample A: exclude New Jersey and Washington from the main sample				
Expansion	0.154**	0.161**	0.132**	0.031
	(0.076)	(0.074)	(0.052)	(0.056)
Observations	17,319	17,319	17,319	17,319
R-squared	0.540	0.572	0.652	0.183
Alternative Sample B: add five late expansion states back to the main sample				
Expansion	0.124**	0.118*	0.077	0.041
	(0.060)	(0.061)	(0.047)	(0.041)
Observations	21,761	21,761	21,761	21,761
R-squared	0.539	0.570	0.650	0.175
Firm Controls	YES	YES	YES	YES
State Controls	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
State FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
State-Specific Linear Trend	YES	YES	YES	YES

This table reports the regression results for the DID model in Equation (1) with alternative sample definitions. In Sample A, we further exclude New Jersey and Washington from our main sample, leading to a narrower definition of the treatment group. In Sample B, we add back five late expansion states (Pennsylvania, Indiana, Alaska, Montana, Louisiana) to the main sample, leading to a broader definition of the treatment group. Column (1) to (4) report the results with the dependent variables: medical liability insurance losses incurred, total losses, premiums earned, and the loss ratio (%) respectively. All the dependent variables are log-transformed. Standard errors are clustered at the state level and are reported in parentheses. *** (**, *) represents significance at the 1% (5%, 10%) level. Firm-level control variables include firm size, leverage, liquidity, stock, and group. State-level control variables include unemployment rate (%), personal income (per capita), population reported with poor or fair health status (%), the number of insurance employees (per capita), the number of healthcare employees (per capita), the number of lawyers (per capita), and tort reform dummy variables.

sample, which results in a narrower definition of the treatment group. In the second alternative sample, we add five late expansion states back to the main sample, leading to a broader definition of the treatment group.

We run the regression in Equation (1) again using these two alternative samples. To save space, we only report the coefficient of our main variable of interest, $Expansion_{st}$, in Table 1.7. In general, the results remain largely the same as those in our main analysis.

Table 1.8 Medicaid Expansion and Malpractice Costs Borne by Hospitals (Alternative Samples)

VARIABLES	(1) Log (Premiums Paid)	(2) Log (Self-Insurance Paid)	(3) Log (Losses Paid)
Alternative Sample A: exclude New Jersey and Washington from the main sample			
Expansion	-0.019	-0.207	0.093
	(0.141)	(0.131)	(0.247)
Observations	24,421	24,421	24,421
R-squared	0.751	0.767	0.762
Alternative Sample B: add the five late expansion states back to the main sample			
Expansion	-0.048	-0.009	0.040
	(0.092)	(0.112)	(0.159)
Observations	28,918	28,918	28,918
R-squared	0.755	0.768	0.762
Hospital Controls	YES	YES	YES
State Controls	YES	YES	YES
Hospital FE	YES	YES	YES
State FE	YES	YES	YES
Year FE	YES	YES	YES
State-Specific Linear Trend	YES	YES	YES

This table reports the regression results of the impact of Medicaid expansion on medical liability costs borne by hospitals using the DID models. Column (1) to (3) report the results with the following dependent variables: medical liability insurance premiums paid, self-insurance premiums paid, and losses paid by hospitals. All dependent variables are log-transformed. Standard errors are clustered at the state level and are reported in parentheses. *** (**, *) represents significance at the 1% (5%, 10%) level. We include two hospital-level control variables: hospital income and total beds, both of which are log-transformed. State-level control variables are same as those used in Table 2. They include unemployment rate (%), personal income (per capita), population reported with poor of fair health status (%), the number of insurance employees (per capita), the number of healthcare employees (per capita), the number of lawyers (per capita), and tort reform dummy variables. We also include hospital fixed effects, state fixed effect, year fixed effect and state-specific linear trends.

That is, we see significant increases in loss incurred and total losses for medical malpractice insurers in expansion states, compared to those in non-expansion states. Insurers' premiums earned in expansion states increased too, but at a lower rate than losses incurred or total losses. We also conduct the hospital-level analysis using these alternative samples. The results are reported in Table 1.8. and are consistent with our findings using the main sample.

1.9 Conclusions

In this paper, we study the impact of the ACA Medicaid expansion on medical liability costs. The expansion of Medicaid has expanded public health insurance to millions of uninsured Americans and provided improved healthcare access. The resulting surge in demand for medical services has increased physicians' exposure to liability risk and associated costs.

Our results show that insurers operating in expansion states, compared to those in non-expansion states, experienced significantly larger increases in medical malpractice insurance losses incurred and total losses in the post-expansion period. As a response, insurers in expansion states increased premiums, but not enough to fully cover the losses. In addition, through tort reforms generally can limit liability payouts, we do not find evidence that the presence of these reforms alleviated the increase in medical liability costs driven by Medicaid expansion. By examining medical malpractice claim frequency and average severity, however, we find that Medicaid expansion increased an insurer's claim frequency significantly but did not affect average claim severity. This explains why severity-focused tort reforms did not function well to mitigate the negative impact of Medicaid expansion. Finally, we find that hospitals did not experience the same type of malpractice loss increases after Medicaid expansion. This provides evidence that expansion effects physician capacity but not hospital capacity.

CHAPTER 2

MEDICAID EXPANSION AND MEDICAL LIABILITY INSURANCE PRICES

2.1 Introduction

As an important part of the medical liability system, medical malpractice insurance provides coverage to practitioners for liability arising from provided services. After more than a decade of continuously lowering prices, medical liability insurance prices turned to an upward trend. In this paper, we find that the ACA Medicaid expansion contributes to the recent increase in prices. Medicaid expansion increased additional demand for healthcare, which adds strain to medical practitioners and increased their medical malpractice costs (Luo, Chen, and Grace, 2020). As a reaction, insurers increased their insurance prices two years after Medicaid expansion, especially for medical practitioners in internal medicine and general surgery.

Medical malpractice claims are frequent. Nearly half (49.2%) of physicians aged 55 and older have been sued during their careers (Guardado, 2017a). The overall costs associated with medical liability, including defensive medicine, are estimated to be $55.6 billion per year (Mello et al., 2010). To avoid placing their personal wealth under medical liability risk, most physicians carry medical malpractice insurance (Danzon, 1985). Meanwhile, medical malpractice insurance is expensive, especially for some practice areas. The market has occasionally experienced crises since the 1970s with extreme price surges. The increase in malpractice insurance prices has received much attention because it might result in physicians' fears of malpractice, affect their practice patterns, and lead to defensive medicine (Baicker, Fisher, and Chandra, 2007).

It is against this background that we study the impact of health care reform on medical liability insurance prices. The medical liability insurance market has experienced years of falling premiums and rate softness but shifted to a slight hardening phase recently (Auden and Globiciki, 2019). Specifically, insurance premiums of this business line in the whole country have decreased yearly since 2006 from over $7.1 billion to less than $5.3 billion in 2016. However, the falling trend ended in 2016, and premiums started to increase. This occurred against a backdrop of negative underwriting profitability (total losses and expenses divided by premiums earned) in the medical malpractice insurance business since 2014 (NAIC, 2019). In this paper, we aim to investigate whether and to what extent medical malpractice insurers changed insurance pricing for three specialties, internal medicine, general surgery, and obstetrics-gynecology (OB-GYN) because of the ACA Medicaid expansion.

The ACA has no substantive provision related to medical malpractice, but it drove up medical liability costs by around 20% to insurers (Luo, Chen, and Grace, 2020) to states that expand Medicaid in 2014. The reason behind this is that, with over 20 million new insureds, physician visits and health service utilization have largely increased, but physician supply grows at a much lower rate (Kirch et al., 2012; Dall, et al., 2018). The unbalanced increase in physician demand and constrained supply exacerbate the existing physician shortages in the U.S. (Huang and Finegold, 2013; Dall et al., 2018; Courtemanche et al., 2019a), which placed more pressures on physicians and increased their medical liability risk. Because insurance prices are based on the expected value of future losses and expenses, higher medical liability insurance costs could cause insurers to increase the insurance price especially for physicians who are more vulnerable after Medicaid expansion.

The staggered roll-out of the ACA Medicaid expansion offers a unique opportunity for us to examine the potential increase in medical liability insurance prices related to the expansion of public health insurance. We use two identification strategies. The first is based on a difference-in-difference (DID) analysis that compares the difference in medical liability insurance prices in all counties in Medicaid expansion states before and after the expansion with counties in non-expansion states. This national-level study uses all cross-state variation in Medicaid expansion status over time to estimate the Medicaid expansion effect. In comparison, the second strategy, which is our preferred strategy, compares medical liability insurance prices in bordering counties in neighboring states with different Medicaid expansion status. The cross-border counties sample is based on policy discontinuities at state borders and considers the variation of medical malpractice insurance prices within each of the cross-state pairs. Because of the high similarity of bordering counties, the cross-border sample may provide a better control-treatment comparison group than the all-county sample.

For each of the two samples, we first study the average expansion effect on medical liability costs and then investigate the time-varying dynamics of this effect using an event study framework. We further test the Medicaid expansion impact on the medical malpractice insurance prices for three specialties separately, aiming to explore which specialty's malpractice insurance price is affected most.

Our medical malpractice insurance price data is from the survey provided by Medical Liability Monitor (MLM) and further organized by Black et al. (2016). The MLM conducts an annual survey of major U.S. medical liability insurers and reports premiums for general surgery, internal medicine, and obstetrics-gynecology (OB-GYN), in each state in which insurers provide coverage since 1990. MLM generally reports rates in nominal dollars for policies with "standard" limits of $1M per occurrence/$3M per calendar year. This database has been consistently used by researchers, regulators, and legislatures to study the medical liability system (e.g., Carrier, et al. 2010; Mello, Studdert, and Kachalia, 2014; Guardado, 2017b). It is regarded as the only and most comprehensive source on medical liability insurance prices from a national and longitudinal perspective (Guardado, 2017b; Black et al., 2016).

As a preview of results, we find, during our sample period from 2010 to 2018, counties in expansion and non-expansion states are comparable in their medical malpractice insurance prices before the health care reform. However, after the ACA Medicaid expansion, especially since the third year of expansion, medical malpractice insurance prices of insurers operating in expansion counties started to surpass their counterparties in non-expansion states and the magnitude of the difference grew over time from 6% to 13% between 2016 to 2018. The dynamics of the impact may reflect a time lag between the policy change and the increasing health service utilization, between malpractice incidences and claim payments from insurers, and between increasing insured losses and rising prices. The results hold using both the all-county sample and the contiguous county-pair sample.

In addition, we investigate the impact of Medicaid expansion on each of the three specialties, respectively. We find a large price increase in prices for internal medicine and a moderate increase in general surgery. The impact on OB-GYN is minimal. The results are consistent with the capacity constrain hypothesis of Luo, Chen, and Grace (2020), who suggests it is the surge in demand for health care services that exacerbated the physicians' capacity constraint and resulted in increasing medical liability. Specifically, recent evidence shows that Medicaid expansion was associated with an increase in medical service for internal medicine and general surgery. For instance, Medicaid expansion caused increases in visits to physicians in general practice (6.6%), overnight hospital stays (2.4%), the rates of diagnosis of diabetes (5.2%), and high cholesterol (5.7%). In contrast, Medicaid expansion was unlikely to induce a sharp increase in the demand for OB-GYN services. This is because, by federal law, all states provide Medicaid coverage for pregnancy-related services to pregnant women with incomes up to 133% before the ACA, and Medicaid provided coverage for nearly 45% of all births in 2010 (Kaiser Family Foundation, 2017). For this reason, Medicaid expansion did not substantially expand Medicaid eligibility to pregnant women and would have a minor effect on the demand for OB-GYN services.

This paper fills a gap in current literature in several ways. First, it empirically examines the dynamic impact of Medicaid expansion on medical liability insurance prices. The results indicate that Medicaid expansion increases medical liability costs in addition to its impacts on the health care system. Understanding this issue provides insights into the degree to which the extension of other public health insurance programs may influence the liability system. Second, while there is a considerable amount of research on medical malpractice insurance claim payments (e.g., Born, Viscusi, and Baker, 2009; Grace and Leverty, 2013). research on medical malpractice insurance prices is sparse mainly due to a lack of data. For other studies on insurance price, most rarely incorporate direct measures of insurance price, but instead, use the reported ratios of losses to premiums, the so-called loss ratio, to proxy insurance prices (e.g., Cummins and Danzon, 1997; Choi and Weiss, 2005; Weiss and Choi, 2008). However, the loss ratio is extremely noisy and provides an unreliable estimate of insurance prices (Harrington, Danzon, and Epstein, 2008). Also, there is substantial variation in the insurance price across specialties, but this is not identifiable in the loss ratio as all medical specialties are combined in the aggregated data. In comparison, the policy-specialty-level price used in our paper provides a more precise and direct measure of medical malpractice insurance prices. Third, medical malpractice rates are determined locally. Using county average prices rather than state-wide total premiums allows us to consider price variations across counties. Lastly, in addition to using the conventional strategy of comparing states with states, we use a local identification strategy based on contiguous county-pairs, which controls for spatial heterogeneity while studying the impact of regional policy change.

The remainder of this paper is organized as follows. In Section 2, we provide some background on medical liability insurance and the ACA Medicaid expansion. We describe the data in Section 3 and discuss our empirical methodologies in Section 4. We present our full-county sample results and the cross-border counties sample results in Section 5. We discuss the robustness analysis in Section 6. Concluding remarks are given in Section 7.

2.2 Institutional Background

2.2.1 Medical Liability System

Two major goals of the medical liability system are to compensate patients injured by medical negligence or intentional actions and to deter medical providers from such behavior (Kessler, 2011; Stamm et al., 2018). Because of the high probability of being involved in a medical malpractice claim over a career, most physicians purchase medical malpractice insurance. State regulations also exist to require physicians to have minimum levels of malpractice insurance to practice, to qualify for state programs that assist them with claims, or in their workplace.

Like all other insurance products, medical malpractice insurance prices are based on the expected value of future losses and expenses. Insurers use historical data to forecast future losses and expenses and determine the premiums which vary considerably across states and specialties. In addition to historical loss information, current economic conditions, market competition, and policy uncertainties, such as changes in the tort system and healthcare system, may also affect insurers' premium estimations. In fact, rapid growth in expected claim costs with increased uncertainty about costs can produce sharp increases in premium rates (Harrington, Danzon, and Epstein, 2008).

Medical malpractice insurance markets have occasionally experienced crises since the 1970s, during which claim payments, as well as defense and investigation costs, increased rapidly, causing sharply ascending insurance prices (Harrington, 1992; Harrington and Litan, 1988; Danzon, 1991). The deterioration in the market prompted many states to institute tort reforms. The rationale for the liability reforms is that limits on liability could reduce the size of court awards, which could in turn limit costs for insurers and restrain price increases over time. Since 2003, the nationwide medical malpractice insurance market has undergone both decreasing losses and premiums. This trend lasted for about a decade and was recently reversed. The purpose of this paper is to investigate whether the ACA Medicaid expansion contributes to this reversal. We are especially interested in the dynamic reaction of insurers in the face of higher medical liability insurance losses after Medicaid expansion. This is an important question because a high medical malpractice insurance price may strongly affect physician's career choices, incentivize them to drop specific coverage, change practice locations, stop seeing patients with potential litigation risk, and eventually reduce the supply of services (Taheri, et al., 2006).

2.2.2 The Affordable Care Act Medicaid Expansion

In the U.S., health care usage is determined not only by health status but also by health insurance. Without health insurance, access to health care is out of reach for many Americans. The U.S. had a significant uninsured population over the past forty years (Frean et al., 2017). Before the ACA, public health insurance programs such as Medicare and Medicaid only covered people older than 65, disabled, or low-income parents (as low as 50% of the family poverty level (FPL) in some states). Low-income childless adults were ineligible for Medicaid in almost every state.

The ACA provided states the option to expand low-cost health care to more low-income within a state. The state-by-state Medicaid expansion, starting in 2014, expanded coverage to households with incomes up to 138% of the FPL. By the end of 2018, 31 states had adopted Medicaid expansion and over 15 million enrollments were from the new adult eligibility group (Centers for Medicare & Medicaid Services, 2020).

A substantial amount of research has studied the impact of Medicaid expansion on insurance coverage, access to care, utilization, and health status. See Mazurenko et al. (2018) for a comprehensive review. These studies find a significant increase in insurance coverage (Frean et al., 2017), enhanced healthcare affordability (Decker, Lipton, and Sommers, 2017; Goldman et al., 2018), improved access to medication and services (Martin et al., 2017; Wherry and Miller, 2016; Miller and Wherry, 2019; Barbaresco et al., 2015), and better health outcomes and survival rates (Barbaresco et al., 2015; Gao, 2017; Swaminathan et al., 2018) in expansion states in comparison to non-expansion states. However, the improvement in healthcare access after Medicaid expansion coincided with a steep increase in the demand for medical services and medical practitioners. Given the existing shortage of physicians, the ACA exacerbated the capacity constraint (Kirch et al., 2012; Dall, et al., 2018; Sargen et al., 2011; Huang and Finegold, 2013) and placed more pressures on medical practitioners. As a result, delays in receiving care, increasing wait times and increasing difficulty in securing appointments (Miller and Wherry, 2017) became more common after the ACA. Also, ambulance response times are slower by 24% on average (Courtemanche et al., 2019b).

It is within this context a limited number of studies have started to explore the extent medical liability costs are affected by Medicaid expansion. Auerback**,** Heaton, and Brantley (2014) employ a micro-simulation model to project that the impact of the ACA on medical malpractice claims and project the cost of claims would increase by 3.4% on average in 2016. Using state-level insurance loss ratio data during 2010-2016, Heaton and Flint (forthcoming) find that Medicaid expansion reduces the auto liability and workers' compensation loss ratios by 6–11%, but does not impact the loss ratio of other lines such as medical malpractice insurance significantly. However, the loss ratio, which is defined as losses divided by premiums, does not reflect the pure losses to insurers. The change in the loss ratio depends on whether a loss increase is offset by a premium increase. The loss ratio would be stable if losses and premiums change in the same direction in the same amount. Instead of using a loss ratio, Luo, Chen, Grace (2020) study the direct medical liability insurance monetary costs to insurers, insureds, and hospitals between 2010 to 2018.

They find that the ACA Medicaid expansion increased medical liability claim costs to insurers by 20%. They also find an increase in insurers' total premiums earned, but that increase was not enough to fully offset rising costs.

Rising premiums after Medicaid expansion may indicate an increase in "price", but a firm's premium earned is the insurer's total revenue or the multiplication of average insurance price and the number of insurance policies sold (Doherty, 1981). Without separating the two factors, increasing premiums may not directly imply the increase in prices. Also, there are systematic differences in medical malpractice insurance prices across specialties, which are averaged out when an aggregated firm-level premium is studied.

Comparing to the above existing studies, our paper explores the impact of Medicaid expansion on the price of medical malpractice insurance policies. The advantage to our approach is that the specialty-specific price data does not miss price variation information across the three specialties. Also, different from total premiums which are the multiplication of price and policy quantities, we use a more precise and direct measure of the price for insurance policies. Moreover, unlike existing studies based on state-year difference-in-difference models, our local identification strategy adds a spatial discontinuity analysis by studying medical malpractice insurance prices in bordering counties with different expansion status. A similar strategy has been used by Dube, Lester, and Reich (2010), Peng, Guo, and Meyerhoefer (2019) and He and Barkowski (2020) in studying the impact of regional policy changes. Restricting the analysis to border county pairs greatly improves the comparability between treatment and control groups (Peng, Guo, and Meyerhoefer, 2019). In the next section, we start to introduce the data that we use.

2.3 Data

To examine the effect of Medicaid expansion on medical malpractice insurance prices, we aggregate price data, county, and state demographic data from various sources to compile a dataset of county-specialty-year observations from 2010 to 2018. Our source of the medical liability insurance price data is from the Medical Liability Monitor survey (MLM). Since 1991, the MLM annual rate survey has provided a continuing overview of the changing rate physicians pay for medical professional liability (medical malpractice) insurance. Each year, the MLM surveys the major writers of medical malpractice insurance in counties that they actively market to physicians. Then they report each insurer's medical malpractice insurance policy price for physicians in each county in three specialties: Internal Medicine, General Surgery, and OB-GYN. The price is the manually approved price for specialties with limits of $1 million per event/$3 million per year, the most common limits. Because where physicians practice largely determines the premiums, the MLM annual rate survey provides a clear picture of typical state-by-state, county-by-county medical malpractice insurance prices. Insurers surveyed by MLM account for 70-80% (depending on the year) of the medical malpractice insurance market in the U.S. As the only and most comprehensive source of medical liability insurance prices from a national and longitudinal perspective, the MLM survey is used by researchers studying the medical malpractice liability system (Carrier, et al. 2010; Mello, Studdert, and Kachalia, 2014; Guardado, 2017b) and is consistently cited by regulators and legislatures such as the General Accounting Office, Department of Health & Human Services, the Congressional Budget Office, and state legislatures. Because the firms in the survey of MLM have some variation across years, we use the weighted county-average rate shared and introduced in

Black et al. (2016). The weight is based on the number of physicians in the three specialties in the county.

To account for county economic and social conditions that might affect medical malpractice insurance prices, we collect several county-level control variables. They include *low birthweight rate*, *poor or fair health status*, *adult smoking rate*, and *primary care physician rate*, all of which are valuable public health indicators for health risk and health-related quality of life. The *low birthweight rate* is the percentage of live births where the infant weighed less than 2,500 grams. *Poor and fair health status* represents the percentage of adults reporting fair or poor health in a county. *The adult smoking rate* is the percentage of the adult population in a county who both report that they currently smoke daily or most days and have smoked at least 100 cigarettes in their whole life. *The primary care physician rate* is the ratio of the population to the number of primary care physicians. In addition to health status, we also include control variables for social and economic status. These are *some college degree*, the percentage of the population ages 25-44 with some post-secondary education; *Violent Crime*, violent crimes per 100,000 population; *Unemployment rate*, the percentage of the county's civilian labor force, ages 16 and older that are unemployed; *rural area ratio*, the percentage of the population in the rural areas; and *female population rate* and *Hispanic population rate*. All the county-level data are from County Health Rankings[15], which collects original data from several data sources such as the American Community Survey, Risk Factor Surveillance System, Bureau of Labor Statistics, Area Health Resource File, and the American Medical Association.

In addition, we use a state-level dataset to track the change of liability rules. Tort

[15] https://www.countyhealthrankings.org/explore-health-rankings/rankings-data-documentation

reforms, started from the 1970s, are designed to limit the liability or censor the right tail of the award distribution, which could in turn reduce costs for insurers and restrain premium increases over time. Evidence exists that some reforms, such as caps on non-economic damages, have reduced medical malpractice claim losses from the 1980s to the 2000s (e.g., Born, Viscusi, and Baker, 2009; Grace and Leverty, 2013; Paik, Black, and Hyman, 2017). In this paper, we use the database of State Tort Law Reforms (Avraham, 2019; DSTLR 6th) to track tort reforms from 1980 to 2018. We include four tort reform dummy variables, i.e., *caps on non-economic damages (CN), caps on punitive damages (CP), joint and several reforms (JS), and collateral source reform (CS)*, to indicate whether a state has adopted a particular tort reform or not in a given year. We focus on these four tort reforms because they are the most influential ones and often considered in prior studies of medical malpractice insurance markets (e.g., Viscusi and Born, 2005; Born, Viscusi, and Baker, 2009; Born and Karl, 2013; Grace and Leverty, 2013).[16]

In addition to tort reforms, another variable capturing a state's regulatory environment is the *Prior Rate Regulation.* The regulatory regimes of insurance rate regulation vary across states but are often categorized into prior approval and competitive rating. In states with prior approval rate regulation, insurers file requests for rate change before the rate adjustment. Insurance commissioners review the insurer's request along with considering the insurer's loss experience and profit margins. After that, they decide to approve or deny the rate request. In states without an approval rate requirement, insurers

[16] The tort system is stable for most of the states in our sample period. During our sample period, only eight states adopted or struck down these four tort reforms. Specifically, North Carolina and Tennessee adopted caps on non-economic damage reform in 2012; South Carolina and Tennessee adopted caps on punitive damage reform in 2012; Pennsylvania adopted joint and several liability reform in 2011. In contrast, Mississippi, Missouri, and Utah struck down caps on non-economic damage reform in 2013; Arkansas and Missouri abolished caps on punitive damage in 2012 and 2015, respectively.

can change a rate without a regulator's prior approval. Evidence shows that states with prior approval requirements tend to have a higher price. This is because it is the high price that causes consumers to demand strict rate regulation (Weiss, Tennyson, and Regan, 2007). We include a dummy variable equal to 1 if a state enacted prior approval rate regulation in year i, 0 otherwise.

Our data on Medicaid expansion status is from the Kaiser Family Foundation. The ACA Medicaid expansion officially started on January 1, 2014. The ACA Medicaid expansion officially started on January 1, 2014. Five states (i.e., California, Connecticut, Minnesota, New Jersey, and Washington) took advantage of the state plan amendment (SPA) or a Section 1115 Waiver to exercise the early expansion option.[17] In our sample, we exclude three states (California, Minnesota, and Connecticut) and Washington D.C., which exercised early expansion options and had newly eligible enrollees before 2014. In New Jersey and Washington, the early expansion option mainly was used to shift people from existing public insurance programs into Medicaid but these plans did not enroll new participants until 2014 (Sommers et al., 2013; Sommers et al., 2014; Nikpay et al., 2015). For this reason, we keep these two states in our sample but regard them as expanding Medicaid in 2014. We also exclude Massachusetts and Vermont that implemented the ACA Medicaid expansion in 2014 but had no new eligible enrollees since then.

We further exclude late-expansion states (Pennsylvania, Indiana, Alaska, Montana, and Louisiana), because the inclusion of late adopters might attenuate the coefficients of interest if the expansion has lagged effects (Peng, Guo, and Meyerhoefer, 2019). Our final sample includes 21 expansion states that implemented Medicaid expansion in 2014

[17] Connecticut expanded Medicaid on April 1, 2010, followed by Minnesota on August 1, 2010, California on November 1, 2010, Washington on January 3, 2011, and New Jersey on April 14, 2011.

(including New Jersey and Washington) and 19 non-expansion states (including 5 states expanding Medicaid after 2018 and 14 states that have not adopted or implemented Medicaid expansion). In the robustness analysis in Section 6, we include the later expansion states in the analysis and the results are largely the same as the main sample.

Tables 2.1.1 and 2.1.2 presents the summary statistics of major variables used in this paper in both full-county sample and cross-border counties sample. The full-county sample includes county-average medical malpractice insurance prices for 2,026 counties. There are 298 counties in the cross-border counties sample with 371 county-pairs and 33 state border pairs. The two tables indicate that physicians pay vastly different prices depending on their specialties. This is due to the substantial variability in the likelihood of malpractice suits and the size of indemnity payments across specialties (Jena et al., 2012). Table 2.1.1 shows that among the three specialties, OB-GYN doctors pay the highest medical malpractice insurance prices, with a mean price of $61,555 and a maximum price of $206,350 per year. The high price for OB-GYN doctors implies the high malpractice risk in OB-GYN practices, and malpractice risk is one of the top three determinants that affect a physician’s decision to include obstetrics in their practice (Xu, et al., 2008). The maximum price is reported in the county of Miami-Dade in Florida. The high price in Miami-Dade is an exception because the cost of settling and defending medical malpractice claims in Florida is 2.9 times the national average (Aon, 2015). In addition, the average price for general surgery doctors is $43,780 but in Miami-dude, general surgery doctors have to pay over $166,046 for a policy on average. Internal Surgery doctors pay the lowest price of medical malpractice insurance with a mean value of $12,744 and a maximum value of $43,933.

Table 2.1.1 Summary Statistics (All Counties Sample)

Variable	Observations	Mean	Std. Dev.	Min	Max
Medical Malpractice Insurance prices	34,194	37,458.48	26,888.280	3,441	206,350.5
Medical Malpractice Insurance prices (General Surgery)	11,302	43,780.05	17,806.48	11,033	166,046.33
Medical Malpractice Insurance prices (Internal Medicine)	12,765	12,744.45	5,194.294	3,441	42,285.667
Medical Malpractice Insurance prices (OB/GYN)	10,127	61,555.26	25,654.87	15,807	206,350.5
Occurrence Policy	34,194	0.102	0.302	0	1
Low Birthweight Rate	34,194	0.083	0.018	0.029	0.189
Poor or Fair Health	34,194	0.169	0.051	0.024	0.498
Unemployment Rate	34,194	0.075	0.028	0.008	0.277
Adult Smoking rate	34,194	0.201	0.05	0.031	0.511
Primary Physician Rate	34,194	0.001	0	0	0.006
Hispanic Population Rate	34,194	0.083	0.115	0.004	0.972
Female Population Rate	34,194	0.505	0.017	0.315	0.58
Some College Degree	34,194	0.575	0.108	0.193	0.905
Violent Crime	34,194	312.884	232.442	0	2332.836
Rural area ratio	34,194	0.44	0.272	0	1
Caps on Non-Economic Damage	34,194	0.545	0.498	0	1
Caps on Punitive Damage	34,194	0.741	0.438	0	1
Prior Rate Regulation	34,194	0.32	0.467	0	1
Number of Counties			2,026		

Table 2.1.2 Summary Statistics (Cross-Border Counties Sample)

Variable	Observations	Mean	Std. Dev.	Min	Max
Medical Malpractice Insurance prices	5,361	32,749.799	24,494.419	2,907	144,821
Medical Malpractice Insurance prices (General Surgery)	1,850	38,387.03	18,154.34	8,986	1111,781
Medical Malpractice Insurance prices (Internal Medicine)	2,016	11,228.78	5,622.483	2,907	38,798
Medical Malpractice Insurance prices (OB/GYN)	1,495	53,561.17	24,598.43	14,465	144,821
Occurrence Policy	5,361	0.053	0.223	0	1
Low Birthweight Rate	5,361	0.078	0.018	0.03	0.189
Poor or Fair Health	5,361	0.164	0.058	0.045	0.455
Unemployment Rate	5,361	0.069	0.027	0.017	0.198
Adult Smoking rate	5,361	0.2	0.055	0.053	0.511
Primary Physician Rate	5,361	0.001	0	0	0.005
Hispanic Population Rate	5,361	0.085	0.124	0.004	0.828
Female Population Rate	5,361	0.502	0.014	0.398	0.56
Some College Degree	5,361	0.59	0.114	0.207	0.897
Violent Crime	5,361	278.473	263.399	0	2,332.836

Rural area ratio	5,361	0.452	0.271	0	1
Caps on Non-Economic Damage	5,361	0.454	0.498	0	1
Caps on Punitive Damage	5,361	0.62	0.485	0	1
Prior Rate Regulation	5,361	0.225	0.418	0	1
Number of Counties		298			
County Pairs		371			
Border Pairs		33			

2.4 Research Design

To investigate the impact of the ACA Medicaid Expansion on medical liability insurance prices, we use two identification strategies. The first is a difference-in-difference (DID) approach which compares medical malpractice insurance prices between counties in expansion and non-expansion states before and after Medicaid expansion. The second strategy uses a local DID method and focuses on policy discontinuities at state borders. Specifically, we employ geographic matching to compare malpractice insurance prices in adjacent counties that are located on opposite sides of a state border where one state expanded Medicaid and the other did not. Because contiguous counties have higher similarities in economic and social factors than two random counties in two expansion and non-expansion states, using cross-border rather than cross-state variation provides better comparability between the treatment group and control group.

Even so, one concern of using cross-border analysis is whether there is a spillover effect of the policy across states. For instance, if Medicaid patients have incentives to seek treatments in the neighboring states, then comparing bordering counties may misestimate the impact of policy and bias results toward zero. However, Medicaid covers out-of-state treatments only when patients encounter an emergency that requires immediate treatments. In all other scenarios, Medicaid coverage cannot be transferred across states. Accordingly, the expansion of Medicaid does not create new incentives for patients to seek cross-border health care, and thus does not cause spill-over demand for healthcare in bordering counties in non-expansion states. We use the U.S. Census County Adjacency File to identify all bordering counties with different expansion states. Only counties that expand Medicaid in 2014 are regarded as expanded counties. This sample includes 30 states and 564 matched county pairs across 30 states. Figure 2.1 presents all the bordering counties with different expansion status. The sample including states that expanded after 2014 is discussed in Section 2.6.

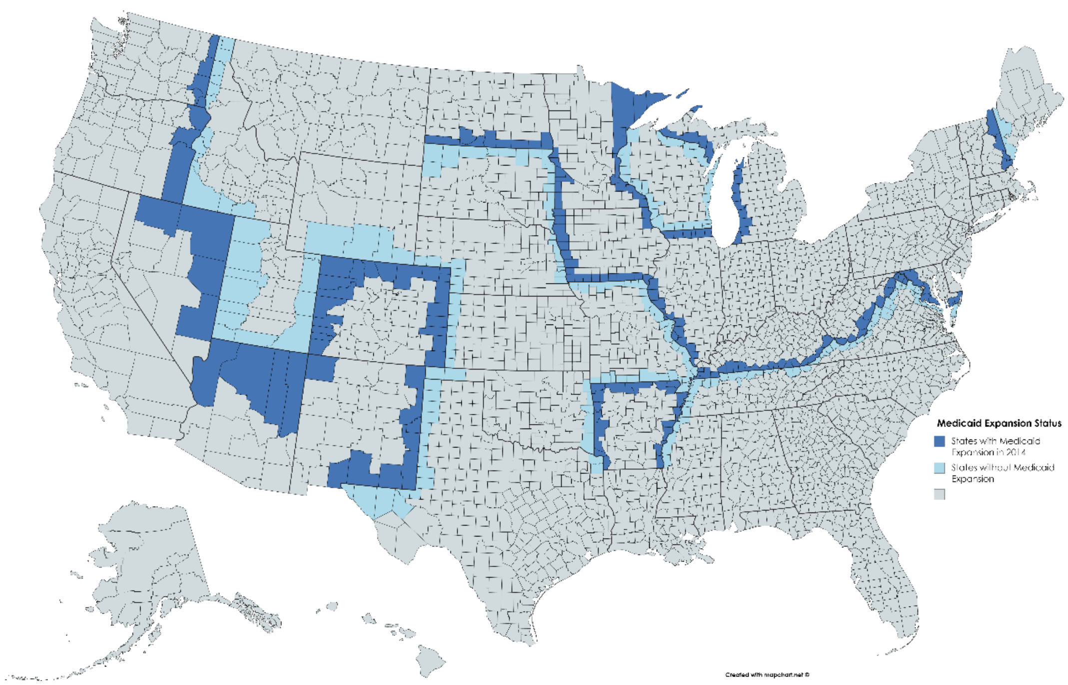

Figure 2.1 Bordering Counties with Different Expansion Status

In the following subsections, we discuss the details of the identification strategy. For each of the two samples, we first study the average expansion effect on medical liability costs and then investigate the time-varying dynamics of this effect using an event study framework. Secondly, we test the Medicaid expansion's impact on medical malpractice insurance prices for three specialties, aiming to explore which specialty's malpractice insurance prices are affected most.

2.4.1 DID Analysis for the Average Impact of Medicaid Expansion

To investigate the impact of the ACA Medicaid Expansion on medical liability insurance prices, we use the following two DID models to estimate the average impact of Medicaid expansion on medical malpractice insurance prices.

(1) Specifications using the all counties sample:

$$Y_{ijst} = \beta_0 + \beta_1 Expansion_{it} + \beta_2 X_{it} + \alpha_t + \delta_i + \gamma_j + \varphi_s \times t + \varphi_j \times t + e_{ijst} \quad (2.1)$$

(2) Specifications using the cross-border counties sample:

(3) $$Y_{ijst} = \beta_0 + \beta_1 Expansion_{it} + \beta_2 X_{it} + \alpha_t + \delta_i + \gamma_j + \theta_p + \varphi_s \times t + \varphi_j \times t + e_{ijst} \quad (2.2)$$

where

Y_{ijst} is average medical malpractice insurance prices in county i of specialty j in state s in year t.

$Expansion_{it}$ is a dummy variable that is equal to 1 if county i is in a state that has implemented Medicaid expansion by December 31st in year *t*, 0 otherwise.

X_{it} is a vector of control variables at the county-level and state-level.

α_t controls for year fixed effect.

δ_i controls for county fixed effects.

γ_j controls for specialty fixed effects.

θ_p controls for the county-pair fixed effect for cross-border counties sample.

t is a continuous trend variable. $\varphi_s \times t$ indicates a state-specific linear trend. $\varphi_j \times t$ indicates a specialty-specific linear trend.

e_{it} is an idiosyncratic error.

The two specifications are comparable except for two differences. First, in the cross-border counties sample, we use county-pair fixed effects, aiming to control factors that two bordering counties share but do not change across the years. Second, while the whole country sample uses state-clustered standard errors, we cluster at both state and state-border in the county-pair sample. State-border clustered standard errors are used to control correlation in the error terms within the same border segment (Dube, Lester, and Reich, 2010).

The estimated coefficient β_1 provides the estimated mean difference in medical malpractice insurance prices between expansion and non-expansion states before and after expansion, controlling for other influencing factors. As stated earlier, a state's Medicaid expansion caused a possible surge in demand for healthcare services. If we believe capacity constraints create challenges for physicians and increase medical malpractice risk (Luo, Chen, and Grace, 2019), then we expect that insurers in expansion states increased their medical liability insurance prices relative to those in non-expansion states after Medicaid expansion. This leads to a positive prediction for β_1.

To account for county economic, social, or legal conditions that might affect medical malpractice insurance prices, we add several county-level control variables introduced in Section 2.3 to reflect a county's economic, social, legal, and regulatory environment. Location is one of the most important determinants of medical malpractice insurance prices and malpractice prices vary markedly across states for identical care (Taheri, et al., 2006). Although we do not claim causality between these control variables and our dependent variable, they may improve identification by acting as proxies for state unobservable characteristics correlated with the pricing of medical malpractice insurance. We also include specialty, county, state, and year fixed effects. Moreover, the medical liability insurance market has experienced underwriting cycles over time (Baker, 2004; Harrington, Danzon, and Epstein, 2008) and the medical malpractice insurance prices have been experiencing a downward trend since around 2003. Considering that each state might experience a different trend in the sample period, we follow Born, Karl, and Montesinos-Yufa (2018) to include a state-specific linear trends to control this effect in this market. We also include specialty-specific linear trends to control for linear trend in medical malpractice insurance prices that varies by specialties.

2.4.2 Event Study for the Dynamic Impact of Medicaid Expansion

To better understand the dynamic impact of Medicaid expansion on medical liability prices, we use an event-study methodology. As more Medicaid eligible participants enter the health care system, we may see the impact of Medicaid expansion varies over time. This is because a time lag exists between when patients received health insurance and visited physicians and any potential liability claim. Also, after medical malpractice incidences occur, it may take months or even years for the claim to evolve into claim settlements and losses incurred to insurers. Thus it may take some time for insurers to realize that costs are indeed rising. After the costs increase, insurers may consider increasing prices consequently.

To investigate the treatment effect dynamics, we use the following specification.

(4) Event-study specifications using the all counties sample

$$Y_{ijst} = \beta_0 + \beta_1 Treat_{i,t=-4} + \beta_2 Treat_{i,t=-3} + \beta_3 Treat_{i,t=-2} + \beta_4 Treat_{i,t=0} + \beta_5 Treat_{i,t=1} + \beta_6 Treat_{i,t=2} + \beta_7 Treat_{i,t=3} + \beta_8 Treat_{i,t=4} + \beta_9 X_{it} + \alpha_t + \delta_i + \gamma_j + \varphi_s \times t + \varphi_i \times t + e_{ijst} \quad (2.3)$$

(5) Event-study specifications using the cross-border counties sample

$$Y_{ijst} = \beta_0 + \beta_1 Treat_{i,t=-4} + \beta_2 Treat_{i,t=-3} + \beta_3 Treat_{i,t=-2} + \beta_4 Treat_{i,t=0} + \beta_5 Treat_{i,t=1} + \beta_6 Treat_{i,t=2} + \beta_7 Treat_{i,t=3} + \beta_8 Treat_{i,t=4} + \beta_9 X_{it} + \alpha_t + \delta_i + \gamma_j + \theta_p + \varphi_s \times t + \varphi_i \times t + e_{ijst} \quad (2.4)$$

In this equation, we define a set of dummy variables indicating the periods before and after the ACA Medicaid expansion adoption in each state. For the Medicaid expansion states, $Treat_{i,t=-4}$ is equal to 1 if the county-state-year observation in expansion states is four years before the adoption of Medicaid expansion and 0 otherwise. Since all expansion states in our sample started Medicaid expansion in 2014, $Treat_{i,t=-4}$ is equal to 1 for observations in the Medicaid expansion states in the year 2010. For non-expansion states, $Treat_{i,t=-4}$ is always equal to 0. We define $Treat_{i,t=-3}$, $Treat_{i,t=-2}$, $Treat_{i,t=0}$, $Treat_{i,t=1}$, $Treat_{i,t=2}$, $Treat_{i,t=3}$, and $Treat_{i,t=4}$ similarly, where $t = 0$ refers to the expansion year, i.e., the year 2014. The year before Medicaid expansion (the year 2013) is regarded as the base year, so $Treat_{i,t=-1}$ is omitted in the regression. This event study framework disentangles the timing of the policy change and can help us explore the change in the impact of Medicaid expansion over time. Other control variables used are the same as those used in equations (2.1) and (2.2) respectively.

In addition to testing the dynamics of the treatment effect, the event study framework can also help us assess the parallel trend assumption underlying the DID analysis. For the all-counties sample, DID analysis is valid only if medical malpractice prices in expansion states and non-expansion states would have followed the same path in the absence of Medicaid expansion. For the cross-border counties sample, the DID analysis relies on contiguous counties being similar in terms of demographic characteristics other than their Medicaid expansion status. While the two assumptions cannot be tested directly, we can test whether the trend of such variables was different in expansion and non-expansion states before Medicaid expansions took place (He and Barkowski, 2018; Peng, Guo, and Meyerhoefer, 2019). If the outcome difference between the treatment group and the control group in pre-treatment years is not significantly different from that in the base year, our test is passed. In other words, the tests for differential pre-treatment trends (i.e., falsification tests) are provided by evaluating whether the coefficients on the "treatment" variables in the pre-treatment years (β_1, β_2, and β_3) are significantly different from 0. This event study framework helps evaluate whether the control group is a valid counterfactual for the treatment group.

2.5 Baseline Results

2.5.1 Average Impacts of Medicaid Expansion

Tables 2.2 and Table 2.3 report the results for the binary DID estimation in Equation (1). The first column presents the results from the observations of all specialties. The second to fourth columns are for the results of General Surgery, Internal Medicine, and OB-GYN respectively. Table 2.3 is comparable to Table 2.2 but uses the cross-border counties sample. Using the 2014 expansion dummy, we do not see a significant increase in medical liability insurance prices in either the all counties sample or the cross-border counties subsample. That is, the coefficient for the expansion dummy is statistically insignificant. However, if there exists a lagged Medicaid expansion effect on insurance prices, it might be averaged out using the aggregated 2014 expansion dummy. Thus, in the next section, our focus turns to the dynamics of the impact.

2.5.2 Dynamic Impacts of Medicaid Expansion

Table 2.4 and Table 2.5 present the regression results for the event study in Equations 2.3 and 2.4 in the all counties sample and the cross-border counties sample. For

Table 2.2 Full Sample Difference-in-Difference Results

VARIABLES	(1) All specialties	(2) General Surgery	(3) Internal Medicine	(4) OB-GYN
Expansion Dummy	0.012	0.034	-0.011	0.012
	(0.030)	(0.038)	(0.028)	(0.030)
Occurrence Policy	-0.114*	-0.173	-0.105	-0.063
	(0.064)	(0.115)	(0.067)	(0.062)
Low Birthweight Rate	0.226	0.020	0.262	0.237
	(0.140)	(0.122)	(0.182)	(0.147)
Poor or Fair Health	-0.001	0.035	-0.005	0.033
	(0.034)	(0.041)	(0.039)	(0.063)
Unemployment Rate	0.027	-0.001	0.236	-0.173
	(0.197)	(0.253)	(0.319)	(0.167)
Adult Smoking rate	-0.087**	-0.067*	-0.101**	-0.094*
	(0.042)	(0.036)	(0.044)	(0.053)
Primary Physician Rate	-4.188	-9.063	-0.944	-0.922
	(5.199)	(6.867)	(7.183)	(4.335)
Hispanic Population (%)	-0.338	-0.493**	-0.255	-0.164
	(0.249)	(0.240)	(0.306)	(0.214)
Female Population (%)	-0.316	-0.563**	-0.279	-0.050
	(0.245)	(0.247)	(0.263)	(0.245)
Some College Degree	0.046*	0.052	0.010	0.058**
	(0.024)	(0.034)	(0.026)	(0.027)
Violent Crime	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Rural area ratio	0.023	0.013	0.035	0.056
	(0.025)	(0.028)	(0.030)	(0.035)
Caps on Non-Economic Damage	-0.041	-0.021	-0.082	-0.011
	(0.033)	(0.024)	(0.068)	(0.014)
Caps on Punitive Damage	0.095	0.046	0.195*	0.023
	(0.060)	(0.058)	(0.112)	(0.028)
Prior Rate Regulation	-0.006	-0.015	-0.009	0.012
	(0.028)	(0.037)	(0.028)	(0.021)
Constant	10.766***	10.940***	9.409***	10.969***
	(0.138)	(0.134)	(0.150)	(0.143)
Observations	34,194	11,264	12,744	10,106
R-squared	0.981	0.971	0.969	0.973
County FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Specialty FE	YES	-	-	-
State-Specific Linear Trend	YES	YES	YES	YES
Specialty-Specific Linear Trend	YES	YES	YES	YES

This table reports regression results for the DID model for the all counties sample in Equation (1). Columns (1)

to (4) report the results with the dependent variables: average medical liability insurance prices and the price for three specialties, General Surgery, Internal Medicine, and OB-GYN respectively. All the dependent variables are log-transformed. Alaska, California, Connecticut, Indiana, Louisiana, Massachusetts, Minnesota, Montana, Pennsylvania, and Vermont are excluded from our sample. Standard errors are clustered at the state level and are reported in parentheses. *** (**, *) indicates significance at the 1% (5%, 10%) level.
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Table 2.3 Border County Difference-Difference Results

VARIABLES	(1) All Specialties	(2) General Surgery	(3) Internal Medicine	(4) OB-GYN
Expansion Dummy	0.486	-0.014	0.402	1.073
	(0.415)	(0.551)	(0.492)	(0.894)
Low Birthweight Rate	0.095	0.273*	-0.011	0.061
	(0.076)	(0.134)	(0.104)	(0.120)
Poor or Fair Health	-0.442	-0.424	-0.940**	-0.085
	(0.322)	(0.462)	(0.393)	(0.314)
Unemployment Rate	-0.103	-0.014	-0.077	-0.158**
	(0.084)	(0.068)	(0.124)	(0.070)
Adult Smoking rate	-29.631	-15.344	-59.783	9.930
	(32.980)	(40.582)	(55.255)	(16.971)
Primary Physician rate	0.050	0.112	0.069	-0.136
	(0.072)	(0.153)	(0.110)	(0.113)
Some College Degree	0.516	-0.698	-0.194	-0.455
	(0.828)	(0.896)	(1.366)	(0.911)
Hispanic Population (%)	-0.078	-0.188	0.173	0.392
	(0.660)	(0.716)	(1.029)	(0.674)
Female Population (%)	0.000	-0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Violent Crime	-0.132**	0.012	-0.057	-0.060
	(0.050)	(0.067)	(0.130)	(0.072)
Rural area ratio	-0.024**	-0.010	-0.048***	-0.014
	(0.011)	(0.013)	(0.015)	(0.013)
Occurrence Policy	0.017	-0.002	0.038*	0.013
	(0.018)	(0.033)	(0.022)	(0.015)
Caps on Non-Economic Damage	0.012	0.004	0.022	0.024
	(0.017)	(0.036)	(0.023)	(0.022)
Caps on Punitive Damage	0.486	-0.014	0.402	1.073
	(0.415)	(0.551)	(0.492)	(0.894)
Prior Rate Regulation	0.095	0.273*	-0.011	0.061
	(0.076)	(0.134)	(0.104)	(0.120)
Constant	10.474***	10.406***	9.029***	10.638***
	(0.379)	(0.462)	(0.478)	(0.365)
Observations	5,361	1,817	1,984	1,458
R-squared	0.980	0.982	0.951	0.986
County FE	YES	YES	YES	YES

Year FE	YES	YES	YES	YES
County-Pair FE	YES	YES	YES	YES
Specialty FE	YES	-	-	-
State-Specific Linear Trend	YES	YES	YES	YES
Specialty-Specific Linear Trend	YES	YES	YES	YES

This table reports regression results for the DID model for the cross-border counties sample in Equation (2). Columns (1) to (4) report the results with the dependent variables: average medical liability insurance prices and the price for three specialties, General Surgery, Internal Medicine, and OB-GYN respectively. All the dependent variables are log-transformed. Alaska, California, Connecticut, Indiana, Louisiana, Massachusetts, Minnesota, Montana, Pennsylvania, and Vermont are excluded from our sample. Standard errors are clustered at the state level and are reported in parentheses. *** (**, *) indicates significance at the 1% (5%, 10%) level.

the all counties sample, we can see that in the pre-treatment period, none of the treatment variables is significant in any of the regressions except the second year prior to Medicaid expansion. However, the magnitude of the difference is negligible in that year. For the cross-border counties sample, we get a similar conclusion to the all counties sample but the price difference between the expansion counties and bordering non-expansion counties in the pre-expansion years is more close to 0. This shows that the cross-border counties sample does provide a more comparable treatment and control groups. Overall, we can conclude that the difference in outcome variables between expansion and non-expansion states in two, three, or four years before the expansion is not significantly different from the difference in one year before expansion. In other words, we do not find any evident trend differential in the pre-treatment period between expansion and non-expansion states. In comparison to the pre-expansion years, we see significant treatment effects for Medicaid expansion on medical malpractice insurance prices in the post-treatment periods, especially in later expansion years. In the first two years, we see some marginal increase in average prices, from column (1), in the expansion states in the all counties sample, but there is no impact in the cross-border counties sample. Starting from the third year of expansion,

the coefficient for the treatment variables becomes positive and significantly different from 0 (significant at the 1% level). The results hold in both samples. We also note that that the

Table 2.4 Full Sample Analysis (Event Study)

VARIABLES	(1) All specialties	(2) General Surgery	(3) Internal Medicine	(4) OB-GYN
4 Years Prior	-0.024	-0.028	-0.037	-0.017
	(0.058)	(0.077)	(0.058)	(0.053)
3 Years Prior	-0.036	-0.031	-0.040	-0.044
	(0.033)	(0.041)	(0.041)	(0.038)
2 Years Prior	-0.038**	-0.024	-0.054	-0.038*
	(0.018)	(0.021)	(0.042)	(0.019)
Treatment Year	0.045**	0.064**	0.037	0.038*
	(0.021)	(0.028)	(0.029)	(0.021)
1 Years After	0.036	0.047	0.075**	-0.017
	(0.023)	(0.036)	(0.028)	(0.037)
2 Years After	0.075***	0.068**	0.126***	0.031
	(0.019)	(0.030)	(0.024)	(0.020)
3 Years After	0.097***	0.081**	0.169***	0.045**
	(0.020)	(0.030)	(0.023)	(0.020)
4 Years After	0.150***	0.136***	0.250***	0.068***
	(0.024)	(0.020)	(0.043)	(0.023)
Constant	10.795***	10.962***	9.466***	10.979***
	(0.108)	(0.108)	(0.125)	(0.109)
Observations	34,194	11,264	12,744	10,106
R-squared	0.981	0.971	0.969	0.973
Policy Controls	YES	YES	YES	YES
County Controls	YES	YES	YES	YES
State Controls	YES	YES	YES	YES
County FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
Specialty FE	YES	-	-	-
Specialty-Specific Linear Trend	YES	YES	YES	YES
State-Specific Linear Trend	YES	YES	YES	YES

This table reports regression results for the event study for the all counties sample in Equation (2). Column (1) to (4) report the results with the dependent variables: average medical liability insurance prices and the price for three specialties, General Surgery, Internal Medicine, and OB-GYN. All the dependent variables are log-transformed. Alaska, California, Connecticut, Indiana, Louisiana, Massachusetts, Minnesota, Montana, Pennsylvania, and Vermont are excluded from our sample. Standard errors are clustered at the state level and are reported in parentheses. *** (**, *) indicates significance at the 1% (5%, 10%) level.

magnitude of the difference kept increasing over the years, from 7.5% (8.6%) in 2 years after expansion, to 9.7% (12.5%) in 3 years after expansion, and 15.0% (15.1%) in 4 years

Table 2.5. Border-County Analysis (Event Study)

VARIABLES	(1) All specialties	(2) General Surgery	(3) Internal Medicine	(4) OB-GYN
4 Years Prior	-0.017	0.037	-0.028	-0.033
	(0.047)	(0.088)	(0.055)	(0.049)
3 Years Prior	0.002	0.029	-0.011	-0.029
	(0.042)	(0.075)	(0.053)	(0.034)
2 Years Prior	-0.025	0.000	-0.047	-0.037*
	(0.023)	(0.043)	(0.042)	(0.019)
Treatment Year	0.062	0.051*	0.146	-0.007
	(0.039)	(0.025)	(0.086)	(0.021)
1 Years After	0.068	0.069*	0.153*	-0.008
	(0.046)	(0.038)	(0.087)	(0.022)
2 Years After	0.086***	0.093***	0.109***	0.045
	(0.024)	(0.026)	(0.027)	(0.028)
3 Years After	0.125***	0.156***	0.177***	0.058**
	(0.032)	(0.041)	(0.035)	(0.026)
4 Years After	0.151***	0.201***	0.222***	0.032
	(0.032)	(0.054)	(0.041)	(0.030)
Constant	10.521***	10.517***	9.076***	10.684***
	(0.356)	(0.415)	(0.502)	(0.326)
Observations	5,361	1,817	1,984	1,458
R-squared	0.980	0.982	0.951	0.986
Policy Controls	YES	YES	YES	YES
County Controls	YES	YES	YES	YES
State Controls	YES	YES	YES	YES
County FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
County-Pair FE	YES	YES	YES	YES
Specialty FE	YES	-	-	-
Specialty-Specific Linear Trend	YES	YES	YES	YES
State-Specific Linear Trend	YES	YES	YES	YES

This table reports regression results for the event study for the cross-border counties sample in Equation (2). Column (1) to (4) report the results with the dependent variables: average medical liability insurance prices and the price for three specialties, General Surgery, Internal Medicine, and OB-GYN. All the dependent variables are log-transformed. Alaska, California, Connecticut, Indiana, Louisiana, Massachusetts, Minnesota, Montana, Pennsylvania, and Vermont are excluded from our sample. Standard errors are clustered at the state level and are reported in parentheses. *** (**, *) indicates significance at the 1% (5%, 10%) level.

after expansion in the all counties sample (the cross-border counties sample in column 1). This result suggests that medical malpractice insurers in the expansion states have significantly higher prices than non-expansion states two years after Medicaid expansion.

Turning to the impact on each specialty respectively, we see significant variation across three specialties. For general surgery, Medicaid expansion states tend to have larger malpractice insurance prices two years after Medicaid expansion. The impact increases significantly by year from 6.8% to 8.1% to 13.6% from 2 years to 4 years after expansion in the full sample. The estimated impact for general surgery using the cross-border counties subsample is larger, from 9.3% to 15.6% to 20.1% in the same period. For internal medicine, the impact seems to be the strongest. Malpractice insurance prices for internal medicine in expansion states are 12.6% (10.9%) higher than that of non-expansion states 2 years after expansions and the magnitude increases to 16.9% (17.7%) and 25.0% (22.2%) in the following two years in the all counties sample (cross-border counties sample).

In contrast, we do not observe a significant impact of Medicaid expansion on medical malpractice insurance prices for OB-GYN physicians. In the all counties sample, there are some minor impacts, 4.5%, and 6.8%, in the third and fourth year after Medicaid expansion, but the magnitude is much smaller than that of other specialties. When we use the cross-border counties as the sample, the impact on OB-GYN doctors is only significant (at the 5%) in the fourth year of expansion and the magnitude is 5.8%.

The fact that we find a significant increase in medical malpractice insurance prices of general surgery and internal medicine but not OB-GYN doctors is consistent with the physician capacity constraint hypothesis of Luo, Chen, Grace (2020). They argue that it is the additional demand for health care that leads to higher medical liability costs. Recent studies have shown that Medicaid expansion caused increases in visits to physicians in general practice (6.6%), overnight hospital stays (2.4%), the rates of diagnosis of diabetes

(5.2%), and high cholesterol (5.7%). In comparison, the demand for OB-GYN services is less likely to experience a large increase due to Medicaid expansion. This is because, before the ACA, a large number of low-income pregnant women were eligible for Medicaid (Kaiser Family Foundation, 2017). There are two pathways for low-income pregnant women to use Medicaid for medical service. The first is traditional Medicaid for adults. The eligibility rule relies on whether the woman's income is below a state's threshold. The second pathway is called pregnancy-only eligibility. Federal law requires mandatory Medicaid eligibility for pregnant women with income up to 133% of the FPL, and states have the option of setting income thresholds higher than this level. After the ACA was implemented, the income threshold was increased from 133% of the FPL to 138% of the FPL in expansion states, but the expansion in eligibility was relatively small. Also, the ACA Medicaid expansion does not expand covered pregnant services. Kaiser Family Foundation (2015) survey finds that most states provide the same benefits to pregnant women no matter whether they qualify for Medicaid through the pregnancy eligibility pathway or the adult pathway. For this reason, Medicaid expansion does not largely expand Medicaid eligibility to pregnant women, so the demand for OB/GYM services remained stable.

To better visualize the time-varying treatment effects, we plot the yearly impacts of Medicaid expansion on medical malpractice insurance prices for all specialties, general surgery, internal medicine, and OB-GYN in Figures 2.2-2.5, respectively, with their 95% confidence intervals. The plot on the left side is for the all counties sample while the plot on the right side is for the cross-border counties sample. The x-axis denotes the year relative to the expansion year and the y-axis displays the size of the treatment coefficients from

Equation (2.2).

To summarize, we find that insurers in expansion states have a significantly higher price in their medical malpractice line of business after the expansion. They start to increase the price for physicians who specialize in internal medicine and general surgery but not OB-GYN. This is because physicians from the two specialties are likely to face higher demand for service after Medicaid expansion and consequent higher medical liability risk.

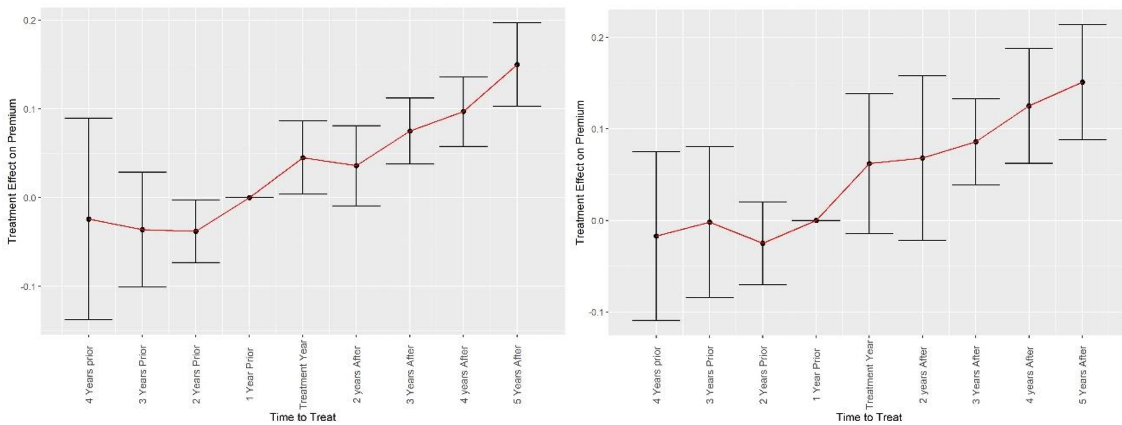

Figure 2.2. Yearly Impacts of Medicaid Expansion on Malpractice Insurance prices of all specialties (Full Sample/Cross-Border Sample)

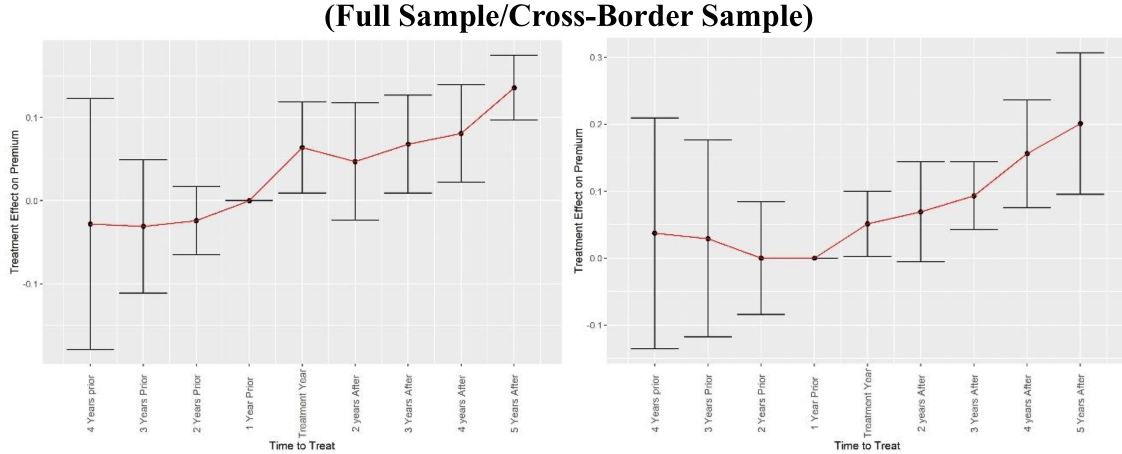

Figure 2.3 Yearly Impacts of Medicaid Expansion on Malpractice Insurance prices of General Surgery (Full Sample/Cross-Border Sample)

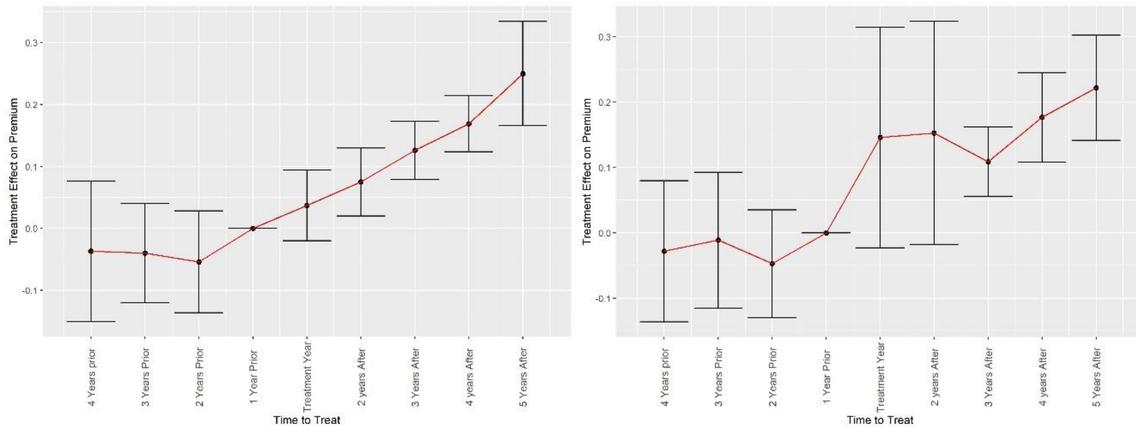

Figure 2.4. Yearly Impacts of Medicaid Expansion on Malpractice Insurance prices of Internal Medicine (Full Sample/Cross-Border Sample)

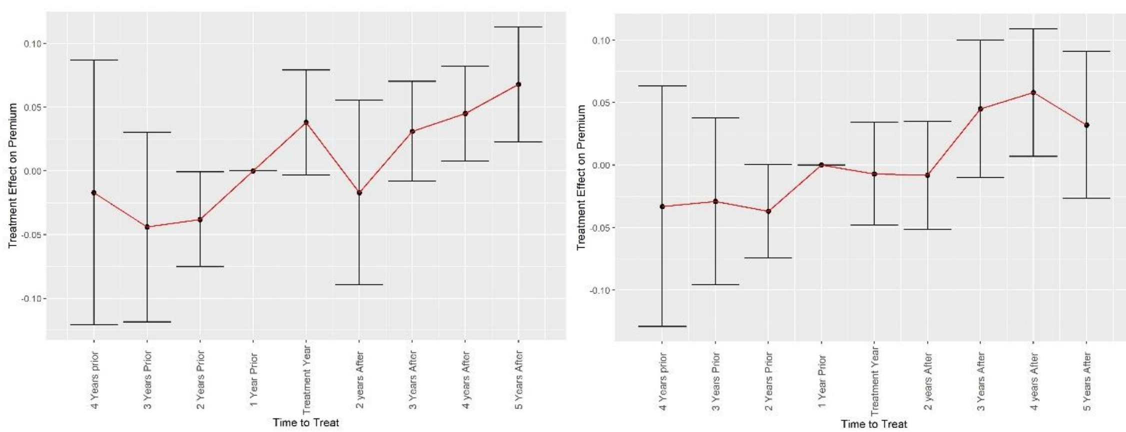

Figure 2.5 Yearly Impacts of Medicaid Expansion on Malpractice Insurance prices of OB-GYN (Full Sample/Cross-Border Sample)

2.6 Robustness Checks

In our main analysis, we exclude five states (California, Connecticut, Massachusetts, Minnesota, and Vermont) which had large numbers of Medicaid enrollees before 2014 and five states which expanded their Medicaid programs after 2014 (Alaska, Indiana, Montana, Pennsylvania, and Louisiana) which expanded Medicaid after 2014 but before 2018. As a robustness check, we add these five late-expansion states back to the sample, leading to a broader definition of the treatment group. For the cross-border counties sample with late expansion states, a late-expansion county is included only if it has different expansion status with its bordering states. For instance, before Pennsylvania expanded Medicaid, bordering counties of Pennsylvania are control groups for bordering counties in New York and New Jersey. However, after Pennsylvania expanded in 2015, bordering counties of Pennsylvania-New York and Pennsylvania-New Jersey pairs are removed because they have the same expansion status. Figure 6 shows the bordering counties with different expansion status when late-expansion states are considered.

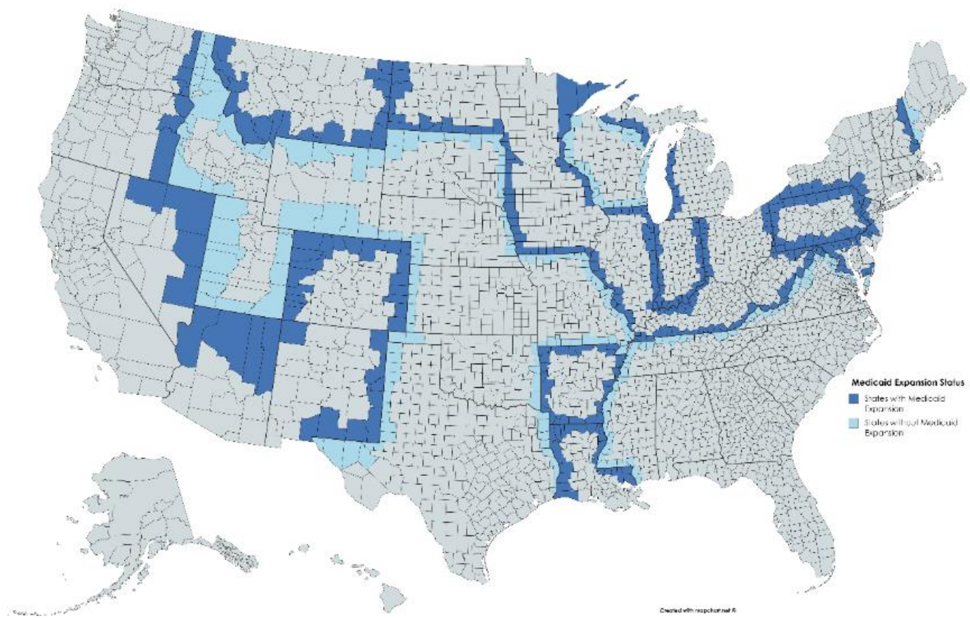

Figure 2.6 Bordering Counties with Different Expansion Status (Including Late-expansion States)

We estimate the regression model in Equations 2.3 and 2.4 again using the alternative samples in Tables 2.6 and 2.7. To save space, we only report the coefficient of event study variables of interest. Overall, the results remain largely the same as those in our main analysis. That is, we see significant increases in county-average medical malpractice prices in expansion states compared to those in non-expansion states especially after the second year of expansion. Also, the impact on the prices is much stronger for physicians in general surgery and internal medicine. OB-GYN physicians experience a minor increase in price two years after expansion in the all counties sample, but the magnitude is much smaller than that of the other two specialties. In the cross-border counties sample, we do not see a significant impact of Medicaid expansion on malpractice insurance prices of OB-GYN physicians. Also, in the 2 years prior to expansion, expansion and non-expansion counties have a minor but significant difference in several columns. One possible explanation is the lack of comparability between late expansion states and non-expansion states due to the influence of other ACA elements. For instance, the year of "2 years prior to expansion" of Lousiana and Montana (implemented Medicaid expansion in 2016) is 2014 but 2012 for states expanding Medicaid in 2014. The year 2014 is the first year of the full implementation of the ACA. The medical liability insurance market of the two aforementioned late expansion states in 2014 might be affected by other elements of the ACA, thus contaminating the 2014 control year. Even so, adding late expansion states to the treatment group does not change our results significantly.

2.7 Conclusions

Medical liability insurance covers physicians' liability, and its price could affect physicians' practice and physician supply. In this paper, we study the impact of the ACA Medicaid expansion on medical liability insurance prices for three specialties, internal medicine, general surgery, and obstetrics-gynecology (OB-GYN). Medicaid expansion has expanded the demand for healthcare and exposed physicians to higher medical liability risks. With higher expected losses, insurers may react by increasing insurance prices.

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Table 2.6. Full Sample Analysis Including Late-Expansion States (Event Study)

VARIABLES	(1) All specialties	(2) General Surgery	(3) Internal Medicine	(4) OB-GYN
4 Years Prior	-0.037	-0.045	-0.053	-0.021
	(0.057)	(0.074)	(0.058)	(0.050)
3 Years Prior	-0.046	-0.044	-0.054	-0.043
	(0.032)	(0.039)	(0.039)	(0.034)
2 Years Prior	-0.040**	-0.028	-0.058	-0.035**
	(0.017)	(0.020)	(0.038)	(0.017)
Treatment Year	0.042**	0.060**	0.034	0.035*
	(0.019)	(0.025)	(0.026)	(0.019)
1 Years After	0.028	0.035	0.064**	-0.016
	(0.022)	(0.035)	(0.026)	(0.032)
2 Years After	0.068***	0.057*	0.116***	0.031*
	(0.019)	(0.030)	(0.023)	(0.018)
3 Years After	0.093***	0.076**	0.163***	0.046**
	(0.019)	(0.029)	(0.022)	(0.019)
4 Years After	0.147***	0.130***	0.245***	0.068***
	(0.024)	(0.020)	(0.041)	(0.022)
Constant	10.787***	10.968***	9.480***	10.970***
	(0.108)	(0.112)	(0.127)	(0.105)
Observations	34,941	11,539	12,939	10,262
R-squared	0.981	0.972	0.969	0.974
County FE	YES	YES	YES	YES
County Controls	YES	YES	YES	YES
State Controls	YES	YES	YES	YES
County FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
County-Pair FE	YES	YES	YES	YES
Specialty FE	YES	-	-	-
Specialty-Specific Linear Trend	YES	YES	YES	YES
State-Specific Linear Trend	YES	YES	YES	YES

This table reports regression results for the event study for the cross-border counties sample in Equation (2). Columns (1) to (4) report the results with the dependent variables: average medical liability insurance prices and the price for three specialties, General Surgery, Internal Medicine, and OB-GYN respectively. All the dependent variables are log-transformed. California, Connecticut, Massachusetts, Minnesota, and Vermont are excluded from our sample. Standard errors are clustered at the state level and are reported in parentheses. *** (**, *) indicates significance at the 1% (5%, 10%) level.

Table 2.7 Border-County Sample Analysis Including Late-Expansion States (Event Study)

	(1)	(2)	(3)	(4)
VARIABLES	All specialties	General Surgery	Internal Medicine	OB-GYN
4 Years Prior	-0.038	0.018	-0.051	-0.054
	(0.055)	(0.080)	(0.055)	(0.055)
3 Years Prior	-0.023	0.016	-0.022	-0.056*
	(0.039)	(0.060)	(0.045)	(0.033)
2 Years Prior	-0.078**	-0.069	-0.084**	-0.086***
	(0.031)	(0.046)	(0.041)	(0.027)
Treatment Year	0.035	0.013	0.113*	-0.015
	(0.031)	(0.028)	(0.065)	(0.023)
1 Years After	0.049	0.038	0.137*	-0.014
	(0.037)	(0.032)	(0.071)	(0.026)
2 Years After	0.064**	0.056**	0.093***	0.034
	(0.024)	(0.025)	(0.026)	(0.028)
3 Years After	0.100***	0.118***	0.150***	0.043
	(0.033)	(0.037)	(0.035)	(0.028)
4 Years After	0.137***	0.170***	0.207***	0.038
	(0.027)	(0.038)	(0.037)	(0.023)
Constant	10.157***	10.036***	8.789***	10.374***
	(0.271)	(0.306)	(0.371)	(0.317)
Observations	8,013	2,661	2,882	2,261
R-squared	0.978	0.974	0.949	0.974
Policy Controls	YES	YES	YES	YES
County Controls	YES	YES	YES	YES
State Controls	YES	YES	YES	YES
County FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
County-Pair FE	YES	YES	YES	YES
Specialty FE	YES	-	-	-
Specialty-Specific Linear Trend	YES	YES	YES	YES
State-Specific Linear Trend	YES	YES	YES	YES

This table reports regression results for the event study for the cross-border counties sample in Equation (2). Columns (1) to (4) report the results with the dependent variables: average medical liability insurance prices and the price for three specialties, General Surgery, Internal Medicine, and OB-GYN respectively. All the dependent variables are log-transformed. California, Connecticut, Massachusetts, Minnesota, and Vermont are excluded from our sample. Standard errors are clustered at the state level and are reported in parentheses. *** (**, *) indicates significance at the 1% (5%, 10%) level.

counties with different Medicaid expansion status over the years 2010-2018, we find that Medicaid expansion leads to significantly higher medical liability insurance prices two years with different Medicaid expansion status over the years 2010-2018, we find that Medicaid after the expansion, and the impact is strong for practitioners in the specialty of internal medicine and general surgery but not for OB-GYN physicians.

Our finding suggests that the expansion of health insurance has an important liability impact beyond its effect on the health care system. Several waves of medical liability crises that involved dramatic increase in prices in the past have caused some insurers to leave the market or go bankrupt. Although we cannot infer, in a short period, whether the recent health reforms will result in the start of a new hard market, the increased prices could lead to problems in malpractice insurance availability and physicians' practices needed medical service. These are questions that deserve future research.

CHAPTER 3

PUBLIC HEALTH INSURANCE EXPANSION AND AUTO INSURANCE: THE CASE OF MEDICAID EXPANSION

3.1 Introduction

After a car accident, multiple insurance products provide coverage for medical expenses related to the accident. Although auto insurance is normally the primary source, having or not having health insurance may change the incentive for using auto insurance and may influence the ultimate payments made by auto insurers. In this paper, we first use a simple theoretical model to demonstrate how accessing public health insurance changes an insured driver's claim falsification behavior. We then use the example of the ACA Medicaid expansion to examine this question empirically. We find that private passenger auto insurance losses and premiums in the Medicaid expansion states, in comparison to non-expansion states, are significantly lower after the expansion. We further find that reduced auto losses and premiums are driven by third-party auto liability insurance rather than auto no-fault auto insurance.

After a car accident, the party paying medical expense depends on the state that the accident occurs. In a no-fault state, all drivers handle their accident claims with their own insurance regardless of fault (as long as the injury is not over some threshold). In other states, the driver who is at fault is responsible for the medical bills and other losses. Although the ACA has no provision related to auto insurance, extending health insurance to people otherwise uninsured provides an additional source of coverage and could possibly affect medical costs borne by auto insurers. This is mainly because having health insurance may change the motivation of drivers to overuse auto insurance.

Without health insurance, auto insurance is the only source for reimbursement for healthcare expenses after a non-work-related car accident. This increases the insured's incentive to use auto insurance to cover pre-existing and/or unrelated complaints. In fact, fraud and buildup are estimated to account for 21% of total costs borne by auto insurers (Insurance Research Council, 2015). However, filing fraudulent or inflated claims is costly. Claimants doing so must incur some costs, which tend to increase with the claim buildup. In contrast, if the low-income driver could use costless public health insurance to pay for all medical expenditures, the motivation for abusing auto insurance and the need for costly falsification would vanish. The injured party's motivation to hire personal injury attorneys to sue the negligent driver is also likely to be diminished.

There are other indirect mechanisms through which expanding public health insurance may reduce auto insurance losses. First, having health insurance may affect how injured drivers are treated after a car accident. Without health insurance, injured drivers might not seek immediate treatment for the fear of high medical bills or because they must struggle to gain access to treatments, which can lead to long-lasting injuries and future treatment issues. In comparison, having health insurance decreases the possibility of delayed treatment and might increase the efficiency of treatment. Second, hospitals often have a discounted contracted rates with insurance companies. With health insurance, especially Medicaid, hospitals charge the insurer of the injured patients the discounted contracted rate rather than the original rate. This further reduces auto insurers' ultimate financial responsibility in the claim payment.

In addition to claiming costs, auto insurers' premiums might also be affected by the health insurance status of policyholders. In a no-fault state, injured drivers without health insurance any additional pay out-of-pocket expenses if their personal injury protection (PIP) coverage is exhausted. For this reason, policyholders may have an incentive to buy auto insurance with a higher PIP limit instead of the minimum coverage required by the law. However, as health insurance becomes an additional source of coverage for medical treatments, a driver's motivation to buy a high-limit auto insurance policy decreases. Also, in states without no-fault rules, people may buy an uninsured motorist (UM) policy or underinsured motorist (UIM) policy to cover medical expenses after a car accident caused by an uninsured/underinsured driver. UM[18] and UIM[19] are required by some states, but in states where the two policies are optional, buying them may not be necessary if the driver has health insurance as a backup. From the perspective of insurers, if fraud and buildup are decreased for drivers with health insurance, their expected losses should be lower, which leads them to charge lower premiums.

The staggered roll-out of the ACA Medicaid expansion offers an opportunity to examine the impact of the public health insurance expansion on an imperfect substitute -- personal auto liability insurance. In the empirical analysis, we employ a difference-in-difference framework that compares the difference in auto insurance losses incurred, total losses, and premiums in Medicaid expansion states before and after the expansion with

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[18] Uninsured motorist bodily injury coverage is required by 19 states including Connecticut, District of Columbia, Illinois, Kansas, Maine, Maryland, Massachusetts, Minnesota, Missouri, Nebraska, New York, North Carolina, North Dakota, Oregon, South Caroline, South Dakota, Vermont, West Virginia, and Wisconsin. Also, in 3 other states, New Hampshire, Rhode Island, and Virginia, uninsured motorist bodily injury coverage is required if auto insurance is purchased.

[19] Among the above 21 states, underinsured motorist bodily injury coverage is further required by 16 states including Connecticut, Illinois, Kansas, Maine, Maryland, Minnesota, Nebraska, New Hampshire, New York, North Carolina, North Dakota, Oregon, Rhode Island, South Dakota, Vermont, and Virginia. Also, Uninsured motorist bodily injury coverage is required by New Hampshire, Rhode Island, Virginia only if auto insurance is purchased.

insurers in non-expansion states. We first study the average expansion effect on auto insurance costs and then investigate the time-varying dynamics of this effect using an event study framework.

To study the impact of Medicaid expansion on personal auto insurance, we use insurance claim losses incurred, total losses (claim losses plus defense costs) incurred to insurers, and premiums to all private passenger auto insurers in the states where they operate. We then separate auto insurance to two business lines, auto liability (third-party liability) and auto no-fault line, to investigate which line is affected more by Medicaid expansion. The first line, private passenger auto liability insurance, covers the liability of the insured for bodily injury of drivers and passengers of other vehicles caused by the insured's negligent behavior. The other line is private passenger auto no-fault insurance. It provides personal injury protection to the insured drivers regardless of fault. Personal no-fault insurance is required by states with a no-fault insurance law and is optional in some other states. We use data from the National Association of Insurance Commissioners (NAIC), which collects extensive financial data from all insurers required to file annual reports in the U.S.

We find that, during the sample period 2010 to 2018, personal auto insurance losses incurred in Medicaid expansion states decreased significantly (i.e., 7.7% lower than in non-expansion states). The total losses, including losses incurred and defense and cost containment expenses, in expansion states, was also approximately 7.7% lower than that in non-expansion states. Our event study results further show that private passenger auto insurance losses decrease in expansion states after the second year of expansion with a significantly growing magnitude each year. We also find that private passenger auto insurers in expansion states decreased premiums by about 3.7% on average in response to the decreasing costs. The event study shows a larger decrease in premiums over time from 4.6% in the first expansion year to 16% in the fifth year of expansion. We do not find consistent evidence of a significant change in the total loss ratio. This implies that premiums fell in response to a reduction in losses.

We further investigate the results of personal auto liability insurance and personal auto no-fault insurance separately and find that the decreasing losses and premiums are mainly driven by the auto liability line. Auto liability insurers in expansion states had around 7.7% lower losses incurred. Also, premiums started to decrease by the second year of expansion. However, we do not see a significant decrease, on average, in either losses or premiums of private passenger auto no-fault insurance in expansion states in comparison to non-expansion states. The event study shows that the private passenger auto no-fault liability insurance losses in expansion states tend to have lower losses and premiums across years than non-expansion states, although this result is statistically insignificant. One possible explanation is that no-fault insurance usually has a relatively low threshold that, even without fraud, the actual medical costs of a car accident are likely to exceed. Thus, drivers may have a lower motivation to falsify with a no-fault policy than a traditional third-party liability policy.

To the best of our knowledge, two other papers are most relevant to our study. Kadiyala and Heaton (2017) study how the 2010 ACA dependent coverage expansion to 19-25-year-old young adults affected their auto insurance bodily injury claims. Using data between 2008 and 2012, they find about a 9% reduction in claims for the 19-25 age group than their counterparties in the 26-34 age group after the dependent coverage expansion.

Using state-level insurance loss ratio data during 2010-2016, a contemporary study by Heaton and Flint (forthcoming) finds that Medicaid expansion reduces the personal passenger auto liability loss ratio by 7%. Our paper is different from Heaton and Flint's paper from several perspectives. First, they focus on the analysis of the loss ratio without studying the two important determinants of the loss ratio, i.e., insurance losses and premiums. The loss ratio is defined as losses divided by premiums earned, measuring how much losses can be covered by premiums earned. However, whether the decrease in the loss ratio is driven by premium changes or loss changes cannot be determined from Heaton and Flint's paper. Also, if losses and premiums change in the same direction by the same amount, then the loss ratio would be stable. In our paper, we are more interested in how the expansion of health insurance affects auto insurance losses incurred by drivers and how it affects auto insurance premiums paid to insurers separately. Second, they use state-level aggregate data so their results do not reflect changes at the state-firm level. We provide a more granular analysis to account for firm heterogeneity and to minimize aggregation bias.

Our contributions to the literature are three-fold. First, we study how the expansion of public health insurance affects auto insurance theoretically and empirically. We expand the general model of insurance falsification to illustrate how public health insurance reduces an insured driver's motivation for inflated claims. Second, we provide firm-state level analysis of the Medicaid expansion impact on auto insurance losses and premiums and use the most recent data up to 2018. Understanding these issues provides some insights into the incentive of drivers in using different insurance products. It also sheds light on the degree to which the extension of other public health insurance programs may influence the medical costs borne by auto insurance. Finally, the firm-state level analysis separates the impact from Medicaid expansion on private passenger auto liability and no-fault auto insurance. Results show that Medicaid expansion decreases private passenger auto liability losses and total losses around 7%, but the impact on the no-fault auto insurance line is marginal. In comparison to Heaton and Flint, we do not find a large Medicaid expansion impact on the loss ratio in both lines.

The remainder of this paper is organized as follows. In Section 2, we provide background information on the ACA Medicaid expansion and auto insurance. We introduce our theoretical model. We describe the data in Section 3 and discuss our empirical methodologies in Section 4. We present the baseline results in Section 5. The robustness check is in Section 6. Concluding remarks are given in Section 7.

3.2 Institutional Background

3.2.1 Auto Insurance System

Private passenger auto insurance is a type of insurance product that provides coverage for vehicles for personal use. There are several types of private passenger auto coverage. These are private passenger auto no-fault, private passenger auto liability, and private passenger auto physical damage. No-fault insurance provides personal injury protection (PIP) to the driver and passengers in the insured vehicle regardless of fault. Auto liability insurance provides coverage for injuries that the insured driver is legally responsible for as a result of an accident. In comparison, damages to the vehicle itself are covered separately through private passenger auto physical damage insurance. It is important to note that nearly all states require auto liability coverage and the state that does not requires a performance bond in lieu of insurance. Thus, vehicle owner must have some level of liability coverage in order to drive.

For injuries encountered in a car accident, the party responsible for medical bills and injuries depends on the state that the accident occurs. In states with no-fault auto insurance laws, drivers are required to buy personal injury protection insurance (PIP). With PIP, drivers file a claim with their own insurance providers for coverage of damages up to a specified limit no matter who caused the accident. After the policy coverage is exhausted, the injured driver's health insurance will be the second source of coverage. Those without health insurance will have to pay out of pocket.

Twelve states have strict compulsory no-fault auto insurance laws. In the strictest form, the law restricts the driver's right to sue a negligent third party unless certain conditions based on the severity of injuries are met. Among the states with a PIP requirement, Kentucky, New Jersey, and Pennsylvania allow motorists to opt-out of the no-fault system and retain their right to sue the negligent third party in all cases. There are additional five add-on states that are not no-fault states but require PIP coverage, and five states that are not no-fault states but have PIP available as optional coverage. Table 3.1 lists all states with strict or add-on no-fault insurance system available. The remaining states allow full tort liability and have no restrictions on lawsuits. In these states, the party at fault is responsible for all bodily injuries and vehicle damage caused by the car accident. In the next section, we introduce the background of the ACA and how it might affect auto insurance.

3.2.2 The Affordable Care Act Medicaid Expansion

The U.S. had a significant population without health insurance (Frean et al., 2017). Before the ACA, public health insurance programs such as Medicare and Medicaid only covered people older than 65, disabled people, or low-income parents (as low as 50% of

Table 3.1 State Auto Insurance Law Summary

Strict No-Fault	Add-on States where PIP is mandatory	Add-on States where PIP is optional
Florida	Arkansas	New Hampshire
Hawaii	Delaware	South Dakota
Kansas	Maryland	Virginia
Kentucky	Oregon	Washington
Massachusetts	Texas	Wisconsin
Michigan		
Minnesota		
New Jersey		
New York		
North Dakota		
Pennsylvania		
Utah		

Note: There are some states which had a no-fault insurance system but repealed it. They include Nevada: effective 1974; repealed 1980; Georgia: effective 1975; repealed 1991; Connecticut: effective January 1, 1973; repealed 1993; Colorado: effective April 1974, repealed July 2003.

the family poverty level (FPL) in some states). Low-income childless adults were ineligible for Medicaid in almost every state. The ACA provides states the option to expand Medicaid eligibility to cover more health uninsured. The state-by-state Medicaid expansion, starting in 2014, expanded coverage to households with income up to 138% of the FPL so that more low-income households are qualified for free or low-cost health care. By the end of 2018, 31 states had adopted and implemented Medicaid expansion and over 15 million enrollees resulted from the new adult eligibility group.[20]

Although the ACA does not include any provision directly targeting the auto insurance industry, it provides an additional source of compensation for medical expenses related to a car accident. A substantial body of research exists to study the impact of Medicaid expansion on insurance coverage to low-income households. See Mazurenko et

[20] Our sample period is from 2010 to 2018. After 2018, five more states adopted Medicaid expansion but are regarded as non-expansion states in our paper.

al. (2018) for a comprehensive review. These studies demonstrate a significant increase in insurance coverage (Frean et al., 2017) enhanced healthcare affordability (Decker, Lipton, and Sommers, 2017; Goldman et al., 2018) and improved access to medication and services (Martin et al., 2017; Miller and Wherry, 2017; Barbaresco et al., 2015; Miller and Wherry, 2019) in expansion states compared to non-expansion states.

Before Medicaid expansion, low-income injured drivers who were not at fault but did not have health insurance would have no choice but to hire a personal injury attorney to sue a negligent third party. With Medicaid, some injured drivers might opt out of the hassle of filing insurance claims and just use their health insurance instead. More importantly, new Medicaid enrollees will have a reduced incentive to overutilize medical treatments provided for injuries associated with auto insurance. A decrease in the incentive to overutilize health care should reduce fraud and buildup. Additionally, Medicaid enrollees are also less likely to be denied by practitioners simply because they have no health insurance. Meanwhile, Medicaid payment rates are much lower than that of payers with private insurance and those for uninsured. Hence low-income injured drivers are likely to have lower medical bills, which will be paid by auto insurers, after they are eligible for Medicaid.

It is against this background that this paper studies the impact of Medicaid expansion on auto insurance. In the next section, we start by using a simple theoretical model to illustrate how access to public health insurance changes an insured's motivation to use auto insurance. After that, we turn to the analysis of data on actual auto insurance.

3.3 A Simple Model

In this section, we use a simple theoretical model to illustrate how having health insurance reduces the incentive of insured drivers to misuse auto insurance. There are many different degrees of fraud, ranging from build-up to opportunistic fraud, to a planned criminal fraud. Claimants may mispresent their total losses, report an accident that did not occur, or even create damages to inflate the claim (Picard, 2013). In our paper, insurance fraud specifically refers to the fact the policyholders misreport the magnitude of their medical costs caused by a car accident.

There are two main theoretical approaches prior literature uses to model insurance fraud. In the first approach, called costly state verification, insurers are assumed to be able to verify insurance claims with some auditing costs (Bond and Crocker, 1997). In comparison, the other appraoch, costly state falsifications assumes that claimants falsify or inflate their losses after a car accident with some costs, but the fraudulent behavior is not identifiable by insurers (Crocker and Morgan, 1998). Our model follows the costly state falsification approach which assumes that there is information asymmetry between insureds and insurers, and insurers cannot obtain the private loss information of the insureds. Auto insurance claims are an area where medical-cost related frauds are very common (Cummins and Tennyson, 1996). This is because injuries such as soft-tissue injuries caused by auto accidents are hard to verify.

In this section, we first describe the general framework of the insurance fraud model widely used in prior literature, we then turn to the model with considering health insurance.

3.3.1 Auto Insurance Fraud Model without Health Insurance

Our approach follows the costly falsification model (Crocker and Morgan, 1998 and Crocker and Tennyson, 2002). An insured driver has an initial wealth W_0 and pays premium P for auto insurance. After a car accident, the driver suffers an injury with actual loss X. X is the driver's private information that the insurer does not know. Then, the driver files a claim Y (to his/her insurer or the insurer of the negligent third party) with value Y ≥ X. The insurer can only observe Y and specifies a coverage of T(Y). To simplify, $T(Y) = \alpha_1 Y$. The parameter α_1 is the proportion of losses that the auto insurer pays. If Y = X, the claim is an honest claim and is assumed to be costless in terms of fraud. If Y > X, the claimant files a fraudulent claim, and the difference between Y and X is the amount of fraud F. However, falsification is not costless in the sense that the claimant has to bear costs associated with falsification such as hiring a lawyer, visiting physicians, or finding a witness. The falsification cost increases with the amount of fraud F and can be presented as C(F). The policyholder's final wealth W becomes

$$W = W_0 - X - P + T(Y) - C(F) \tag{3.1}$$

Like Crocker and Tennyson (2002), we assume that the cost of falsification $C(F) = \frac{1}{2}\gamma F^2 = \frac{1}{2}\gamma(Y - X)^2$ where γ is an exogenous falsification cost parameter. Thus, we assume a small amount of fraud, (Y-X), is expected to be relatively easy to accomplish, but a large amount of fraud is more costly. Given actual losses, the benefit, and cost of fraud, the injured driver selects an optimal F which maximize his total wealth. This indicates that he selects a fraud amount that satisfies the first-order condition equal to 0. This implies

$$\frac{\partial(W)}{\partial(F)} = \frac{\partial\left(W_0 - X - P + T(Y) - C(F)\right)}{\partial(F)} = 0 \tag{3.2}$$

$$F = Y - X = \frac{\alpha_1}{\gamma} \tag{3.3}$$

The implication of equation (3) is that the diver will engage in fraudulent claims as long as the auto insurance payment ratio α_1 is positive.

3.3.2 Auto Insurance Fraud Model with Public Health Insurance

In the conventional setting of insurance fraud, health insurance is not considered (Crocker and Morgan, 1998 and Crocker and Tennyson, 2002). Now we turn to add public health insurance to this model, to see how it will affect an insured driver's total wealth and determination of fraud. Specifically, after a car accident, the injured driver is sent to the hospital to receive treatment. Auto insurance is the first payer for medical bills but it only covers treatments to injuries directly related to the car accident with total compensation $\mathrm{T}(\mathrm{Y})$. In comparison, as the secondary payer, a health insurer will (partially or fully) cover all medical treatments the insured driver needs, regardless of the cause of the injury or health condition. Here, we assume that there is no health care provider fraud, and medical treatments are determined only based on the health status of the patient. We use $\bar{Y}$ to represent the total cost of treatments that an insured driver needs. Then the coverage of health insurance will be $\mathrm{H}(\bar{Y}-T(Y))$, which is the remaining part of medical costs not covered by auto insurance. Like T(Y), we assume H(Y) follows a linear coverage schedule, $H(Y)=\beta_1 Y$. The parameter β_1 is the proportion of medical costs that the health insurer pays. Also, public health insurance, such as Medicaid, is costless to low-income drivers as long as their income is below some threshold. Now the wealth of a low-income driver with public health insurance becomes

$$\mathrm{W}_0-\mathrm{X}-\mathrm{P}+\mathrm{T}(\mathrm{Y})-\mathrm{C}(\mathrm{F})+\mathrm{H}(\bar{Y}-T(Y)) \qquad (3.4)$$

One important point here is that $\bar{Y}$ is not only the total cost of treatments that the injured driver receives but also the maximum claimed losses for medical payments that an auto insurance policyholder could claim with the auto insurance company. Here, $\bar{Y}$ includes the original loss X caused by the car accident and additional treatments for all preexisting health issues that need treatments. The medical cost for all preexisting health issues is essentially the maximum build-ups, $\bar{F}$, that the injured driver can claim. $\bar{Y} = X + \bar{F}$. In other words, $\bar{Y}$ is no longer related to the fraudulent claim F that the insured chooses to report but the maximum F, $\bar{F}$, he/she can report. $\bar{F}$ can be regarded as a constant in a post-accident treatment period. This is a reasonable belief. In particular, one main reason why low-income auto insurance policyholders may have an incentive to commit fraud is that, without health insurance, they have no access to health service. Thus, they may try to exhaust auto insurance coverage to cover as many health issues as possible. However, with health insurance, all of their medical treatments (after the auto insurance company pays) will be fully or partially covered by health insurance no matter whether these problems are related to a car accident. The total cost of the treatment might be beyond the expectation of the insured. Especially, for some injured drivers who are long-term uninsured, the treatment of an accident injury may lead doctors to discover other critical health issues that the driver was not aware of but needs treatment for, leading $\bar{Y}$ to be higher than the Y that he/she would claim without health insurance. Thus,

$$H(\bar{Y} - T(Y)) = \beta_1\big(Y - T(Y)\big) = \beta_1(\mathrm{X} + \bar{F}) - \alpha_1\beta_1(\mathrm{X} + \mathrm{F}) \tag{3.5}$$

The total wealth of the insured driver is

$$\mathrm{W}_0 - \mathrm{X} - \mathrm{P} + \alpha_1(\mathrm{X} + \mathrm{F}) - \mathrm{C}(\mathrm{F}) + \beta_1(\mathrm{X} + \bar{F}) - \alpha_1\beta_1(\mathrm{X} + \mathrm{F}) \tag{3.6}$$

Given this function, the insured decides how much fraud to claim to maximize the total wealth by satisfying the first-order condition equals to 0.

$$\frac{\partial(W)}{\partial(\mathrm{F})} = \frac{\partial(\mathrm{W}_0 - \mathrm{X} - \mathrm{P} + \mathrm{T}(\mathrm{Y}) - \mathrm{C}(\mathrm{F}) + \mathrm{H}(\bar{Y} - T(Y)))}{\partial(\mathrm{F})} = 0 \tag{3.7}$$

That is, $$\frac{\partial(W)}{\partial(\mathrm{F})} = \frac{\partial(\mathrm{W}_0 - \mathrm{X} - \mathrm{P} + \alpha_1(\mathrm{X}+\mathrm{F}) - \mathrm{C}(\mathrm{F}) + \beta_1(\mathrm{X}+\bar{F}) - \alpha_1\beta_1(\mathrm{X}+\mathrm{F}))}{\partial(\mathrm{F})} = 0 \tag{3.8}$$

After simplifying the equation, we get

$$\alpha_1 - \gamma F - \alpha_1 \beta_1 = 0 \tag{3.9}$$

Which indicates that

$$F = \frac{\alpha_1(1-\beta_1)}{\gamma} \tag{3.10}$$

We could see that as health insurance coverage β_1 increases, the injured driver would claim less fraudulent losses. When $\beta_1 = 0$, there is no health insurance and the analysis collapses to our analysis in Section 3.1. in which fraud, F is equal to $\frac{\alpha_1}{\gamma}$. In contrast, while the public health insurance has full coverage with $\beta_1 = 1$, the injured driver would have no motivation to engage in a fraudulent claim related to medical treatments. Admittedly, the driver might still engage in other fraudulent activities such as exaggerating repair costs of the damaged car.

Furthermore, in our analysis, we assume that an honest claim is costless to pursue while fraudulent claiming bears the cost C(F). Essentially, the cost of fraud C(F) in the model can be further generalized to any effort to maximize the total claim payment especially when the injured party considers filing a car accident lawsuit. Without health insurance, the injured driver may bear costs to hire an attorney to do negligence investigation and to sue the third party. The motivation maybe decreased if health insurance could pay for medical expenses without any additional cost.

The primary implication of the simple model is that public health insurance may reduce the incentives of claimants to commit fraud related to medical costs. With less fraud, auto insurers' losses and premiums may be lower. The recent health reform of Medicaid expands public health insurance to low-income drivers in some states but not others, giving us an appropriate venue for examining the implication of our model. In the next section, we turn to the analysis of data of auto insurers.

3.4 Data

To examine the effect of Medicaid expansion on auto insurance costs, we utilize auto insurers' data and state demographic data from various sources to compile a dataset of firm-state-year observations from 2010 to 2018. Our source of the firm-state-year medical liability insurance data is from the Exhibit of Premiums and Losses (Statutory Page 14) from insurer filings with the NAIC. In this exhibit, auto insurers provide their losses incurred and premiums earned data by insurance line for each calendar year in each state where they operate. *Premiums earned* are premiums collected by insurers for the portion of policies that coverage has been provided. *Losses incurred* are indemnity payments that have been made and estimated to be made in the future as a result of auto insurance accidents occurring in the current year. In addition to losses incurred, we also consider defense and cost containment expenses, which are expenses incurred during the process of investigating claims such as expenses paid to defense attorneys and expert witnesses. We call the sum of losses incurred and defense and cost containment expenses as an insurer's *total losses*. *The loss ratio* is defined as total losses divided by premiums earned and is used to measure an insurer's profitability. A low loss ratio indicates "profitability", and a loss ratio larger than 1 indicates an accounting loss. To ensure that our sample consists of insurers actively participating in the auto insurance market, we exclude observations with auto insurance premiums earned in a state less than or equal to $10,000. We further exclude those with state-aggregated losses less than or equal to $500, which are likely due to reporting errors or accounting issues.[21]

We use a set of firm-level control variables, including firm size, liquidity, leverage, organizational form, and group affiliation status. These data are obtained from the NAIC database as well. *Firm Size* is measured by the natural logarithm of an insurer's total admitted assets. Leverage and liquidity are included to capture an insurer's financial strength. *Liquidity* is measured by the cash and short-term investments scaled by total admitted assets. *Leverage* is defined as total liabilities scaled by surplus. We also include two dummy variables to control for an insurer's organizational form and affiliation status. The dummy variable, *Stock*, is equal to 1 if an insurer is a stock insurer and 0 for other organizational forms. The dummy variable, *Group*, is equal to 1 if the firm is a member of an insurance group and 0 for single unaffiliated insurers.

We also include state-level control variables reflecting state economic, social, or legal environments that may affect the personal auto insurance. Although we do not claim causality between these control variables and our dependent variable, they may improve identification by acting as proxies for state unobservable characteristics correlated with losses and premiums for personal auto insurance. We collect data on tort reforms from the State Tort Law Reforms database (Avraham, 2019; DSTLR 6th). This database tracks tort reforms from 1980 to 2018. We include four tort reform dummy variables, i.e., *caps on non-economic damages (CN), caps on punitive damages (CP), joint and several reforms (JS), and collateral source reform (CS)*, to indicate whether a state has adopted a particular tort reform or not in a given year. We focus on these four tort reforms because they are the

[21] The observations that we exclude from the sample account for only 0.003% of total premiums earned in the private passenger auto liability insurance market and 0.01% of total premiums earned in the private passenger no-fault auto insurance market.

most influential ones and often considered in prior studies.[22]

In addition, we include the *number of lawyers* (per capita), the *number of healthcare employees* (per capita), and the *number of insurance employees* (per capita) to control for the capacity/power of each relevant group. We include the *unemployment rate* and *personal income* (per capita) to reflect the economic status of a given state in a specific year. We also use the ratio of the population reported in *poor or fair health status* and the ratio of *adults with obesity* to control for average health quality at the state level. Moreover, we use three variables to reflect the environment of the transportation system in that state. We use the *number of registered automobiles per square mile* to measure vehicle ownership in the states. We use the proportion of licensed *young drivers* under the age of 19 years old to measure the relative riskiness of drivers of the state. Also, we use average daily *traffic per lane* to measure the average traffic load in that state. These are critical parameters measuring the transportation system of a state[23].

The data for Medicaid expansion is from Medicaid.gov.[24] The ACA Medicaid expansion officially started on January 1, 2014. In our sample, we exclude three states (California, Minnesota, and Connecticut) and Washington D.C., which exercised early expansion options and had newly eligible enrollees before 2014. We exclude

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[22] The tort system is stable for most of the states in our sample period. During our sample period, only eight states adopted or struck down these four tort reforms. Specifically, North Carolina and Tennessee adopted caps on non-economic damage reforms in 2012; South Carolina and Tennessee adopted caps on punitive damage reform in 2012; Pennsylvania adopted joint and several liability reform in 2011. In contrast, Mississippi, Missouri, and Utah struck down caps on non-economic damage reforms in 2013; Arkansas and Missouri abolished caps on punitive damages in 2012 and 2015, respectively.

[23] The number of lawyers in each state is obtained from the American Bar Association. The number of healthcare employees, the number of insurance employees and the unemployment rate in each state are from the Bureau of Labor Statistics. The personal income data are from the Bureau of Economic Analysis. The ratio of population in poor or fair health status and adult with obesity are from the database of County Health Rank which collects data originally from the Risk Factor Surveillance System. *number of registered automobiles per square mile*, young driver, and traffic per lane are from the Federal Highway Administration's Highway Statistics Series Publications.

[24] https://www.fhwa.dot.gov/policyinformation/statistics/2018/

Massachusetts and Vermont which implemented Medicaid expansion in 2014 but had no newly eligible enrollees since then. We also exclude five states (Pennsylvania, Indiana, Alaska, Montana, and Louisiana) that expanded Medicaid coverage later in our sample period. The final sample includes 21 expansion states that implemented Medicaid expansion in 2014 and 19 non-expansion states (including 5 states that adopted Medicaid expansion after 2018 and 14 states that have not adopted it yet).[25] Including the late-expansion states give us similar results.

Table 3.2 below presents the summary statistics of our data on personal auto insurance. We have personal auto firm-state observations of 44,611. We have 44,242 observations for the auto liability line and 12,788 for the auto no-fault line. Some firms have both lines in each state, so the total firm-state observations for auto insurance are fewer than the sum of the two individual lines. On average, a private passenger auto insurer earned premiums of $17.507 million in a state in a given year. Auto liability insurance has relatively higher average premiums earned, with $15.073 million, than auto no-fault insurance with $8.757 million premium. The average auto insurance losses incurred is $12.268 million, $10.103 million for the auto liability line, and $8.373 million for the auto no-fault line. The average auto insurance total losses is $12.994 million overall, $10.636 million for the auto liability line, and $8.757 million for the auto no-fault line. The average loss ratio is about 88.8% overall, 83.1% for the auto liability line while 126.6% for the auto no-fault line. A loss ratio of the no-fault line larger than 1 indicates that auto insurers have negative underwriting profitability in no-fault insurance business on average. It is

[25] Our treatment group includes New Jersey and Washington, two early expansion states. They used the early expansion option to shift people from existing public insurance programs into Medicaid but did not enroll any new people until 2014 (Sommers et al., 2013; Sommers et al., 2014; Nikpay et al., 2015). For this reason, we keep these two states in our sample but regard them as expanding Medicaid coverage in 2014.

noteworthy that losses incurred, total losses, premiums earned, and loss ratios are highly skewed, so we use log-transformed data for these variables in our subsequent regression analysis.

3.5 Empirical Analysis

3.5.1 DID Analysis for the Average Impact of Medicaid Expansion

To investigate the impact of the ACA Medicaid Expansion on personal auto insurance, we use a difference-in-difference (DID) approach to compare auto insurance outcome variables in expansion and non-expansion states before and after Medicaid expansion. The first identification strategy uses a binary DID model as shown in equation (1),

$$Y_{ist} = \beta_0 + \beta_1 Expansion_{st} + \beta_2 X_{ist} + \alpha_t + \delta_i + \varphi_s + \varphi_s \times t + e_{ist} \qquad (3.11)$$

where

Y_{ist} represents insurer i's auto insurance premiums earned, losses incurred, total losses, or loss ratio in state s in year t.

$Expansion_{st}$ is a dummy variable that is equal to 1 if state s implemented Medicaid expansion in year t, and 0 otherwise.

X_{ist} is a vector of control variables at the firm-level and state-level.

α_t controls for year fixed effects.

δ_i controls for firm fixed effects.

φ_s controls for state fixed effects.

t is a continuous trend variable. $\varphi_s \times t$ are the state-specific linear trends.

Table 3.2 Summary Statistics

	N	Mean	Std. Dev.	p25	Median	p75
Losses Incurred (million)	44,611	12.268	54.769	0.218	1.322	6.283
Losses Incurred of Auto Liability Insurance	44,242	10.103	4.043	0.210	1.238	5.713
Losses Incurred of Auto No-Fault Insurance	12,788	8.373	51.549	0.086	0.461	2.5642
Total losses (million)	44,611	12.994	58.829	233,941	1.388	6.568
Total Losses of Auto Liability Insurance	44,242	10.636	40.300	0.225	1.301	5.982
Total Losses of Auto No-Fault Insurance	12,788	8.757	38.060	0.128	0.640	3.385
Premiums Earned (million)	44,611	17.507	73.037	0.360	2.014	9.360
Premiums Earned of Auto Liability Insurance	44,242	15.073	5.992	0.353	1.918	8.569
Premiums Earned of Auto No-Fault Insurance	12,788	8.757	38.060	0.128	0.640	3.385
Total loss ratio (%)	44,611	88.8	493.3	50.9	67.4	86.0
Total Loss Ratio of Auto Liability Insurance	44,242	83.1	455.7	50.3	66.9	85.2
Total Loss Ratio of Auto No-Fault Insurance	12,788	126.6	2083.4	48.7	69.8	98.7
Expansion dummy	44,611	0.888	4.933	0.509	0.674	0.86
Liquidity	44,611	0.066	0.118	0.009	0.025	0.065
Total Assets(million)	44,611	19.885	2.072	18.433	19.658	21.258
Leverage	44,611	0.527	0.223	0.432	0.587	0.681
Stock	44,611	0.856	0.351	1	1	1
Group	44,611	0.953	0.213	1	1	1
Personal income (per capita)	44,611	0.014	0.016	0.004	.008	0.014
Number of lawyers (per capita)	44,611	0.003	0.001	0.003	00.003	0.003
Insurance employment (per capita)	44,611	0.008	0.002	0.006	0.007	0.009
Unemployment rate	44,611	0.159	0.03	0.134	0.156	0.179
Poor or fair health status	44,611	0.282	0.032	0.26	0.283	0.304
Adult population with obesity	44,611	0.068	0.022	0.052	0.066	0.083
Young driver ((per capita)	44,611	0.031	0.009	0.025	0.03	0.038
Vehicles miles (per capita)	44,611	0.01	0.002	0.009	0.01	0.011
Traffic per lane	44,611	4.878	1.803	3.718	4.904	5.853
Caps on Non-Economic Damage Caps	44,611	0.48	0.5	0	0	1
Caps on Punitive Damage Caps	44,611	0.669	0.471	0	1	1
Collateral Source Reform	44,611	0.64	0.48	0	1	1
Joint and Several Reform	44,611	0.789	0.408	1	1	1

e_{ist} are idiosyncratic errors.

The estimated coefficient β_1 provides the estimated mean difference in the auto insurance outcome variable in expansion and non-expansion states during the post-expansion period as compared to the mean difference before expansion, controlling for firm characteristics, state demographic and economic covariates, tort systems, and firm, state, and year fixed effects. Since the insurance market has experienced underwriting cycles over time, and each state might show a different trend in the cycle, we include a state-specific linear trend to control for this effect in this market.

As stated earlier, Medicaid expansion in a state has provided an additional source of coverage for medical bills after a car accident to those without health insurance, we expect that Medicaid expansion losses and premiums in both no-fault and private passenger auto liability lines are lower. Thus, we hypothesize that β_1 is negative when the dependent variable is losses incurred, total losses, and premiums earned. When the dependent variable is the loss ratio, we do not have a prediction for the sign of β_1 because it depends on whether any loss decrease is offset by a premium increase.

It is noteworthy that the tort system is stable for most of the states during our sample period, so the impact of the tort system in these states is mainly captured by the state fixed effects. The coefficients of the tort reform dummy variables only reflects the average performance of insurers in a few states that newly adopted or abrogated a certain tort reform during our sample period in comparison to all other states.

3.5.2 Event Study for the Dynamic Impact of Medicaid Expansion

To better understand the dynamic impact of Medicaid expansion on auto insurance, we use an event-study. As more Medicaid eligible patients enter the health care system, we may see that the impact of Medicaid expansion varies over time. To investigate the treatment effect dynamics, we use the following specification,

$$Y_{ist} = \beta_0 + \beta_1 Treat_{s,t=-4} + \beta_2 Treat_{s,t=-3} + \beta_3 Treat_{s,t=-2} + \beta_4 Treat_{s,t=0} + \beta_5 Treat_{s,t=1} + \beta_6 Treat_{s,t=2} + \beta_7 Treat_{s,t=3} + \beta_8 Treat_{s,t=4} + \beta_9 X_{ist} + \alpha_t + \delta_i + \varphi_s + \varphi_s \times t + e_{ist}. \quad (3.12)$$

In this equation, we define a set of dummy variables indicating the periods before and after the ACA Medicaid expansion was adopted in each state. For Medicaid expansion states, $Treat_{s,t=-4}$ is equal to 1 if the observation in expansion states is four years before the adoption of Medicaid expansion and 0 otherwise. Since all expansion states in our sample started Medicaid expansion in 2014, $Treat_{s,t=-4}$ is equal to 1 for observations in expansion states in the year 2010. For non-expansion states, $Treat_{s,t=-4}$ always equals 0. We define $Treat_{s,t=-3}$, $Treat_{s,t=-2}$, $Treat_{s,t=0}$, $Treat_{s,t=1}$, $Treat_{s,t=2}$, $Treat_{s,t=3}$, and $Treat_{s,t=4}$ similarly, where $t = 0$ refers to the expansion year, i.e., the year 2014. The year before Medicaid expansion (the year 2013) is regarded as the base year, so $Treat_{s,t=-1}$ is omitted in the regression. This event study framework disentangles the timing of the policy change and can help us explore the variation in the impact of Medicaid expansion over time.

Also, the event study framework can help assess the parallel trend assumption underlying the DID analysis. DID analysis is valid only if, in the absence of Medicaid expansion, the auto insurance outcome variables for insurers in expansion states and non-expansion states follow the same trend. While this assumption cannot be tested directly, we can test whether the trend of such variables was different between expansion and non-expansion states before the expansion took place. By evaluating whether the coefficients on the "treatment" variables in the pre-treatment years (β_1, β_2, and β_3) are different from 0, we can determine if the outcome difference between the treatment group and the control group in pre-treatment years is not significantly different from that in the base year. If the three variables are equal to 0, then our test is passed. In other words, this event study framework helps evaluate whether the control group is a valid counterfactual for the treatment group (Grecu, Dave, and Saffer, 2019).

3.6 Baseline Results

3.6.1 Average Impact of Medicaid Expansion

Tables 3.3.1 to 3.3.3 reports the results for the binary DID estimation in Equation (3.11) for the total personal auto insurance covering personal bodily injuries. Standard errors are clustered by state. We use four dependent variables: premiums earned, losses incurred, total losses, and the loss ratio (%). These variables are all log-transformed. In Tables 3.3 and 3.4, we present the results for auto liability insurance and auto no-fault insurance respectively but only our main interested variable, Expansion, is presented. The control variables used in the three tables are the same.

We find that, on average, private passenger auto insurers' losses incurred (total losses) in expansion states decreased by 7.7% (7.7%) after Medicaid expansion as compared to those operating in non-expansion states. The percentage decrease in premiums earned in expansion states relative to the increase in non-expansion states was 3.7% (significant at 10%). The loss ratio decreased by 4.0% on average in expansion states, although this is statistically insignificant. When we separate the results to auto liability and auto no-fault insurance lines, we find that the decrease in total personal auto insurance losses is driven by the auto liability insurance line, with a 7.6% (7.7%) losses incurred

Table 3.3.1 Medicaid Expansion and Private Passenger Auto Liability and No Fault Combined (Average Effect)

VARIABLES	(1) Log (Losses Incurred)	(2) Log (Total Losses)	(3) Log (Premiums Earned)	(4) Log (Loss Ratio)
Expansion	-0.077**	-0.077**	-0.037*	-0.040
	(0.031)	(0.030)	(0.021)	(0.028)
Liquidity	0.014	-0.009	-0.001	-0.008
	(0.128)	(0.124)	(0.111)	(0.045)
Firm size	0.434***	0.428***	0.442***	-0.014
	(0.044)	(0.042)	(0.040)	(0.016)
Leverage	-0.235**	-0.228*	-0.310***	0.082*
	(0.116)	(0.113)	(0.106)	(0.046)
Stock	-0.723***	-0.705***	-0.602***	-0.103
	(0.181)	(0.178)	(0.147)	(0.076)
Group	0.054	0.059	0.011	0.048
	(0.091)	(0.087)	(0.072)	(0.042)
Personal Income	-6.207	-4.923	-8.300***	3.378
	(4.486)	(4.482)	(2.814)	(4.318)
No. of Lawyers (per capita)	-44.167	-48.051*	-59.230***	11.179
	(27.169)	(27.948)	(21.289)	(12.389)
No. of Insurance Employees (per capita)	55.439**	53.404**	34.607	18.797
	(22.107)	(23.279)	(22.645)	(20.403)
Poor or Fair Health Status	-0.070	-0.252	-0.396	0.144
	(0.810)	(0.801)	(0.722)	(0.593)
Adults with Obesity	2.053**	1.937*	2.389**	-0.452
	(1.010)	(0.985)	(1.072)	(0.690)
Unemployment Rate	0.151	0.340	-1.027	1.366
	(1.066)	(1.071)	(0.642)	(1.012)
Young Driver	-0.115	0.097	1.990	-1.893
	(2.361)	(2.301)	(2.090)	(2.189)
Vehicles mile	22.519	16.685	31.807	-15.122
	(42.996)	(41.515)	(22.436)	(32.727)
Traffic per Lane	-0.009	-0.007	-0.024	0.018
	(0.050)	(0.049)	(0.036)	(0.041)
Caps on Non-Econ Damages	-0.027	-0.034	-0.018	-0.016
	(0.058)	(0.059)	(0.033)	(0.030)
Caps on Punitive Damages	0.071	0.073	0.109***	-0.037
	(0.056)	(0.054)	(0.028)	(0.032)
Constant	4.655***	4.926***	5.166***	4.366***
	(1.086)	(1.049)	(0.912)	(0.662)
Observations	44,611	44,611	44,611	44,611
R-squared	0.622	0.627	0.647	0.146
State FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES

State-specific Linear Trend	YES	YES	YES	YES
Firm Control	YES	YES	YES	YES
State Control	YES	YES	YES	YES

Table 3.3.2 Medicaid Expansion and Private Passenger Auto Liability Insurance Only (Average Effect)

VARIABLES	(1) Log (Losses Incurred)	(2) Log (Total Losses)	(3) Log (Premiums Earned)	(4) Log (Loss Ratio)
Expansion	-0.076**	-0.077***	-0.038	-0.039*
	(0.028)	(0.027)	(0.023)	(0.023)
Observations	44,242	44,242	44,242	44,242
R-squared	0.619	0.624	0.648	0.141
State FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
State-specific Linear Trend	YES	YES	YES	YES
Firm Control	YES	YES	YES	YES
State Control	YES	YES	YES	YES

Table 3.3.3 Medicaid Expansion and Private Passenger No-fault Auto Insurance Only (Average Effect)

VARIABLES	(1) Log (Losses Incurred)	(2) Log (Total Losses)	(3) Log (Premiums Earned)	(4) Log (Loss Ratio)
Expansion	0.002	0.020	-0.058	0.069
	(0.064)	(0.059)	(0.050)	(0.068)
Observations	12,788	12,788	12,788	12,788
R-squared	0.704	0.714	0.730	0.257
State FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
State-specific Linear Trend	YES	YES	YES	YES
Firm Control	YES	YES	YES	YES
State Control	YES	YES	YES	YES

The three tables report regression results for the DID model in Equation (1) on aggregated private passenger auto insurance, auto liability, and auto no-fault insurance separately. Column (1) to (4) report the results with the dependent variables: private passenger auto insurance losses incurred, total losses, premiums earned, and loss ratio (%) respectively. All the dependent variables are log-transformed. Alaska, California, Connecticut, Indiana, Louisiana, Massachusetts, Minnesota, Montana, Pennsylvania, and Vermont are excluded from our sample. Standard errors are clustered at the state level and are reported in parentheses. *** (**, *) indicates significance at the 1% (5%, 10%) level. Firm-level control variables include firm size, leverage, liquidity, stock, and group. State-level control variables include unemployment rate (%), personal income (per capita), population reported with poor or fair health status (%), adults with obesity (%), the number of insurance employees (per capita), the number of healthcare employees (per capita), the number of lawyers (per capita), number of registered automobiles per square mile, young drivers (%), average traffic per lane, and tort reform dummy variables. The dummy variables for collateral resource reform and joint and several reforms are omitted because they are time-invariant.

(total losses) decrease. We see an average decrease in premiums (though statistically insignificant) and a decrease in the loss ratio (marginally significant). In comparison, we do not have a significant decrease in losses or premiums in the private passenger no-fault insurance line.

Regarding firm characteristics, we find that firm size is significantly positively associated with an insurer's loss incurred, total losses, and premiums earned in its auto insurance liability line. Stock insurers tend to have lower losses and premiums earned than insurers with other organizational forms. Firms with higher leverage have lower losses and premiums.

When it comes to state-level controls, we find that insurers operating in a state with more employees in the insurance industry (per capita) tend to have higher losses incurred and premiums in their private passenger auto insurance. States with higher personal incomes (per capita) have lower premiums. In comparison, insurers operating in states with more lawyers (per capita) tend to have lower premiums earned and lower losses incurred. States with more adults with obesity have higher losses and premiums in auto insurance. We do not find significant impacts for the state-level control variables for the loss ratio.

3.6.2 Dynamic Impact of Medicaid Expansion

Table 4.1 presents the regression results of the event study in Equation (2) with the focus on aggregated private passenger auto insurance. Tables 4.2 and 4.3 focus on auto liability, and auto no-fault insurance, respectively.

From Table 4.1., we could see that in the pre-treatment period, none of the treatment variable coefficients is significantly different from zero in any of the regressions from Columns (1) to (4). This means that the difference in outcome variables between expansion

Table 3.4.1 Medicaid Expansion and Private Passenger Auto Insurance (Event Study)

	(1) Log (Losses Incurred)	(2) Log (Total Losses)	(3) Log (Premiums Earned)	(4) Log (Loss Ratio)
4 Years Prior	0.026	0.030	0.020	0.010
	(0.044)	(0.046)	(0.032)	(0.048)
3 Years Prior	0.068	0.067	0.042	0.025
	(0.040)	(0.041)	(0.034)	(0.043)
2 Years Prior	0.046	0.049	0.017	0.032
	(0.039)	(0.040)	(0.031)	(0.029)
Treatment Year	-0.030	-0.028	-0.046**	0.018
	(0.031)	(0.029)	(0.022)	(0.022)
1 Years After	-0.104***	-0.109***	-0.083***	-0.026
	(0.037)	(0.036)	(0.029)	(0.026)
2 Years After	-0.108**	-0.115***	-0.157***	0.042
	(0.041)	(0.041)	(0.029)	(0.027)
3 Years After	-0.092**	-0.101**	-0.153***	0.052
	(0.045)	(0.047)	(0.037)	(0.036)
4 Years After	-0.073	-0.078	-0.160***	0.082**
	(0.056)	(0.056)	(0.040)	(0.040)
Observations	44,611	44,611	44,611	44,611
R-squared	0.622	0.627	0.647	0.147
Firm Controls	YES	YES	YES	YES
State Controls	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
State FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
State-specific Linear Trend	YES	YES	YES	YES

and non-expansion states two (three, or four) years before expansion is not significantly different from the difference one year before expansion. In other words, we do not find any trend differential in the pre-treatment period between expansion and non-expansion states. In comparison, we see significant treatment effects for Medicaid expansion for losses incurred, total losses, and premiums earned in the post-treatment period. For losses incurred and total losses, the effect started from the second year of expansion and lasted

Table 3.4.2 Medicaid Expansion and Private Passenger Auto Liability Insurance (Event Study)

	(1) Log (Losses Incurred)	(2) Log (Total Losses)	(3) Log (Premiums Earned)	(4) Log (Loss Ratio)
4 Years Prior	-0.028	-0.020	-0.005	-0.025
	(0.179)	(0.172)	(0.091)	(0.120)
3 Years Prior	0.032	0.037	0.036	0.001
	(0.041)	(0.043)	(0.029)	(0.044)
2 Years Prior	0.049	0.047	0.039	0.009
	(0.040)	(0.041)	(0.035)	(0.039)
Treatment Year	0.041	0.043	0.006	0.036
	(0.035)	(0.036)	(0.029)	(0.026)
1 Years After	-0.031	-0.032	-0.050**	0.017
	(0.027)	(0.025)	(0.022)	(0.020)
2 Years After	-0.104***	-0.113***	-0.092***	-0.023
	(0.032)	(0.031)	(0.029)	(0.024)
3 Years After	-0.117***	-0.127***	-0.163***	0.030
	(0.039)	(0.038)	(0.029)	(0.026)
4 Years After	-0.095**	-0.106**	-0.155***	0.046
	(0.042)	(0.043)	(0.037)	(0.034)
Observations	44,242	44,242	44,242	44,242
R-squared	0.619	0.624	0.649	0.141
Firm Controls	YES	YES	YES	YES
State Controls	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
State FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
State-specific Linear Trend	YES	YES	YES	YES

for three years with time-varying magnitudes. Take the total losses regression in column (2) in Table 3.4.1 as an example, private passenger auto insurers' total losses in expansion states and non-expansion states did not have much difference in the first year of expansion (i.e., the year 2014), but the auto insurance losses in expansion states decreased by 10.9% in the second year of expansion compared to those operating in non-expansion states. The difference was -11.5% in 2016, and -10.1% in 2017, both statistically significant. The

Table 3.4.3 Medicaid Expansion and Private Passenger Auto No-fault Insurance (Event Study)

	(1) Log (Losses Incurred)	(2) Log (Total Losses)	(3) Log (Premiums Earned)	(4) Log (Loss Ratio)
4 Years Prior	0.032	0.040	-0.110**	0.142
	(0.074)	(0.068)	(0.047)	(0.086)
3 Years Prior	0.036	0.028	-0.057	0.079
	(0.085)	(0.085)	(0.046)	(0.092)
2 Years Prior	-0.024	-0.014	0.014	-0.031
	(0.086)	(0.078)	(0.052)	(0.062)
Treatment Year	-0.049	-0.032	-0.063	0.022
	(0.067)	(0.063)	(0.053)	(0.078)
1 Years After	-0.068	-0.050	0.007	-0.065
	(0.074)	(0.068)	(0.060)	(0.099)
2 Years After	-0.069	-0.048	-0.040	-0.020
	(0.081)	(0.075)	(0.051)	(0.091)
3 Years After	-0.111	-0.077	-0.060	-0.025
	(0.106)	(0.094)	(0.088)	(0.112)
4 Years After	-0.173*	-0.162*	-0.054	-0.121
	(0.095)	(0.089)	(0.075)	(0.111)
Observations	12,788	12,788	12,788	12,788
R-squared	0.704	0.714	0.730	0.258
Firm Controls	YES	YES	YES	YES
State Controls	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
State FE	YES	YES	YES	YES
Year FE	YES	YES	YES	YES
State-specific Linear Trend	YES	YES	YES	YES

Tables 3.4.1 to 3.4.3 report the regression results for the event study in Equation (2) for aggregated private passenger auto insurance, private passenger auto liability, and private passenger auto no-fault insurance. Columns (1) to (4) report the results with the following dependent variables: medical liability insurance losses incurred, total losses, premiums earned, and loss ratio (%) respectively. All the dependent variables are log-transformed. Alaska, California, Connecticut, Indiana, Louisiana, Massachusetts, Minnesota, Montana, Pennsylvania, and Vermont are excluded from our sample. Standard errors are clustered at the state level and are reported in parentheses. *** (**, *) represents significance at the 1% (5%, 10%) level. Firm-level control variables include firm size, leverage, liquidity, stock, and group. State-level control variables include unemployment rate (%), personal income (per capita), population reported with poor or fair health status (%), adults with obesity (%), the number of insurance employees (per capita), the number of healthcare employees (per capita), the number of lawyers (per capita), number of registered automobiles per square mile, young drivers (%), average traffic per lane, and tort reform dummy variables

results indicate that the private passenger auto insurance line in Medicaid expansion states experience significantly lower losses than non-expansion states. It provides evidence to support our argument that Medicaid expansion contributes to the decrease in auto liability insurance losses. The impact coefficient is -7.8% in 2018 but is insignificant. For premiums earned, we could see premiums earned decreased since the first year of expansion in expansion states in comparison to their counterparts in non-expansion states. The difference was -4.6%, -8.3%, -15.7 %, -5.3%, and -15.8%, respectively, in the five years after expansion. The comparable decreases in losses and premiums earned resulted in a stable loss ratio overall except for a minor increase in the fifth year of expansion.

After that, we investigate the impact on private passenger auto liability and auto no-fault insurance separately. In the first two years of expansion, the two auto liability insurers in Medicaid expansion states have lower losses incurred and total losses since the third year of expansion and the magnitude of the difference was -10.4%, -11.7%, and -9.5% respectively after that (-11.3%, -12.7% and -10.6% respectively for total costs).

In comparison, for auto no-fault insurance, Medicaid expansion states tend to have lower losses incurred and total losses in the treatment year and the magnitude of the impact increases over time from -4.9%, to -6.8%, to -6.9%, to -11.1% and to -17.3% respectively (-3.2%, to -5.0%, to -4.8%, to -7.7% and to -16.2% respectively for total costs). However, the standard deviation of the dynamic effect is very large, which may indicate more variation in the impact of Medicaid expansion on the auto no-fault insurance line. We do not see a clear pattern on the impact of premiums earned and loss ratio in the no-fault insurance line. To better visualize the time-varying treatment effects and compare the impact of Medicaid expansion on the two lines, we plot the yearly impacts of Medicaid expansion on auto losses incurred, total losses, premiums earned, and loss ratios for the auto liability and auto no-fault insurance line in Figures 3.1-3.4, respectively, with 95% confidence intervals. The plot on the left side is for auto liability insurance while the plot on the right side is for no-fault auto insurance. The x-axis denotes the year relative to the expansion year and the y-axis displays the size of the treatment coefficients from Equation (3.2).

3.7 Conclusion

In this paper, we study the impact of the expansion of public health insurance on private passenger auto insurance. The expansion of public health insurance is not directly targeted at auto insurance but provides previously uninsured (from a health insurance perspective) injured driver with an additional source of coverage for medical bills. In this paper, we first use a simple theoretical model to illustrate how having public health insurance reduces the incentive of low-income insured drivers to inflate auto insurance claims related to medical expenses. The main implication of the model is that expanding health insurance may reduce auto insurance losses.

Then, we test the implication of this model using the ACA Medicaid expansion. By studying private passenger auto insurers' performance in expansion states and no expansion states before and after the ACA Medicaid expansion, we find that Medicaid expansion led to significantly lower private passenger auto insurance losses and premiums. Also, we find that the decrease is largely driven by private passenger auto liability insurance rather than auto no-fault insurance.

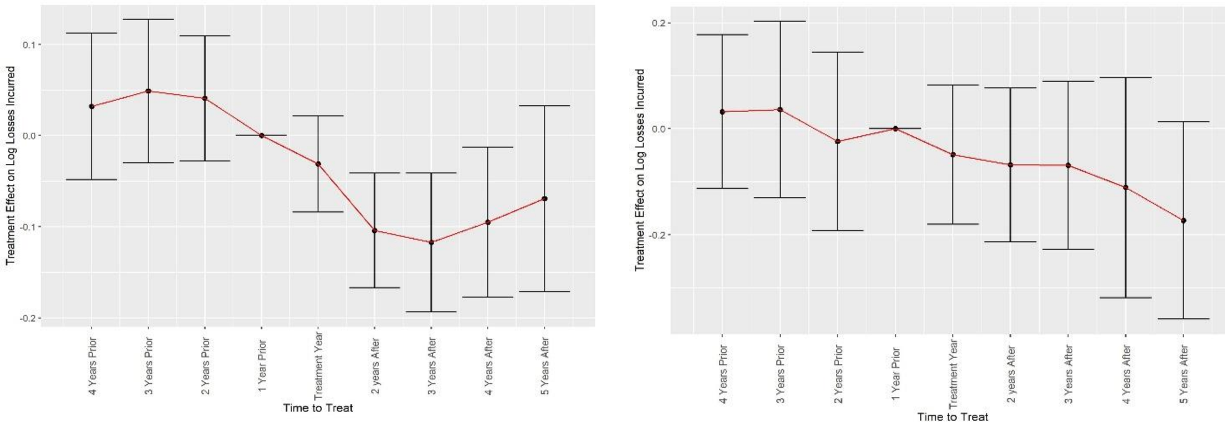

Figure 3.1 Yearly Impacts of Medicaid Expansion on Private Passenger Auto Insurance Losses Incurred (Auto Liability/No-fault)

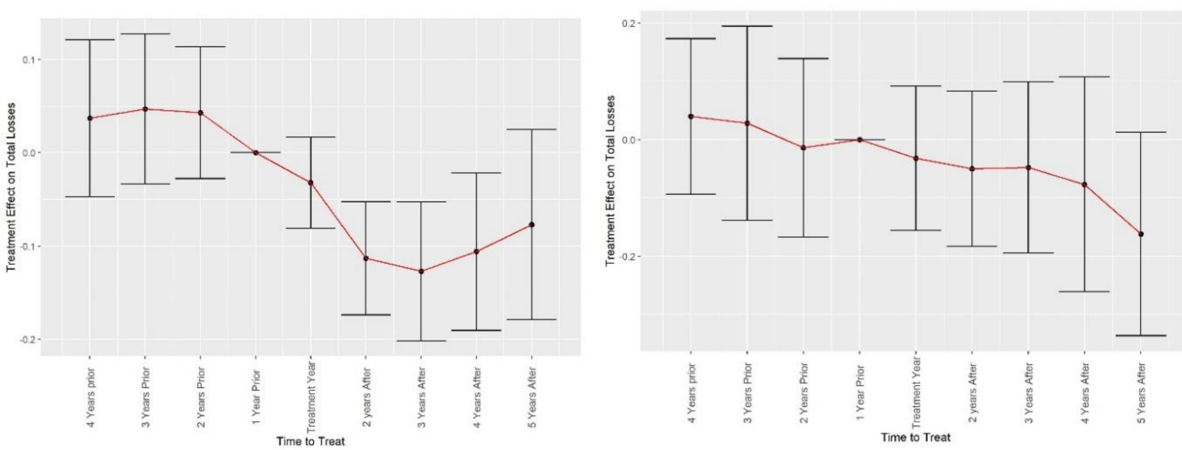

Figure 3.2 Yearly Impacts of Medicaid Expansion on Private Passenger Auto Insurance Total Losses Incurred (Auto Liability/No-fault)

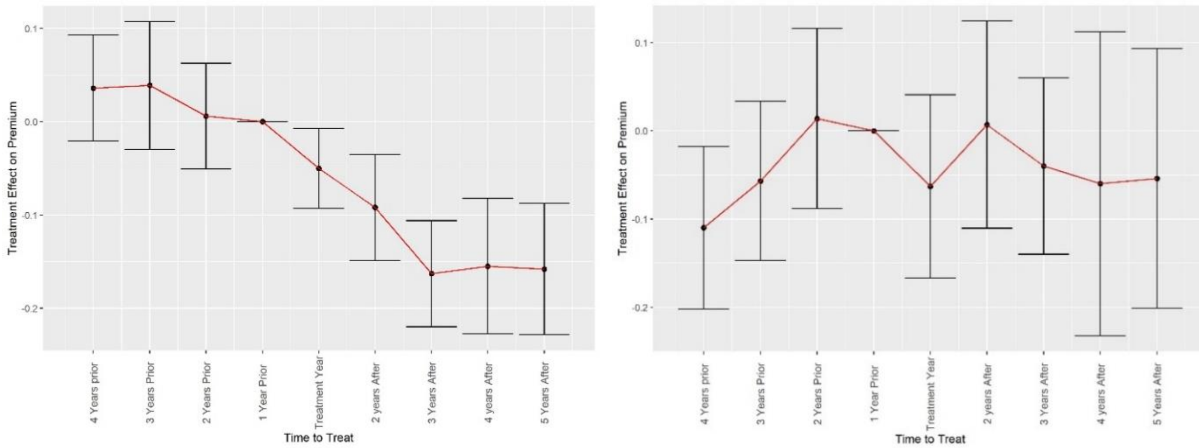

Figure 3.3 Yearly Impacts of Medicaid Expansion on Private Passenger Auto Insurance Premiums Earned (Auto Liability/No-fault)

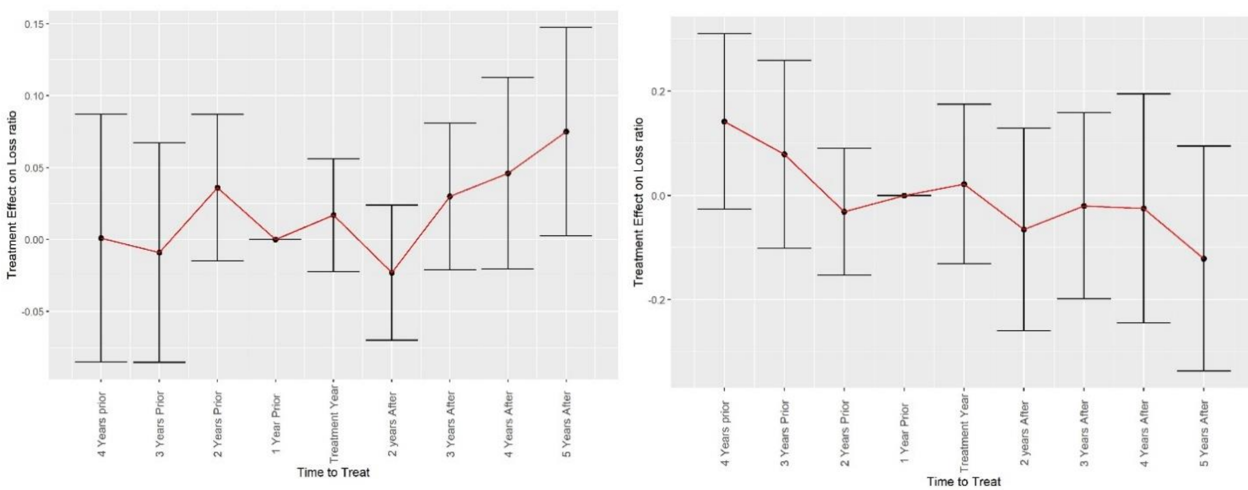

Figure 3.4 Yearly Impacts of Medicaid Expansion on Private Passenger Auto Insurance Loss Ratio (Auto Liability/No-fault)

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APPENDIX

Appendix A. The Healthcare Reform and Sample Selection

The ACA Medicaid Expansion started officially on January 1, 2014. Five states and Washington, D.C. took advantage of the state plan amendment (SPA) or a Section 1115 Waiver to exercise the early expansion option. Connecticut was the first to expand Medicaid eligibility on April 1, 2010, followed by Minnesota on March 1, 2010, California on November 1, 2010, Washington on January 3, 2011, and New Jersey on April 14, 2011.

California's expansion was taken under a Section 1115 waiver. It extended eligibility to people with incomes as high as 200% FPL, which is even higher than the ACA's eligibility threshold of 138% FPL. Similarly, Washington D.C. has expanded Medicaid to people with income up to 133% FPL via the SPA since July 1, 2010 and then further raised the eligibility limit to 200% FPL via a Section 1115 waiver since December 1, 2010. The eligibility limit was 75% FPL under the State Plan Amendment on March 1, 2010 and increased to 250% via a Section 1115 waiver on August 1, 2010 in Minnesota and 56% FPL in Connecticut before 2014 (68% in some counties). Because early expansion in California, Connecticut, Minnesota, and Washington D.C. increased Medicaid enrollment before 2014, they might not be comparable to other states expanding Medicaid in or after 2014. We, therefore, exclude them from our sample used in the main analysis.

In New Jersey and Washington, the early expansion option mainly was used to shift people from existing public insurance programs into Medicaid but did not enroll any new participants until 2014 (Sommers et al., 2013; Sommers et al., 2014; Nikpay et al., 2015). For this reason, we keep these two states in our sample but regard them as expanding

Medicaid coverage in 2014.

Two other states, Massachusetts and Vermont, adopted the ACA Medicaid expansion in 2014. However, Massachusetts has provided free healthcare insurance for residents earning less than 150% FPL since 2006 and Vermont has provided Medicaid to individuals whose income is below 150% FPL since 1995.[26] Because the two states had large Medicaid enrollment before 2014 but no newly eligible enrollees since 2014, we exclude them from our sample.

Among the remaining 43 states, 24 states implemented Medicaid expansion during our sample period, with 19 expanding Medicaid in 2014 and 5 from 2015 to 2018.[27] Virginia and Maine expanded Medicaid in 2019, Idaho and Utah expanded in 2020, Nebraska has adopted but not yet implemented expansion, and 14 states have not adopted the expansion.[28]

We decide to exclude five late adopters which expanded Medicaid during the period of 2015-2018 from our sample, because their pre- and post-treatment periods are not consistent with other expansion states. Also, including late adopters might attenuate the coefficients of interest if the expansion has lagged effects (Peng et al., 2020).

In summary, we exclude three early expansion states (California, Minnesota, Connecticut) and Washington D.C., which had newly eligible enrollees before 2014. We exclude Massachusetts and Vermont which have implemented Medicaid expansion since

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[26] Medicaid enrollment data reported to the Medicaid Budget and Expenditure System shows that there were no additional newly eligible enrollees in these two states since 2014. Thus, these two states are essentially not "treated" after the expansion.

[27] In our sample, states that expanded Medicaid in 2014 include Arkansas, Arizona, Colorado, Delaware, Hawaii, Illinois, Iowa, Kentucky, Maryland, Michigan, New Hampshire, New Mexico, New York, Nevada, North Dakota, Ohio, Oregon, Rhode Island, and West Virginia. Pennsylvania, Indiana, Alaska, Montana, and Louisiana expanded Medicaid between 2015 and 2018.

[28] Alabama, Florida, Georgia, Kansas, Mississippi, Missouri, North Carolina, Oklahoma, South Carolina, South Dakota, Tennessee, Texas, Wisconsin, and Wyoming did not adopted Medicaid expansion by 2020.

2014 but had no newly eligible enrollees since then. We also exclude five late expansion states (Pennsylvania, Indiana, Alaska, Montana, and Louisiana). Our final sample includes 21 expansion states that implemented Medicaid expansion in 2014 (including New Jersey and Washington) and 19 non-expansion states (including 5 states that adopted or implemented Medicaid expansion after 2018 and 14 states that have not adopted it yet).

Table A1 in Appendix A shows the status of each state in terms of their Medicaid expansion decision and tort reforms.

Table A: Healthcare Reform and Tort Reform Status

State	Medicaid Expansion	Caps on Non-Economic Damage	Caps on Punitive Damage	Collateral Source Reform	Joint and Several Reform
Alaska	2015	Yes	Yes	Yes	Yes
Alabama	No	No	Yes	Yes	No
Arkansas	2014	No	No*	No	Yes
Arizona	2014	No	No	Yes	Yes
California	Early	Yes	No	Yes	Yes
Colorado	2014	Yes	Yes	Yes	Yes
Connecticut	Early	No	No	Yes	Yes
Delaware	2014	No	No	Yes	No
Florida	No	Yes	Yes	Yes	Yes
Georgia	No	No	Yes	No	Yes
Hawaii	2014	Yes	No	Yes	Yes
Iowa	2014	No	No	Yes	Yes
Idaho	2020	Yes	Yes	Yes	Yes
Illinois	2014	No	Yes	Yes	No
Indiana	2015	No	Yes	Yes	No
Kansas	No	Yes	Yes	No	Yes
Kentucky	2014	No	No	No	Yes
Louisiana	2016	No	Yes	No	Yes
Massachusetts	2014*	Yes	No	Yes	No
Maryland	2014	Yes	No	No	No
Maine	2019	No	No	Yes	No
Michigan	2014	Yes	Yes	Yes	Yes
Minnesota	Early	No	No	Yes	Yes
Missouri	No	No*	No*	Yes	Yes
Mississippi	No	No*	Yes	No	Yes
Montana	2016	Yes	Yes	Yes	Yes
North	No	Yes*	Yes	No	No

Carolina					
North Dakota	2014	Yes	Yes	Yes	Yes
Nebraska	2020	No	Yes	Yes	Yes
New Hampshire	2014	No	Yes	No	Yes
New Jersey	Early	No	Yes	Yes	Yes
New Mexico	2014	No	No	No	Yes
Nevada	2014	Yes	Yes	Yes	Yes
New York	2014	No	No	Yes	Yes
Ohio	2014	Yes	Yes	Yes	Yes
Oklahoma	No	Yes	Yes	Yes	Yes
Oregon	2014	No	Yes	Yes	Yes
Pennsylvania	2015	No	Yes	Yes	Yes*
Rhode Island	2014	No	No	Yes	No
South Carolina	No	Yes	Yes*	No	Yes
South Dakota	No	Yes	No	Yes	Yes
Tennessee	No	Yes*	Yes*	Yes	Yes
Texas	No	Yes	Yes	No	No
Utah	2020	No*	No	Yes	Yes
Virginia	2019	No	Yes	No	No
Vermont	2014*	No	No	No	Yes
Washington	Early	No	Yes	Yes	Yes
Wisconsin	No	Yes	Yes	Yes	Yes
West Virginia	2014	Yes	Yes	Yes	Yes
Wyoming	No	No	No	No	Yes
Total	31	22	30	35	39

We report the current status of each state participating in Medicaid Expansion and adopting certain tort reforms in this table. We report the expansion year for each state. We also use 1 to indicate that a state adopted a certain tort reform and 0 otherwise. States that have adopted tort reforms but ruled them unconstitutional before 2010 are regarded as non-tort states. Most states have a stable tort system during our sample period of 2010 - 2018 except for those marked with *. North Carolina and Tennessee adopted caps on non-economic damage reform in 2012; South Carolina and Tennessee adopted caps on punitive damage reform in 2012; Pennsylvania adopted joint and several liability reform in 2011. Mississippi, Missouri, and Utah struck down caps on non-economic damage reform in 2013; Arkansas and Missouri struck down caps on punitive damage reform in 2012 and 2015, respectively.