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Seeing is believing: The effects of optometrist scope of practice expansion

Kihwan Bae[1] | **Edward Timmons**[1] | **Protik Nandy**[2]

[1]West Virginia University, Morgantown, West Virginia, USA

[2]University of Minnesota – Duluth, Duluth, Minnesota, USA

Correspondence
Kihwan Bae, West Virginia University, 83 Beechurst Ave, Morgantown, WV 26505, USA.
Email: kihwan.bae@mail.wvu.edu

Abstract

We examine how the emergence of optometrists as new "eye doctors" affected population eye health outcomes and optometrist earnings in the United States. Using the staggered adoption of optometrist prescription authority across states, we find suggestive evidence that optometrist scope of practice expansion reduced vision impairment and mitigated racial and ethnic disparities in eye health. We also find that the policy is associated with an increase in hourly wages among optometrists who are not self-employed. These findings imply that allowing optometrists to use medications for eye treatments effectively expanded the primary eye care workforce and therefore improved public eye health.

KEYWORDS
earnings, optometry, scope of practice, vision impairment

JEL CLASSIFICATION
I18, J44, K31

1 | INTRODUCTION

The United States is experiencing a shortage of physicians that has been exacerbated by the COVID-19 pandemic, and the shortage is expected to grow primarily due to population growth and aging (IHS Market Ltd, 2021). Pivoting specifically to the provision of eye health and vision care, the availability of ophthalmologists is trending downwards despite a growing demand for eye care (U.S. Department of Health and Human Services, 2016). Due to eye problems emerging with age, older people need eye care much more frequently than the young. For example, approximately half of Americans have cataracts by age 75 (American Academy of Ophthalmology, 2021). However, the number of ophthalmologists dropped from 6.30 per 100,000 individuals in 1995 to 5.68 in 2017 (Feng et al., 2020).[1] Given the limited accessibility to ophthalmologists, it has been suggested to leverage optometrists who have complementary skills for eye care (Feng et al., 2020; Gibson, 2015).

Indeed, the role of optometrists in eye care has substantially expanded over the past several decades. In the early twentieth century, optometrists were strictly eye examiners with no permission for medical eye care. Beginning in the 1970s, optometrists have gradually obtained the authority to prescribe medications. This scope of practice expansion has allowed optometrists to diagnose and treat patients with eye diseases or disorders without referrals to ophthalmologists. This means that upon the receipt of prescription authority, optometrists started transforming from "refractionists" to

Abbreviations: ACS, American Community Survey; ATE, average treatment effect; DID, difference-in-differences; DPA, diagnostic pharmaceutical agents; SIPP, survey of income and program participation; TPA, therapeutic pharmaceutical agents; TWFE, two-way fixed effects.

"eye doctors." From the perspective of patients, the policy effectively added optometrists with proper training to the body of primary eye care providers. The federal government added to the momentum by classifying optometrists as medical doctors for Medicare reimbursement since 1986.[2] With their extended role in primary eye care, the number of optometrists increased from 11.06 per 100,000 individuals in 1990 to 16.11 in 2017 (Feng et al., 2020). In the healthcare sector and even in the labor market as a whole, it is a remarkable and unprecedented change in the role of a particular occupation. Moreover, the emergence of new "eye doctors" coincides with a noticeable decline in visual impairment in the U.S. between 1984 and 2010 (Tanna & Kaye, 2012). Despite this, little attention has been paid to the impact of optometrist scope of practice expansion in the existing literature.

In this paper, we examine the effects of optometrist prescription authority on public eye health and optometrist earnings. States have introduced and expanded optometrist prescription authority in multiple phases. First, optometrists were allowed to use medications only for diagnostic purposes—diagnostic pharmaceutical agent (DPA) prescription authority. After that, states passed laws on therapeutic pharmaceutical agent (TPA) prescription authority that allow medications for treatment purposes. In addition, the scope of permissible TPA broadened with amplification laws. This study focuses on the effects of TPA prescription authority as a significant expansion of access to medical eye care. The policy is expected to have improved public eye health, given a potential positive association between eye care access and health outcomes (Wang et al., 2022).

This study is crucial for advancing our understanding of optometrist scope of practice expansion given the scarcity of existing literature. There are a few studies on optometrist laser surgery authority, but it is a more recent policy change in only a handful of states (Mahr & Erie, 2017; Stein et al., 2016, 2018). These studies have found that laser surgical authority did not improve access to and quality of eye care. However, we could not find any study on the effect of optometrist prescription authority, which is the backbone of optometrist scope of practice expansion so far. Our study fills the gap and demonstrates that optometrist prescription authority did not reduce, but may have improved population eye health.

Moreover, the study adds an interesting case to the literature on occupational licensing and scope of practice regulations. Several studies have documented that scope of practice regulations affect labor market outcomes like earnings.[3] For example, Kleiner et al. (2016) finds that nurse practitioner scope of practice expansion raised nurse practitioner wages but reduced physician wages. Also, a growing number of studies have shown that broadening scope of practice improves access to care without a discernible compromise in care quality.[4] Two recent studies, Traczynski and Udalova (2018) and Alexander and Schnell (2019), have found evidence of improvements in health outcomes after the scope of practice expansion of nurse practitioners. Similarly, we provide some evidence on a positive effect of optometrist scope of practice expansion on public eye health and optometrist earnings.[5]

To identify the effect of optometrist TPA prescription authority, we take advantage of staggered adoption of the policy across states over time. In the analysis of population eye health, using a difference-in-differences (DID) event-study design, we estimate dynamic treatment effects on vision impairment since the passage of glaucoma TPA laws as a proxy for optometrist TPA prescription authority. In the analysis of optometrist earnings, we use a two-way fixed effects (TWFE) OLS estimation to quantify association between TPA laws and optometrist hourly wages. These methods help isolate the effects of the state-level policy from the effects of contemporary changes in eye care demand and supply at the national level.[6]

We use data from three different sources. First, we employ information on state legislation on optometrist TPA prescription authority complied by Cooper (2012). Next, we utilize the 1984 to 2008 Survey of Income and Program Participation (SIPP) for the analysis of population eye health. Lastly, we use the 1980 to 2000 decennial Census and the 2001 to 2010 American Community Survey (ACS) for the analysis of optometrist earnings.

Our estimates provide some evidence that granting optometrists TPA prescription authority improved both population eye health outcomes and optometrist earnings. Vision impairment declined by 12% on average over a 15-year period after the policy change. The effect was not instant but emerged 6 years after the policy change. Moreover, the policy brought a larger decline in vision impairment among the non-White population, who might have more limited access to medical care, than Whites. Also, TPA prescription authority is associated with about a 13% increase in hourly wages among optometrists who are not self-employed. These estimates are broadly robust to changes in sample, model specification, and estimation method.

These findings imply that allowing optometrists to practice to the full extent of their training might encourage them to provide higher valued-added services and subsequently improve public eye health. For example, treating eye diseases like glaucoma is a higher value-added service than writing a prescription for eyeglasses or contact lenses. As states allowed optometrists to use medications, particularly for treatment purpose, optometrists with proper training became able to treat patients without sending them to ophthalmologists.[7] The appearance of eye treating optometrists might increase access to medical eye care, thereby improving public eye health.[8] Their increased earnings may be attributable to optometrists who started to provide medical eye care services after the policy change.[9]

2 | OPTOMETRIST SCOPE OF PRACTICE

2.1 | Evolution of optometrist scope of practice

The eye care industry specializes in safeguarding ocular health and the correction of eye problems that can impact vision capacity. The global eye care market size was $125.16 billion in 2018 and is expected to reach $192.85 billion by 2026, as per Vision Care Market 2020.[10] In the eye care industry, ophthalmologists and optometrists provide primary eye care that consists of diagnosing and treating eye diseases or disorders.[11] Primary eye care is supported by other eye care professionals such as ophthalmic registered nurses, ophthalmic medical assistants, and ophthalmic photographers.[12] In addition, opticians manufacture or sell corrective eyeglasses or contact lenses. According to Feng et al. (2020), there are 18,512 ophthalmologists and 52,625 optometrists in 2017.

Optometrists were not allowed to diagnose or treat eye diseases or disorders until the 1970s. Before that time, ophthalmologists essentially had a monopoly in the market for primary eye care services—having unique authority to diagnose and treat eye diseases or disorders, in addition to providing prescriptions for eyeglasses and contact lenses. Conversely, optometrists focused on vision correction areas through general eye examinations that often lead to prescriptions for eyeglasses or contact lenses.[13] Since the 1970s, however, the role of optometrists has gradually expanded to include the practices previously reserved for ophthalmologists.[14] This crucial change in eye care provision coincides with growing demand for ophthalmic services due to population aging and advancements in eye care technologies. To address the excess demand for eye care at an affordable cost, states have expanded optometrist scope of practice by allowing optometrists to use medications and perform surgical procedures.[15]

Optometrist scope of practice expansion in prescription authority mostly occurred from the 1970s–1990s.[16] States initially enacted DPA laws that authorized optometrists to use medications for diagnostic purposes. Rhode Island enacted the first DPA law in 1971 and Maryland was the final state to enact this change in 1989. With the DPA prescription authority, optometrists can utilize drugs to facilitate eye examinations. The next wave of optometrist scope of practice expansion established TPA laws that allowed optometrists to use medications for treatment purposes. West Virginia and North Carolina, early adopters of this legislation, introduced the DPA and TPA law together in 1976 and 1977, respectively. Other states first enacted TPA laws in the 1980s and the 1990s—several years after enacting DPA laws. The District of Columbia was the last jurisdictions to enact TPA legislation in 1998. Table 1 shows when each state passed the first TPA legislation, and Figure 1 provides a color-coded map on the timing of the first TPA law enactment by three groups of states: those allowed TPA in the 1970s, 1980s, and 1990s. As shown in Figure 1, states in the Midwest expanded optometrist scope of practice earlier than states in New England, the Mid-Atlantic, and Pacific regions.

After the establishment of the first TPA law, optometrists were authorized to use prescription drugs to treat eye diseases or disorders, meaning that they can treat patients with certain eye problems without referring them to ophthalmologists.[17] But their eligibility to use other types of drugs such as drugs for glaucoma treatment, oral drugs, controlled substances, or injectable drugs differs across states. Four states (AL, NC, UT, WI) were exceptional and granted optometrists full TPA prescription authority immediately upon the passage of TPA law. Thereafter, states have broadened TPA prescription authority beyond prescription drugs through amplification laws. For example, 24 states allowed the use of drugs for glaucoma treatments in amplification laws while 26 states and DC did so in the first TPA law. Table 1 shows when each state passed amplification laws. However, these is no common sequence of TPA amplifications by states. Figure 2 shows the number of states, cumulatively, that have allowed optometrists to prescribe each type of drugs for treatment purposes. The figure reveals that states tend to have amplified the TPA prescription authority from prescription drugs to drugs for glaucoma treatment to controlled substances. As a result of a continuation of the scope of practice expansion, optometrists today can use prescription drugs and drugs for glaucoma treatment in all jurisdictions and oral drugs, controlled substances, and injectables in more than two-thirds of all states and jurisdictions.

TABLE 1 State legislation on optometrist TPA prescription authority.

State	First TPA	Glaucoma	Orals	Controlled substances	Injectables
Alabama	1995	1995	1995	1995	1995
Alaska	1992	1992	2007	2007	2007
Arizona	1993	1993	1999	1999	1999
Arkansas	1987	1987	1997	1997	1997
California	1996	2000	1996	2000	2000
Colorado	1988	1996	1988	1988	2011
Connecticut	1992	1996	1992	1996	1996
Delaware	1994	1994	1994		
D.C.	1998	1998	1998		1998
Florida	1986	1986			
Georgia	1988	1994	1994	1994	
Hawaii	1996	1996	2004		2004
Idaho	1987	1993	1993	1993	1993
Illinois	1995	1995	1995	2007	2007
Indiana	1991	1991	1991		
Iowa	1985	1987	1985	1987	2002
Kansas	1987	1996	1999	1999	
Kentucky	1986	1986	1996	1996	1996
Louisiana	1993	1993	1993	2005	1993
Maine	1987	1996	1996	1996	1995
Maryland	1995	1995	1995		1995
Massachusetts	1997				
Michigan	1994	1997	2002	2002	
Minnesota	1993	1993	2003	2003	2003
Mississippi	1994	1994	2005	2005	2005
Missouri	1986	1995	1986	1986	
Montana	1987	1999	1987	1987	1999
Nebraska	1986	1998	1993	1993	
Nevada	1995	1999	1995	1999	
New Hampshire	1993	2002	1993	1993	1993
New Jersey	1992	1992	2004	2004	1992
New Mexico	1985	1985	1995	1995	2007
New York	1995	1995			
North Carolina	1977	1977	1977	1977	1977
North Dakota	1987	1997	1987	1997	1987
Ohio	1992	1992	1992	2007	2007
Oklahoma	1984	1984	1994	1994	1994
Oregon	1991	1991	2001	2001	2001

TABLE 1 (Continued)

State	First TPA	Glaucoma	Orals	Controlled substances	Injectables
Pennsylvania	1996	2002	1996	1996	
Rhode Island	1985	1997	2008	2008	
South Carolina	1993	1993	1993	1993	
South Dakota	1986	1994	1991	1991	
Tennessee	1987	1993	1993	1993	1993
Texas	1991	1999	1999	1999	1999
Utah	1991	1991	1991	1991	1991
Vermont	1994	2004	2004	2004	2004
Virginia	1988	1996	1996	1996	1996
Washington	1989	1989	2003	2003	2003
West Virginia	1976	1976	1997	1997	2010
Wisconsin	1989	1989	1989	1989	1989
Wyoming	1987	1987	1995	1995	

Source: Table 3. The Date Legislation Was First Enacted Authorizing The Prescription Of Drugs, Glaucoma Drugs, Oral Drugs, Controlled Narcotic Substances, Or Use Of Injectable Agent. As of Feb. 23, 2012. Cooper (2012).

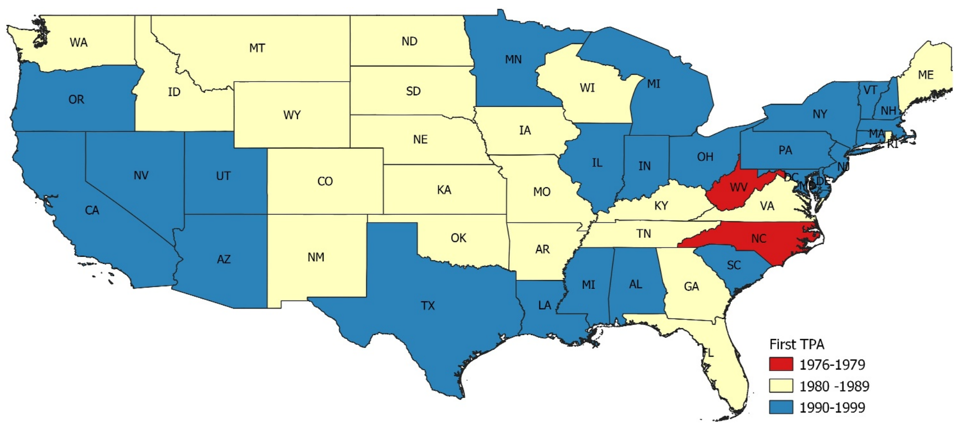

FIGURE 1 Optometrist TPA Prescription Authority: 1976–1999. The figure is based on state legislations on optometrist prescription authority complied by Cooper (2012). TPA, therapeutic pharmaceutical agent.

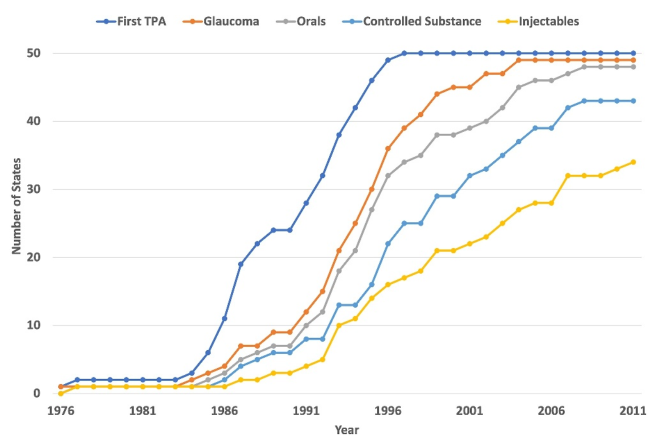

FIGURE 2 Trends in optometrist TPA prescription authority expansion: 1976–2011. The figure is based on state legislations on optometrist prescription authority complied by Cooper (2012).

2.2 | Relevant literature

In the area of optometry, little research exists on the effects of scope of practice expansion over the past several decades. Exceptions are a few studies on optometrist laser surgery authority, which were allowed in Oklahoma in 1998 and later by a few other states. Mahr and Erie (2017) showed that there was no difference in access to laser capsulotomy in Oklahoma, measured by driving distance or time, between Medicare beneficiaries' who received the procedure from an optometrist and those who did from an ophthalmologist. Similarly, Stein et al. (2018) documented that about a half of Medicare beneficiaries who received surgical care from optometrists lived within a 30-min travel distance from the nearest ophthalmologist office. Also, Stein et al. (2016) examined a clinical outcome of laser trabeculoplasty and found that ophthalmologists were less likely to repeat the same procedure than optometrists.[18] These studies imply limited improvements in the geographic proximity to and quality of eye care from optometrist scope of practice expansion to laser surgical procedures. We complement the studies by analyzing the effects of optometrist prescription authority and demonstrating an improvement in public eye health after the policy.

Two other studies on optometrist prescription of contact lens are also relevant to our study. Norris and Timmons (2020) examined the impact of the 2004 Fairness to Contact Lens Consumers Act that required contract lens prescribers, including optometrists, to release contact lens prescriptions to opticians. They found that the legislation effectively reduced the monopolistic power of optometrists with respect to selling contact lenses and subsequently their earnings. Cooper J. C. (2012) showed that the same legislation did not have a systematic effect on pricing in the contact lens market. By comparison, optometrist TPA laws opened up a new business opportunity of medical eye care for optometrists, which might have different implications on optometrist earnings.

Outside of the optometrist market specifically, there are a growing number of papers that explore the effects of scope of practice changes. Several studies have documented that scope of practice expansion has a positive earnings effect on the profession with the expansion, but a negative earnings effect on competing professions (Kleiner, 2016). Perry (2009) found that greater practice authority for nurse practitioners raised their own earnings and reduced physicians' earnings, and that greater practice authority for physician assistants lowered nurse practitioners' earnings. Similarly, Kleiner et al. (2016) showed that independent prescription authority for nurse practitioners raised their wages by 5% but reduced physician wages by 3%. Cai and Kleiner (2020) found that allowing physical therapists to access patients without physician referral reduced earnings of occupational therapists. Timmons et al. (2016) documented that favorable scope of practice for chiropractors raised their wages by 7–8%. In dentistry, Goldsmith (1989) found that as dental hygienists experience less autonomy from dentists, their incomes subsequently decrease. A related paper by Kleiner and Won Park (2010) also showed that allowing dental hygienists to be self-employed raised their wages by 10%. But not all studies have found the positive earnings effect of a scope of practice expansion. Dueker et al. (2005) found that advanced practice registered nurses (APRN) wages were 21 percent lower in states with full prescriptive authority. Nichols and Case-Smith (1996) found that as physical therapists gained greater professional independence from physicians that they experienced a reduction in earnings. Aligned with the former group of literature, we find positive earnings effects of optometrist scope of practice expansion with prescription authority.

Furthermore, several studies have reported that expanding scope of practice leads to improved access to care, particularly among rural and underserved populations, without decreasing care quality.[19] For example, nurse practitioners' independent practice increased visits to doctor's office (Stange, 2014), the number of prescriptions in community health centers or retail clinics (Kurtzman et al., 2017; Spetz et al., 2013), and the frequency of routine checkups (Traczynski & Udalova, 2018). Conversely, their restricted scope of practice turned out not to improve the quality of primary care, such as chronic disease management and cancer screening (Perloff et al., 2019) and infant mortality rates (Kleiner et al., 2016). Similarly, independent practice of certified nurse midwives did not reduce maternal and infant health outcomes (Hoehn-Velasco et al., 2021; Markowitz et al., 2017; Yang et al., 2016), and independent practice of certified registered nurse anesthetists did not increase surgical inpatient mortality rates or complication rates from anesthesia (Dulisse & Cromwell, 2010). There is even some evidence on the improvement in health outcomes after the scope of practice expansion: nurse practitioner independent practice improved people's self-reported health status (Traczynski & Udalova, 2018), parental evaluation of child health (Bhai & Mitchell, 2022), and mental health outcomes (Alexander & Schnell, 2019). Allowances for psychologist prescription authority have also been found to reduce suicide rates (Choudhury & Plemmons, 2021). In addition, there is some evidence that restrictions on nurse practitioner practice caused an increase in service prices (Kleiner et al., 2016), and that broader physician assistant prescription privileges lowered the cost of outpatient claims per Medicaid beneficiary (Timmons, 2017). To the literature, we add a new piece of evidence on positive health effects of optometrist scope of practice expansion with prescription authority.

3 | DATA AND EMPIRICAL METHOD

3.1 | Measures of the scope of practice

Our goal is estimating a causal effect of allowing optometrists to prescribe medications. An apparent challenge to the analysis is a complex evolution of optometrist prescription authority: it was not a one-shot policy change but a gradual expansion with multiple phases that were not common across states, as detailed in the previous section. To address the issue, we simplify the dimensions of policy variation in optometrist prescription authority.

Between diagnostic pharmaceutical agents (DPA) and therapeutic pharmaceutical agents (TPA), we focus on TPA prescription authority as a significant expansion of access to medical eye care. Even though DPA prescription authority is important as a prerequisite for the subsequent TPA prescription authority, it alone is not likely to have a meaningful effect on the services provided by optometrists. Without TPA prescription authority, optometrists can diagnose patients with eye diseases or disorders, but are not permitted to treat patients. Conversely, if optometrists were allowed to use medications for both diagnosing and treating patients, they could more effectively provide primary eye care.[20]

For data on the timing of TPA prescription authority, we use legislative research complied by Cooper (2012). As shown in Table 1, Cooper's data provides detailed information on the introduction and expansion of optometrist TPA prescription authority as of February 23, 2012. It breaks down TPA into five categories and specifies the timing of legislative changes relevant to each category.

Given the five phases of TPA prescription authority expansions, we further simplify our measure of optometrist scope of practice expansion. In the analysis of population eye health outcomes, we use the policy of allowing optometrist to use glaucoma medications as a proxy for optometrist TPA prescription authority. This simplification of policy variation allows us to harness an event-study design with arbitrary heterogeneity in treatment effects. The analysis is expected to identify a lower bound of the effect of overall TPA prescription authority because allowing glaucoma medications is a part of the reform. In the analysis of optometrist labor market outcomes, the same approach is not possible due to limitations of data, and we use policy variations in three phases of TPA prescription authority expansion. Specifically, we define three treatment variables: the first TPA law, TPA law allowing glaucoma medications, and TPA law allowing controlled substances. We do not separately consider TPA laws allowing oral or injectable medications because these medications were mostly allowed with controlled substances, as shown in Table 1.

3.2 | Population eye health outcomes

To analyze the effect of optometrist TPA prescription authority expansion on population eye health outcomes, we use 1984 to 2008 Survey of Income and Program Participation (SIPP) panels obtained from the NBER and CEPR websites (Center for Economic and Policy Research, 2014; National Bureau of Economic Research, 2020). The SIPP is a household survey with a short panel on a variety of topics. Each of the 1984 to 2008 panels ran 2–5 years with 6–16 waves of data collection every four months from four rotation groups that are surveyed in non-overlapping calendar months. The SIPP collects individual-level data on vision impairment at most twice in each panel as a part of a topical module on functional limitations and disability. We compile vision impairment and demographic data in SIPP 1984 Wave 3, 1988 Wave 6, 1990 Waves 3 and 6, 1991 Wave 3, 1992 Waves 6 and 9, 1993 Waves 3 and 6, 1996 Waves 5 and 11, 2001 Waves 5 and 8, 2004 Wave 5, and 2008 Wave 6.[21] We use the individual-level data as a pooled cross-section but not as a collection of panels because panel data on vision impairment are only available for 1992, 1993, 1996, and 2001 panels, and each panel is too short (at most bi-annual in the 1996 panel) for the study of staggered policy adoptions.

We define population eye health outcome measurements based on two questions on vision impairment in the survey. The first question is "Does [the person] have (any) difficulty seeing words and letters in ordinary newspaper print even when wearing glasses or contact lenses if [the person] usually wears them?" The word "any" was removed from surveys conducted in calendar year 1994 or later. The question had been a Yes-or-No question, but it gave three options, Yes, No, or Blind, from calendar year 1997 on. To respondents chose "Yes" to the first question regardless of the survey year, the second question followed: "Is [the person] able to do this at all?" in 1984 to 1988 panels or "Is [the person] able to see the words and letters in ordinary newsprint at all?" in 1990 to 2010 panels. In all panels, it is a Yes-or-No choice. We define a person's vision is impaired if the person chose "Yes" or "Blind" to the first question. Then, we categorize the blind and those who chose "No" to the second question as people with "no vision". People with "some vision" are those who answered "Yes" to the second question.[22]

We study the sample of individuals aged 15 or above, who are in the universe of SIPP questions on functional limitations and disability throughout the sample period. Among 50 states and DC, observations in 12 states (AK, IA, ID, ME, MS, MT, ND, NM, SD, VT, WY, WV) that are not consistently identifiable in the SIPP are excluded from the sample. As a result, our study sample contains 646,135 observations in 35 states and the District of Columbia (DC) surveyed in 12 calendar years spanning from 1984 to 2010.

In the sample, 4.4% of individuals reported vision impairment, as shown in column (1) in Table 2. Columns (2) to (4) show that the proportion of people with difficulty in seeing gradually declined from 6.65% in the 1980s to 4.57% in the 1990s to 3.59% in the 2000s. The change is mostly due to a decline in people with some vision. The proportion of people with no vision stayed around 0.85% and is little changed over time. Figure 3 details the declining trend by three groups of states based on the timing of their first TPA law enactment. All three groups show gradually declines in the share of people with vision impairment. North Carolina, the first state allowing optometrist TPA prescription authority in the

TABLE 2 Descriptive statistics on population: Eye health outcome.

Variable	(1) All	(2) 1984–1989	(3) 1990–1999	(4) 2000–2010
Vision impairment	0.0440	0.0665	0.0457	0.0359
Some vision	0.0354	0.0580	0.0369	0.0273
No vision	0.0087	0.0085	0.0088	0.0086
Age	43.5	42.0	43.0	44.8
	(18.5)	(18.4)	(18.3)	(18.6)
Female	0.531	0.530	0.533	0.529
Black	0.109	0.096	0.103	0.121
Hispanic	0.098	0.063	0.095	0.112
Other race and ethnicity	0.045	0.027	0.038	0.060
First TPA law	0.734	0.137	0.658	1.000
TPA on glaucoma	0.606	0.091	0.451	0.974
TPA on controlled substances	0.385	0.052	0.228	0.711
Observations	646,135	58,051	356,496	231,588

Note: Unweighted means. Standard deviations are in parentheses. The sample consists of individuals aged 15 or above in 38 states and DC that are consistently identifiable in 1984 to 2008 SIPP panels.

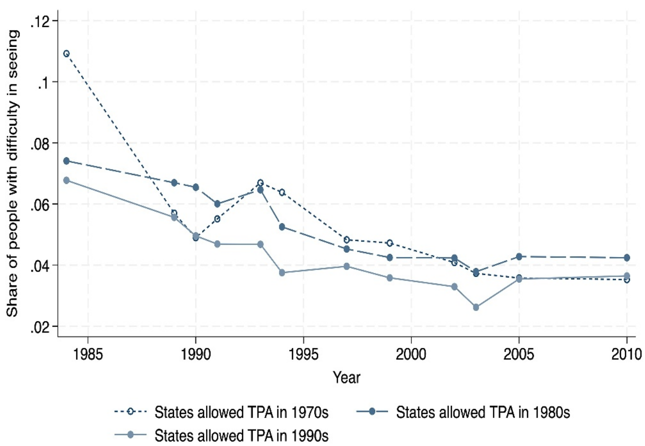

FIGURE 3 Trend in population eye health outcome: 1984–2010. The figure is based on population aged 15 or above in 38 states and DC that are consistently identifiable in the SIPP 1984 to 2008 panels.

1970s, saw a sharp reduction in vision impairment in the 1980s. In the second group of states that passed their first TPA laws in the 1980s, vision impairment on average increased relative to other groups in the 1980s and early 1990s, but subsequently improved in the mid- and late 1990s. The third group of states that allowed optometrist TPA prescription authority in the 1990s saw relative declines in vision impairment in the early 1990s and early 2000s. These patterns indicate that there might be a time lag between the scope of practice expansion and improvements in the eye health outcome.

3.3 | Labor market outcomes

To examine how optometrist TPA prescription authority affects optometrist hourly wages, we use decennial Census data from 1980 to 2000 and American Community Survey (ACS) data from 2001 to 2010 obtained from the IPUMS USA website (Ruggles et al., 2021).[23] The 1980 Census is the first decennial Census with information on usual working hours a week—an essential variable necessary for the computation of hourly wages.

We study the sample of 2387 optometrists at age 18–64 who are full-time, full-year workers with wage and salary income. In this study, full-time workers are defined as workers who usually work no less than 35 h a week and full-year workers worked no less than 50 weeks in the previous year of the survey. The sample does not have optometrists in two states (AK, ME). Our analysis also examines the policy's effect on workers who are not self-employed, whose wage and salary income may better reflect the market value of optometric services than that of self-employed optometrists. Self-employed workers tend to underreport their income by about 25% in U.S. household surveys, and the share of underreported income varies over time (Hurst et al., 2014).[24]

In the sample, optometrist hourly wages are on average $54.53 (in 2019 dollars), as shown in column (1) in Table 3. About a half of them are self-employed workers with wage and salary income throughout the sample period.[25] Females (23.8%), blacks (1.3%), and Hispanics (2.4%) are underrepresented in the optometrist population, while those who obtained postgraduate education (96.1%) are overrepresented. Columns (2)–(5) show that optometrist hourly wages

TABLE 3 Descriptive statistics on optometrists: Labor market outcome.

Variable	(1) All	(2) 1980 census	(3) 1990 census	(4) 2000 census	(5) 2001–2010 ACS
Hourly wages ($2019)	54.53	48.84	50.98	57.18	55.72
	(36.96)	(29.62)	(32.84)	(40.50)	(37.86)
Self-employed	0.491	0.498	0.437	0.479	0.511
Age	42.1	41.9	39.4	41.2	43.3
	(10.1)	(12.2)	(9.9)	(9.2)	(9.8)
Female	0.238	0.117	0.143	0.232	0.293
Black	0.013	0.000	0.010	0.010	0.018
Hispanic	0.024	0.020	0.023	0.016	0.028
No college education	0.014	0.089	0.008	0.000	0.006
Some college education	0.007	0.052	0.005	0.000	0.002
4-year college education	0.018	0.113	0.038	0.000	0.001
Postgraduate education	0.961	0.746	0.949	1.000	0.991
First TPA	0.783	0.012	0.299	1.000	1.000
TPA on glaucoma	0.703	0.012	0.151	0.802	0.973
TPA on controlled substances	0.488	0.008	0.102	0.408	0.735
Observations	2387	248	391	495	1253

Note: Unweighted means. Standard deviations are in parentheses. The sample consists of full-time, full-year optometrists with wage and salary income at age 18–64 in 48 states (except Alaska and Maine) and the District of Columbia in 1980 to 2000 decennial Censuses and 2001 to 2010 American Community Surveys.

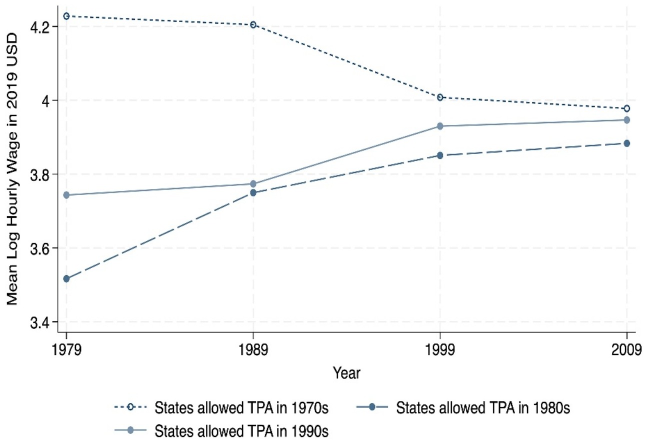

FIGURE 4 Trend in optometrist hourly wages: 1979–2010. The figure is based on optometrists in 25 states that have at least one full-time, full-year, non-self-employed optometrist in each decade (1980, 1990, 2000 Census and ACS 2001–2010). Considering the reference year of wage variables in the Census, data points are located on 1979 for the 1980 Census, 1989 for the 1990 Census, and 1999 for the 2000 Census. The average of the ACS 2001–2010 data is located on 2009 for presentation purposes.

trended up from $48.84 in the 1980 Census to $55.72 in the 2001–2010 ACS. Their hourly wages substantially increased between the 1990 and 2000 Census, when the fraction of optometrists with TPA prescription authority also substantially increased. The shares of female and black optometrists gradually increased over time, and optometrists without postgraduate education almost disappeared by the 2000 Census.[26]

Figure 4 shows trends in hourly wages of optometrists by three groups of states: states that enacted the first TPA law in the 1970s, the 1980s, and then the 1990s. The first group includes NC only, which allowed full TPA prescription authority in 1977. This may explain why NC's trend line starts at its highest point in 1979. When the second group of states allowed the TPA prescription authority in the 1980s for the first time, the group's average log hourly wages noticeably increased more than the other two groups. Similarly, when the third group of states enacted the first TPA law in the 1990s, the group's outcome increased absolutely and relatively to the other two groups.

3.4 | Empirical methodology

We use the staggered adoption of optometrist TPA prescription authority by states to identify the policy's effect on health and labor market outcomes. In the analysis of the population eye health outcome, we use a difference-in-differences (DID) event-study design with the staggered adoption of the glaucoma TPA law. Our analysis focuses on estimating the average treatment effects (ATEs) on vision impairment by relative periods since the passage of the glaucoma TPA law. Estimating the time path of treatment effects is particularly relevant for our study based on a medical consensus that eye diseases or disorders progress slowly with aging (Centers for Disease Control and Prevention, 2021) and that medical studies usually track patients with glaucoma treatments years after treatment to measure the effect on vision loss or blindness (Susanna et al., 2015). A limitation of the event-study on the glaucoma TPA law is that it is likely to estimate the combined effect of glaucoma TPA and other phases of TPA prescription authority that were allowed at the same time or in the following years. For example, some states allowed glaucoma TPA and controlled substances TPA at the same time. Due to this limitation, we suggest an interpretation of our estimate as a lower bound effect estimate of overall TPA prescription authority rather than the effect of glaucoma TPA prescription authority alone. Also, as a robustness check, we compare the event-study result on glaucoma TPA law with those on other four phases of TPA law.

In the event-study design, we do not impose any restriction on treatment effect heterogeneity. For example, treatment effects can change over time, and the time path of treatment effects can vary across states. A body of recent literature demonstrated that OLS estimation in two-way fixed effects (TWFE) models may fail to produce meaningful treatment effect estimates (Borusyak et al., 2022; de Chaisemartin and D'Haultfoeuille, 2020; Goodman-Bacon, 2021; Imai & Kim, 2021). To address the issue, studies also proposed alternative methods of estimation and inference (Borusyak et al., 2022; Callaway & Sant'Anna, 2021; de Chaisemartin and D'Haultfoeuille, 2022; Gardner, 2021; Sun & Abraham, 2021).

For estimation and inference, we adopt Gardner's two-stage difference-in-differences method (Gardner, 2021). It is the most applicable to our study among several alternative methods.[27] To identify causal effects, we impose two standard assumptions on our event-study design. First, the parallel trends assumption requires that potential untreated outcomes have common time trends across states. Next, the no anticipation assumption requires that the policy only affects post-treatment observations but not pre-treatment observations. Under the assumptions, we use untreated outcomes observed in pre-treatment periods to construct counterfactual untreated outcomes for treated observations in post-treatment periods. This idea of estimation under heterogeneous treatment effects is implementable through a two-stage estimation procedure proposed by Gardner or also an imputation-based estimation procedure by Borusyak et al. (2022). We adopt Gardner's method for the sake of computational efficiency given that both methods produce the same dynamic treatment effect estimates.[28]

Our two-stage procedure is as follows: the first stage estimates state and year fixed effects and coefficients on covariates only with untreated observations in the regression model

$$Y_{ist} = \alpha_s + \lambda_t + \gamma X_{ist} + \epsilon_{ist}$$

where i indexes an individual, s indexes a state, t indexes a year, Y_{ist} is an outcome, α_s is state fixed effects, λ_t is year fixed effects, X_{ist} is individual or state characteristics, and ϵ_{ist} is an error term. The second stage regresses the adjusted outcome $(Y_{ist} - \widehat{\alpha}_s - \widehat{\lambda}_t - \widehat{\gamma} X_{it})$ on a set of dummies indicating relative periods since the treatment of glaucoma TPA laws. Regression coefficients on the dummies identify dynamic treatment effects. Statistical inferences are based on standard error estimates clustered by states. All of these procedures are implemented with individual-level data and the Stata package *did2s* written by Butts (2022). The outcome variable is a binary indicator on vision impairment. Individual characteristics include age, age squared, female dummy, black dummy, Hispanic dummy, and an "other race and ethnicity" dummy. We do not control for education in the model of eye health due to a potential endogeneity issue—difficulty in seeing may lower educational attainment.[29]

For a robustness check, we compare our baseline estimates with OLS estimates under the assumption of treatment effect homogeneity in TWFE event-study model:

$$Y_{ist} = \alpha_s + \lambda_t + \sum_h \tau_h 1[t - E_s = h] + \gamma X_{ist} + \epsilon_{ist}$$

where $1[\cdot]$ is an indicator function, E_s is the year when state s is first treated, and h is the number of years before or after the treatment. If the time path of treatment effects is common across states, the OLS estimates of τ_h for each relative period would be valid as dynamic treatment effect estimates. Otherwise, the OLS estimates will be biased and systematically different from our baseline estimates.

In our analysis of optometrist labor market outcomes, due to the small sample size with observations in mixed frequency, dynamic models of treatment effects are not applicable. Instead, we use the following static TWFE regression model under treatment effect homogeneity:

$$Y_{ist} = \alpha_s + \lambda_t + \beta D_{st} + \gamma X_{ist} + \epsilon_{ist}$$

where i indexes an individual, s indexes a state, t indexes a year, Y_{ist} is an outcome, α_s is state fixed effects, λ_t is year fixed effects, D_{st} is policy dummies, X_{it} is individual characteristics, and ϵ_{ist} is an error term. Our outcome variable is the log of hourly wages. The model includes three policy dummy variables, varying across state-by-year cells: the first TPA law, TPA law allowing glaucoma medications, and TPA law allowing controlled substances. Each policy dummy has a value of 1 for a state-by-year cell if the state allowed the particular type of TPA by the year, and a value of 0 otherwise. The coefficient vector β measures the effect of each phase of TPA laws on the outcome after accounting for the other phases of TPA laws.[30] We are primarily interested in the sum of the individual coefficients in β as an estimate of the overall effect of the TPA law. The model also includes state fixed effects, year fixed effects, and individual characteristics. For estimations on optometrist hourly wages, we account for the following individual characteristics: age, age squared, female dummy, black dummy, Hispanic dummy, and educational attainment dummies (individuals without college education, those with some college education, and those with 4-years of college education).

4 | RESULTS

4.1 | Scope of practice and population eye health outcome

We found that allowing optometrists to prescribe medications for treating patients did not have an instant effect on vision impairment but improved it with a time lag of several years. Figure 5 shows event-study estimates on the treatment effect of optometrist TPA prescription authority on vision impairment for 15 years since the event. Under unconditional parallel trends, Panel A shows that treatment effects are close to zero for 1–5 years since the policy change and evolve to be negative for later years. Particularly, point estimates for 8–14 years are consistently negative and some of them are statistically significant at the 5% level. The pattern holds for our baseline estimates in Panel B under conditional parallel trends. In both panels, placebo estimates for 5 years before the event indicate no noticeable differences in pre-treatment outcomes between the treated and untreated.[31]

Our event-study estimates are noisy partly due to compositional changes in treatment and control states. First, event-study estimates with a longer lag are generally identified with a smaller number of treatment and control states. As an extreme case, the treatment effect with a 14-year time lag is estimated with 10 treatment states and a single control state, Massachusetts, which is never-treated during the sample period. Next, given uneven yearly data on our vision impairment outcome, each event-study estimate is identifiable with a subset of treatment states whose outcome are observed with the exact time lag only. For example, Pennsylvania that was treated in 2002, contributes for the

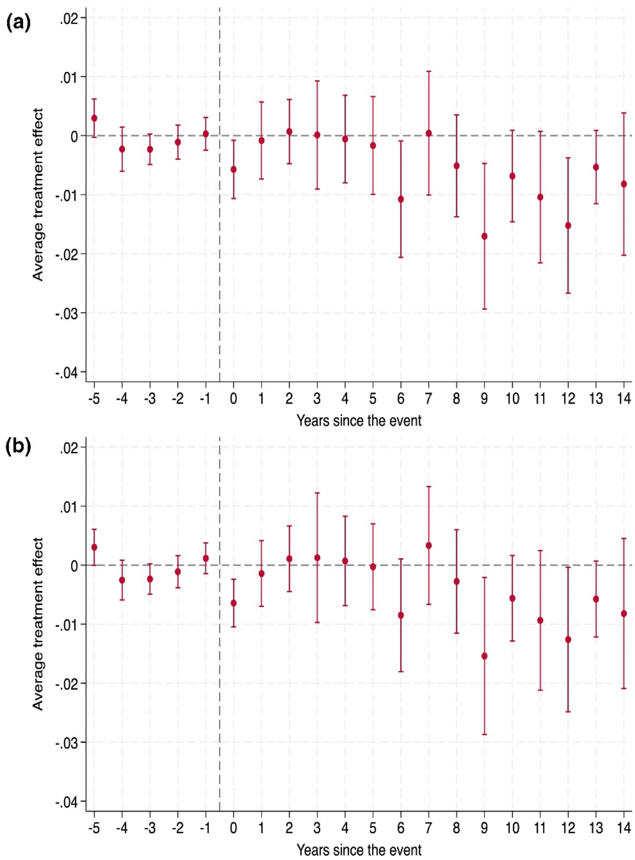

FIGURE 5 Optometrist TPA prescription authority dynamic treatment effects on vision impairment. Panel (a) Without Covariates under Unconditional Parallel Trends. Panel (b) With Covariates under Conditional Parallel Trends. Event-study point estimates and their 95% confidence intervals based on Gardner (2021)'s two-stage estimation and standard errors clustered by states. Outcome is a binary indicator of whether a person has difficulty in seeing. Treatment is whether an individual resides in a state that allows optometrists to prescribe glaucoma medications. The sample consists of individuals aged 15 or above in 38 states and DC that are consistently identifiable in SIPP panels. Two states, North Carolina and Oklahoma, that are always treated in the sample period are excluded from the estimation. Estimates in Panel A are obtained from a model without covariates under the assumption of unconditional parallel trends, while those in Panel B are from a model with covariates under the assumption of conditional parallel trends. The model with covariates include age, age squared, female, black, Hispanic, and other race and ethnicity dummy. Estimates for years before the event are placebo estimates.

identification of event-study estimates with a lag of 0, 1, 3, and 8 years, respectively, but not for estimates with other time lags. These two factors seem relevant to volatile changes in consecutive event-study estimates and wide confidence intervals for long-lagged effect estimates in Figure 5 Panels A and B.

In spite of these limitations, our point estimates of the treatment effect with a lag of 8 or more years are surprisingly consistent with a negative sign. For a causal interpretation of this lagged effect, parallel trends between a never-treated state, Massachusetts, and other states are crucial. Our finding of lagged treatment effects on vision impairment is in line with the fact that common eye diseases and disorders progress slowly (Centers for Disease Control and Prevention, 2021), and that medical studies usually track patients with glaucoma treatments years after treatment to measure the effect on vision loss or blindness (Susanna et al., 2015). For this reason, states might not see an instant decline in vision impairment upon the passage of optometrist TPA prescription authority. However, they might observe the outcome changed years after the policy change when patients treated by optometrists maintain good vision while those who had no access to optometrists for medical eye care experience vision impairment.

Table 4 presents aggregated treatment effect estimates by five-year bins and for 15 years since the event. The first row shows that a partially aggregated estimate for 0–4 years is close to zero (Column 1), but those for 5–9 years and 10–14 years are negative and statistically significant (Columns 2 and 3) under unconditional parallel trends. Column (4) shows the overall treatment effect estimate is also negative and statistically significant. When we account for covariates under conditional parallel trends as shown in the next row, aggregated treatment effect estimates slightly decrease and become less significant. Our baseline estimates in the second row demonstrate that allowing optometrists to prescribe medications reduced the share of people with vision impairment by 0.83% points (or 19% of sample mean) in 10–14 years. The overall average treatment effect for 15 years since the policy is 0.52% points (or 12%).[32]

Next, we examine how optometrist TPA prescription authority affected demographic subgroups. Table 5 presents aggregated treatment effect estimates on each demographic subgroup sample specified in the row heading. By age groups, the overall estimated effect on people aged 50 or above is larger than that on people aged below 50 (Column 4). It is partly because older people have a higher incidence of vision impairment and as a result higher demand for eye care. Relative to the sample mean outcome of each group (Column 5), the policy reduced vision impairment by a larger percentage among the younger group. Also, the effect emerged more quickly among people younger than 50. By gender, the dynamic and overall effect estimates are similar between males and females, but males experienced a larger percentage decline in vision impairment when we account for the sample mean outcome. By race and ethnicity, non-Whites (including Blacks, Hispanics, and those of other race and ethnicity) saw a larger decline in vision impairment than Whites. This finding is aligned with the fact that glaucoma is more prevalent and severe among Blacks and Hispanics (Halawa et al., 2022; Siegfried & Shui, 2022). The result also suggests that the policy narrowed disparities in eye health between the historically advantaged and disadvantaged in medical care.

We also found that allowing optometrists to prescribe medications for eye treatment mostly benefited people with some vision but not those with no vision, as shown in Table 6. The second row of Table 6 shows that the proportion of people with some vision due to vision impairment diminished on average by 0.62% points (or 18% of sample mean) since the policy. In contrast, the proportion of people with no vision did not decrease, as shown in the third row. This is

TABLE 4 Optometrist TPA prescription authority aggregated treatment effects on vision impairment.

	(1)	(2)	(3)	(4)	(5)	(6)
	Partially aggregated					
Model specification	0–4 years	5–9 years	10–14 years	Overall ATE	Mean outcome	Sample size
Without covariates	−0.0013 (0.0016)	−0.0068** (0.0030)	−0.0092*** (0.0028)	−0.0063*** (0.0023)	0.0435	615,296
With covariates	−0.0010 (0.0017)	−0.0047 (0.0030)	−0.0083*** (0.0028)	−0.0052** (0.0023)	0.0435	615,296

Note: Outcome is a binary indicator of whether a person has difficulty in seeing. Treatment is whether an individual resides in a state that allows optometrists to prescribe glaucoma medications. The sample consists of individuals aged 15 or above in 38 states and DC that are consistently identifiable in SIPP panels. Two states, North Carolina and Oklahoma, that are always treated in the sample period are excluded from the estimation. Each cell reports aggregated treatment effect estimates from Gardner's two-stage difference-in-differences estimation by the period since the treatment specified in the column header by the model specification specified in the row header. Overall ATEs in Column (4) means aggregated effects for 0–14 years since the treatment. All aggregations are done by simple average of treatment effects by periods since the treatment. The model with covariates include age, age squared, female, black, Hispanic, and other race and ethnicity dummy. Standard errors are clustered by state and presented in parentheses.

*, **, *** represent statistical significance at the 10%, 5%, and 1% level, respectively.

TABLE 5 Optometrist TPA prescription authority aggregated treatment effects on vision impairment: Heterogeneity by demographic subgroups.

	(1)	(2)	(3)	(4)	(5)	(6)
	Partially aggregated				Mean	Sample
Sample	0–4 years	5–9 years	10–14 years	Overall ATE	outcome	size
All (Baseline)	−0.0010 (0.0017)	−0.0047 (0.0030)	−0.0083*** (0.0028)	−0.0052** (0.0023)	0.0435	615,296
Age 50 below	−0.0023** (0.0011)	−0.0056*** (0.0017)	−0.0073*** (0.0020)	−0.0055*** (0.0015)	0.0179	397,974
Age 50 or above	−0.0001 (0.0033)	−0.0056 (0.0062)	−0.0133** (0.0058)	−0.0073 (0.0048)	0.0902	217,322
Male	−0.0020 (0.0019)	−0.0053** (0.0026)	−0.0092*** (0.0028)	−0.0058*** (0.0022)	0.0363	288,717
Female	−0.0002 (0.0021)	−0.0044 (0.0037)	−0.0077** (0.0035)	−0.0049* (0.0030)	0.0497	326,579
White	−0.0021 (0.0017)	−0.0024 (0.0028)	−0.0068** (0.0027)	−0.0041* (0.0023)	0.0419	459,274
Non-white	−0.0037 (0.0026)	−0.0245*** (0.0068)	−0.0245*** (0.0056)	−0.0192*** (0.0046)	0.0478	156,022

Note: Each cell reports aggregated treatment effect estimates by the period specified in the column header by the demographic subsample specified in the row header. The full sample consists of individuals aged 15 or above in 38 states and DC that are consistently identifiable in SIPP panels. Two states, North Carolina and Oklahoma, that are always treated in the sample period are excluded from the estimation. Overall ATEs in Column (4) means aggregated effects for 0–14 years since the treatment. All aggregations are done by simple average of treatment effects by periods since the treatment. All estimates are obtained from a model with covariates including age, age squared, female, black, Hispanic, and other race and ethnicity dummy under the assumption of conditional parallel trends. Standard errors are clustered by state and presented in parentheses.

*, **, *** represent statistical significance at the 10%, 5%, and 1% level, respectively.

TABLE 6 Optometrist TPA prescription authority aggregated treatment effects on vision impairment: Heterogeneity by degrees of vision impairment.

	(1)	(2)	(3)	(4)	(5)	(6)
	Partially aggregated				Mean	Sample
Outcome	0–4 years	5–9 years	10–14 years	Overall ATE	outcome	size
Vision impairment (Baseline)	−0.0010 (0.0017)	−0.0047 (0.0030)	−0.0083*** (0.0028)	−0.0052** (0.0023)	0.0435	615,296
Some vision	−0.0018 (0.0014)	−0.0052* (0.0027)	−0.0097*** (0.0027)	−0.0062*** (0.0022)	0.0353	615,296
No vision	0.0008* (0.0005)	0.0005 (0.0005)	0.0014** (0.0007)	0.0010** (0.0004)	0.0087	615,296

Note: Each cell reports aggregated treatment effect estimates by the period specified in the column header by the outcome specified in the row header. The sample consists of individuals aged 15 or above in 38 states and DC that are consistently identifiable in SIPP panels. Two states, North Carolina and Oklahoma, that are always treated in the sample period are excluded from the estimation. Overall ATEs in Column (4) means aggregated effects for 0–14 years since the treatment. All aggregations are done by simple average of treatment effects by periods since the treatment. All estimates are obtained from a model with covariates including age, age squared, female, black, Hispanic, and other race and ethnicity dummy under the assumption of conditional parallel trends. Standard errors are clustered by state and presented in parentheses.

*, **, *** represent statistical significance at the 10%, 5%, and 1% level, respectively.

consistent with an intuition that medical eye care, including glaucoma treatment, may be more effective to reduce a preventable or treatable partial vision loss than a complete vision loss or blind of both eyes from the birth or by accidents.

The improvement in the population eye health outcome might be attributable to an increased access to care due to the optometrist scope of practice expansion at least in two ways: an instant addition of optometrists to the body of primary eye care providers upon the policy, and a gradual increase in the number of optometrists after the policy.[33] According to Feng et al. (2020), the number of optometrists was about 74% larger than the number of ophthalmologists in the early 1990s. Furthermore, the number of optometrists increased 46% from 1990—2018, while the number of ophthalmologists declined in 1995–2017. If we assume that only 20% of optometrists provide primary eye care after obtaining TPA prescription authority, a back-of-the-envelope calculation would suggest an instantaneous 34.8% increase in the number of primary eye care providers and an additional 2.7% increase in each decade after the policy.[34]

Our findings are robust to additional controls for contemporary policy changes across states. First, the second row of Table 7 shows estimates when we account for a policy change in contact lens prescription release by optometrists between 1978 and 2004 (Norris & Timmons, 2020). If this policy change improves an access to contact lens, our vision impairment outcome could decline regardless of the optometrist scope of practice expansion. However, the additional control of contact lens prescription release policy does not make a meaningful change in our treatment effect estimates, meaning that the positive health effect of optometrist prescription authority is not confounded with potential benefits from the contact lens prescription release policy. Next, if we control for an amplification law on controlled substance TPA prescription authority for optometrists, the overall estimated effect increases by 0.23% points as shown in the last row of Table 7. It suggests that treatment effects in our baseline model might be underestimated because of amplification laws following glaucoma TPA laws. Despite this, we do not account for this control in our baseline estimation because of potential bias relevant to a few states that allowed controlled substances in pre-treatment periods.[35]

Moreover, we found our estimates robust to alternative estimation and inference methods. Figure 6 presents alternative dynamic treatment effect estimates based on the TWFE OLS event-study method. In comparison to our baseline estimates (red circles), TWFE OLS estimates (blue squares) are mostly smaller than our baseline estimates by

TABLE 7 Optometrist TPA prescription authority aggregated treatment effects on vision impairment: Robustness to contemporary policy changes.

	(1)	(2)	(3)	(4)	(5)	(6)
	Partially aggregated				Mean	Sample
Model specification	0–4 years	5–9 years	10–14 years	Overall ATE	outcome	size
Baseline	−0.0010 (0.0017)	−0.0047 (0.0030)	−0.0083*** (0.0028)	−0.0052** (0.0023)	0.0435	615,296
Lens prescription release	−0.0012 (0.0019)	−0.0050* (0.0029)	−0.0087*** (0.0028)	−0.0055** (0.0023)	0.0435	615,296
Controlled substances TPA	−0.0027 (0.0021)	−0.0066* (0.0036)	−0.0109*** (0.0036)	−0.0075** (0.0031)	0.0435	615,296

Note: Each cell reports aggregated treatment effect estimates by the period specified in the column header by the model with or without a contemporary policy control in the row header. The sample consists of individuals aged 15 or above in 38 states and DC that are consistently identifiable in SIPP panels. Two states, North Carolina and Oklahoma, that are always treated in the sample period are excluded from the estimation. Overall ATEs in Column (4) means aggregated effects for 0–14 years since the treatment. All aggregations are done by simple average of treatment effects by periods since the treatment. All estimates are obtained from a model with covariates including age, age squared, female, black, Hispanic, and other race and ethnicity dummy under the assumption of conditional parallel trends. Standard errors are clustered by state and presented in parentheses.

*, **, *** represent statistical significance at the 10%, 5%, and 1% level, respectively.

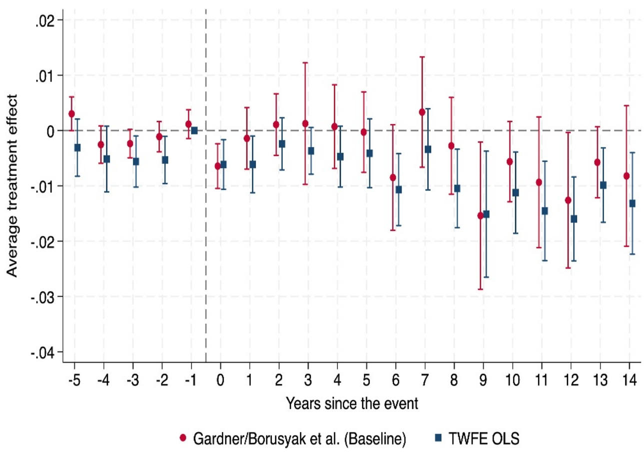

FIGURE 6 Optometrist TPA prescription authority dynamic treatment effects on vision impairment: Alternative Methods. Event-study point estimates and their 95% confidence intervals based standard errors clustered by states. Red circles are Gardner (2021) or Borusyak et al. (2022) estimates and blue squares are TWFE OLS estimates. The sample consists of individuals aged 15 or above in 38 states and DC that are consistently identifiable in SIPP panels. Two states, North Carolina and Oklahoma, that are always treated in the sample period are excluded from the estimation. All estimates are obtained from a model with covariates including age, age squared, female, black, Hispanic, and other race and ethnicity dummy under the assumption of conditional parallel trends. Estimates for years before the event are placebo estimates.

about a half percentage points after the policy. In pre-treatment periods, placebo estimates from TWFE OLS are negative and about half of them are statistically different from zero, implying that TWFE OLS may overestimate the treatment effect. These findings are clarified by aggregated treatment effect estimates in Table 8. The second row shows that the aggregated treatment effect estimate from TWFE OLS is larger than our baseline estimates by 0.47% points.

So far, we examine the time-lagged positive health effect of optometrist scope of practice expansion based on glaucoma TPA laws. Given data on five phases of TPA prescription authority expansion, as shown in Table 1, we compare our baseline estimates with placebo estimates from similar analyses on alternative phases of TPA laws. Table 9 summarizes that all except glaucoma TPA laws do not have a statistically significant effect on vision impairment. More specifically, the first TPA has almost null effects, while TPA prescription authority for orals, controlled substances, and injectables have positive but statistically insignificant effects. These findings suggest that glaucoma TPA is the most significant part of optometrist prescription authority. As an additional robustness check, we confirm that our baseline estimates are unlikely to be obtained from placebo TPA expansions. As shown in Appendix Table A3 column (4), when we randomly assign the timing of glaucoma TPA laws across states and estimate the effect of placebo laws, we obtain a negatively significant estimate in 3 out of 100 trials with the minimum of −0.0012, which is much smaller in magnitude than our baseline estimate (−0.0052).[36]

TABLE 8 Optometrist TPA prescription authority aggregated treatment effects on vision impairment: Robustness to alternative methods.

	(1)	(2)	(3)	(4)	(5)	(6)
	Partially aggregated					
Method	0–4 years	5–9 years	10–14 years	Overall ATE	Mean outcome	Sample size
Gardner/Borusyak et al. (Baseline)	−0.0010 (0.0017)	−0.0047 (0.0030)	−0.0083*** (0.0028)	−0.0052** (0.0023)	0.0435	615,296
TWFE OLS	−0.0046*** (0.0016)	−0.0088*** (0.0031)	−0.0130*** (0.0030)	−0.0097*** (0.0025)	0.0435	615,296

Note: Each cell reports aggregated treatment effect estimates by the period specified in the column header by the method specified in the row header. The sample consists of individuals aged 15 or above in 38 states and DC that are consistently identifiable in SIPP panels. Two states, North Carolina and Oklahoma, that are always treated in the sample period are excluded from the estimation. Overall ATEs in Column (4) means aggregated effects for 0–14 years since the treatment. All aggregations are done by simple average of treatment effects by periods since the treatment. All estimates are obtained from a model with covariates including age, age squared, female, black, Hispanic, and other race and ethnicity dummy under the assumption of conditional parallel trends. Standard errors are clustered by state and presented in parentheses.

*, **, *** represent statistical significance at the 10%, 5%, and 1% level, respectively.

TABLE 9 Optometrist TPA prescription authority aggregated treatment effects on vision impairment: Robustness to other phases of TPA expansion.

	(1)	(2)	(3)	(4)	(5)	(6)
	Partially aggregated					
TPA phase	0–4 years	5–9 years	10–14 years	Overall ATE	Mean outcome	Sample size
First TPA	0.0001 (0.0021)	0.0031 (0.0039)	−0.0015 (0.0043)	0.0006 (0.0029)	0.0494	343,940
Baseline (glaucoma)	−0.0010 (0.0017)	−0.0047 (0.0030)	−0.0083*** (0.0028)	−0.0052** (0.0023)	0.0435	615,296
Orals	−0.0028 (0.0024)	−0.0033 (0.0040)	−0.0052 (0.0044)	−0.0037 (0.0037)	0.0435	615,296
Controlled substances	−0.0011 (0.0026)	−0.0047 (0.0044)	−0.0061 (0.0043)	−0.0040 (0.0037)	0.0435	615,296
Injectables	−0.0006 (0.0029)	−0.0037 (0.0047)	−0.0025 (0.0048)	−0.0026 (0.0041)	0.0435	615,296

Note: Each cell reports aggregated treatment effect estimates from each phase of TPA expansion specified in the row header, by the period specified in the column header. The sample consists of individuals aged 15 or above in 38 states and DC that are consistently identifiable in SIPP panels. Two states, North Carolina and Oklahoma, that are always treated in the sample period are excluded from the estimation. Also, the sample for estimation on the first TPA does not include observations from 1998 when all states have adopted the first TPA. Overall ATEs in Column (4) means aggregated effects for 0–14 years since the treatment. All aggregations are done by simple average of treatment effects by periods since the treatment. All estimates are obtained from a model with covariates including age, age squared, female, black, Hispanic, and other race and ethnicity dummy under the assumption of conditional parallel trends. Standard errors are clustered by state and presented in parentheses.

*, **, *** represent statistical significance at the 10%, 5%, and 1% level, respectively.

Despite all these findings from causal inference methods, there could remain concern on the causal interpretation of the negative association between optometrist scope of practice expansion and vision impairment outcomes with several years of time lag. Secular changes in eye care supply, demand, technology, and insurance during the sample period also raises a possibility of confounding factors that are not accounted in our study. Our analysis assumes that increasing demand for eye care, advances in eye care technology, and broadening of insurance coverage are a nationwide phenomenon that are not systematically correlated with a state's decision on optometrist scope of practice expansion. Otherwise, our estimates could be biased due to confounding factors and therefore not causal but associational findings.

4.2 | Scope of practice and optometrist hourly wages

We also estimated the effect of scope of practice expansion on the labor market for optometrists. Our results suggest that granting TPA prescription authority to optometrists is not associated with hourly wages of all optometrists but positively associated with those of optometrists who are not self-employed. The first three columns of Table 10 shows estimation results on the sample of all optometrists. As shown in column (1) of the table, the estimate on the first TPA law is negative but statistically insignificant. But the estimate is obtained without a consideration of amplification laws. When glaucoma TPA and controlled substances TPA are accounted for sequentially in columns (2) and (3), the overall effect estimate becomes smaller and close to zero.

By contrast, the last three columns of the table show positive wage effects among those who are not self-employed. As shown in column (4) of the table, optometrist hourly wages on average are higher by 0.073 log points (or 7%) in states that introduced the first TPA law than in other states after the policy change. After accounting for the effects of amplification laws on glaucoma medications, estimates in column (5) show that the combined effect of first TPA and glaucoma TPA is larger and more significant. Moreover, column (6) shows estimates when we further accounts for amplification laws on controlled substances. Again, each of the three estimates in the columns is small and insignificant, but they jointly are the largest and most significant.

Our baseline specification is column (6), which includes all three policy variables and individual controls. The sum of estimates in column (6) shows that optometrist TPA laws overall is associated with higher optometrists' hourly wages

TABLE 10 Effects of optometrist TPA on optometrist hourly wages.

	All optometrists			Optometrists not self-employed		
Policy variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
First TPA (a)	−0.052	−0.080	−0.079	0.073	0.047	0.049
	(0.104)	(0.104)	(0.103)	(0.063)	(0.069)	(0.069)
Glaucoma medications (b)		0.064	0.057		0.058	0.044
		(0.081)	(0.078)		(0.047)	(0.047)
Controlled substances (c)			0.022			0.040
			(0.055)			(0.050)
Observations	2378	2378	2378	1211	1211	1211
Clusters	49	49	49	49	49	49
R-squared	0.11	0.11	0.11	0.25	0.25	0.25
Joint test (d = a + b + c)	−0.052	−0.016	−0.001	0.073	0.105*	0.132*
	(0.104)	(0.115)	(0.125)	(0.063)	(0.060)	(0.073)

Note: Outcome variable is the log of hourly wages. The sample consists of full-time, full-year optometrists with wage and salary income at age 18–64 in 48 states (except Alaska and Maine) and the District of Columbia in 1980 to 2000 decennial Censuses and 2001 to 2010 American Community Surveys. Self-employed optometrists are included in the sample for columns (1) to (3) but not for columns (4) to (6). All regressions include state and year fixed effects and individual controls, whose estimates are not reported in the table. Individual controls include age, age squared, female, black, Hispanic, and three education group dummies. Regressions for columns (1) to (3) also include a dummy for self-employed workers. Standard errors are clustered by state and presented in parentheses.

*, **, *** represent statistical significance at the 10%, 5%, and 1% level, respectively.

by 0.132 log points (12.4%), which is statistically significant at the 10% level. Individual estimates on the first TPA law, TPA law on glaucoma medications, and that on controlled substance are all statistically insignificant but in a similar size between 0.040 and 0.049 log points, which suggests that each phase of the TPA prescription authority expansion made a small positive incremental change in optometrist earnings.

These results indicate that the scope of practice expansion with TPA laws raised the value of service provided by optometrists. Although optometrists had been trained to diagnose and treat eye diseases and disorders in optometry schools at least from the 1960s (Caplan, 2017), they could not fully utilize their new training until obtaining the authority to legally do so. Upon the passage of the initial TPA law, optometrists became eligible to treat patients with eye diseases and disorders, a market long monopolized by ophthalmologists. Moreover, as they were allowed to use medications for glaucoma treatment, controlled substances, and injectables by amplification laws, they became able to engage in more advanced procedures of eye diagnosis and treatment.[37]

Diverging results between the full sample of optometrists and the subsample of those who are not self-employed suggest that optometrists at group or multidisciplinary practices may be the major beneficiary of the scope of practice expansion. They are likely to be younger and more educated on knowledge and skills for new functions based on therapeutic prescription authority than those in the solo practice often sticking to their traditional role. Also, there is a possibility that the scope of practice expansion and a secular development in group or multidisciplinary practice may synergize and lead to a productivity increase among optometrists.

Our estimates are broadly robust to changes in sample and model specification. Table 11 compares our baseline estimates on hourly wages in column (1) with two alternative estimates in columns (2) and (3). Column (2) shows that estimates obtained from a regression that account for the policy change in contact lens prescription release by optometrists. As shown in columns (1) and (2), the additional control makes the estimates slightly smaller and less significant. According to the result, the positive effect of the expansion of prescription authority on optometrist earnings seems not to be confounded much with the contact lens prescription release policy's negative earnings effect (Norris & Timmons, 2020). In addition, column (3) shows estimates if we exclude North Carolina (NC) from the sample. NC is the only state that allowed the full TPA prescription authority in the 1970s and made no change in the TPA prescription authority during the sample period. Compared to the baseline estimates in column (1), estimates from the new sample in column (3) are a bit smaller and statistically insignificant. But still the alternative estimates support that our baseline estimates are not dominated by NC.

TABLE 11 Robustness of estimates on hourly wages: Changes in sample and specification.

Policy variables	(1) Baseline	(2) Lens policy controlled	(3) Except NC
First TPA (a)	0.049	0.050	0.037
	(0.069)	(0.068)	(0.070)
Glaucoma medications (b)	0.044	0.034	0.031
	(0.047)	(0.055)	(0.055)
Controlled substances (c)	0.040	0.035	0.033
	(0.050)	(0.053)	(0.053)
Observations	1211	1211	1186
Clusters	49	49	48
R-squared	0.25	0.25	0.25
Join test (d = a + b + c)	0.132*	0.119	0.101
	(0.073)	(0.087)	(0.089)

Note: Columns (1) replicate the estimates in column (6) in Table 10. The sample consists of full-time, full-year optometrists who are not self-employed at age 18–64 in 48 states (except Alaska and Maine) and the District of Columbia in 1980 to 2000 decennial Censuses and 2001 to 2010 American Community Surveys. The model of column (2) adds a lens policy dummy to the baseline model of column (1) to account for the contract lens prescription release policy by states. The sample of column (3) excludes optometrists in North Carolina from the sample of column (1). Outcome variable is the log of hourly wages. All regressions include state and year fixed effects and individual controls, whose estimates are not reported in the table. Individual controls include age, age squared, female, black, Hispanic, and three education group dummies. Standard errors are clustered by state and presented in parentheses.

*, **, *** represent statistical significance at the 10%, 5%, and 1% level, respectively.

TABLE 12 Effects of optometrist TPA on optometrist hourly wages: Triple differences.

Policy variables	(1) Baseline	(2) Except physicians	(3) Except opticians	(4) Occupation dummies controlled
First TPA (a)	0.068	0.069	0.068	0.074
	(0.067)	(0.072)	(0.067)	(0.072)
Glaucoma medications (b)	0.048	0.045	0.048	0.052
	(0.044)	(0.044)	(0.044)	(0.044)
Controlled substances (c)	0.024	0.036	0.024	0.043
	(0.047)	(0.047)	(0.047)	(0.048)
Clusters	49	49	49	49
Observations	715,759	663,147	710,232	715,759
R-squared	0.41	0.37	0.41	0.52
Join test (d = a + b + c)	0.140*	0.150*	0.140*	0.169**
	(0.077)	(0.080)	(0.078)	(0.081)

Note: Outcome variable is the log of hourly wages. The sample consists of full-time, full-year healthcare workers who are not self-employed at age 18–64 in 48 states (except Alaska and Maine) and the District of Columbia in 1980 to 2000 decennial Censuses and 2001 to 2010 American Community Surveys. The sample of column (1) includes optometrists and all other healthcare professionals. The sample of column (2) excludes physicians. The sample of column (3) excludes opticians. All regressions include optometrist dummy, policy dummies, state and year fixed effects, the interaction terms between optometrist dummy and state and year fixed effects, and individual controls whose estimates are not reported in the table. Individual controls include age, age squared, female, black, Hispanic, and three education group dummies. The regression model of column (4) additionally includes occupation dummies. Standard errors are clustered by state and presented in parentheses.

*, **, *** represent statistical significance at the 10%, 5%, and 1% level, respectively.

As a further robustness check to our estimates on hourly wages, we conduct triple differences estimation using healthcare practitioners other than optometrists as a control group. Optometrists and other healthcare practitioners are both working in the healthcare sector, but only optometrists are expected to have been affected by changes in optometrist TPA prescription authority. Hence, it is reasonable to assume that other healthcare professional wages might not be systematically affected by changes in optometrist TPA prescription authority and to use them as the control group in the triple difference estimation. If there were state-specific time-varying shocks on optometrist earnings, and if the shocks had similar effects on other healthcare professional earnings, the triple differencing would remove a potential bias arising from the shocks. Table 12 shows triple differences estimates on optometrist hourly wages. These estimates are slightly larger and statistically more significant than our baseline difference-in-differences estimates. Estimates in column (1) show that the optometrist TPA laws altogether raised optometrist hourly wages by 0.140 log points (13.1%), which is similar to the result from our baseline specification (0.132 log points or 12.4%). It is also informative to look at triple differences estimates after excluding ophthalmologists or opticians from the control group because they work in the eye care industry and their earnings might be affected by the optometrist TPA laws. Columns (2) and (3) confirms that triple difference estimates slightly increase even if we exclude physicians or opticians from the control group.[38] Lastly, column (4) shows that triple difference estimates become larger if we account for potentially different trends in occupational earnings among other healthcare professionals.

These results, combined with the results on vision impairment, provide a more complete picture on the economic and health implications of optometrist scope of practice expansion. Optometrist TPA prescription authority improved public eye health, as well as optometrist earnings, by expanding the role of optometrists from eye examiners to primary eye care providers. We believe the two results are complementary because the increase in optometrist earnings may reflect the value of the improvement in public eye care.

5 | CONCLUSION

In this paper, we provide one of the earliest pieces of evidence that granting optometrists prescription authority resulted in an improvement in public eye health, as policy makers intended. Our difference-in-differences estimation found that vision impairment declined by 12% on average in the 15 years following optometrist TPA prescription authority. Our results are much stronger for non-Whites than Whites. We also found suggestive evidence that the policy increased optometrist earnings—overall TPA laws are associated with higher optometrist hourly wages by about 13%, and each phase of the TPA prescription authority expansion contributed to an incremental and cumulative change. These findings have important implications on ongoing policy debates on scope of practice expansions of optometrists and other healthcare practitioners to meet the rapidly growing demand for medical services given the limited supply of physicians. Further, expansions in provider scope of practice may help alleviate disparities in health care outcomes for Blacks and Hispanics.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this article are available from the corresponding author upon reasonable request.

ORCID

Kihwan Bae https://orcid.org/0000-0003-0457-459X
Edward Timmons https://orcid.org/0000-0001-6431-6061

ENDNOTES

[1] During the period, the number of medical doctors per 100,000 individuals increased from 243.9 in 1995 to 260.4 in 2018 (World Health Organization, 2021). The decline of ophthalmology in medicine is mostly attributed to a diminishing ophthalmology curriculum in medical schools, limited residency slots, and difficulty in a crossover between ophthalmology and other disciplines (Liao, 2021; Linz et al., 2018; Moxon et al., 2020).

[2] Since the Medicare Optometry Parity Amendment in 1986, the federal government has classified optometrists as medical doctors for Medicare reimbursement (Garland, 1987). The legislation made optometrists eligible for Medicare reimbursement for any services that would be covered if provided by a medical doctor. Also, it is likely that favorable scope of practice and Medicare reimbursement policy might interplay and reinforce potential improvements in access to optometric eye care. Nevertheless, the change in Medicare reimbursements should have a similar impact nationwide and not weaken our identification strategy.

[3] Perry, 2009, Kleiner et al., 2016, Timmons et al., 2016, Cai & Kleiner, 2020, Goldsmith, 1989, Kleiner & Park, 2010.

[4] About access to care, see Stange, 2014, Kurtzman et al., 2017, Spetz et al., 2013, Traczynski & Udalova, 2018. About care quality, see Kleiner et al., 2016, Perloff et al., 2019, Markowitz et al., 2017, Dulisse & Cromwell, 2010, Traczynski & Udalova, 2018, Alexander & Schnell, 2019.

[5] The case study of optometrists provides a unique advantage in studying the effect of scope of practice expansion with prescription authority. Optometrists face no restrictions on independent practice, and there is no concern on the possibility of prescription authority confounded with practice authority. In contrast, other healthcare professionals like nurse practitioners are not permitted to practice independently from physicians until it is allowed by scope of practice regulations.

[6] For example, the Medicare reimbursement policy change or technological advances might have affected eye care demand and supply nationwide. See Footnote 2 for more details on the Medicare reimbursement policy changes. With respect to technological advances in eye care, there were crucial developments in diagnostic imaging technology, laser surgery like LASIK, and silicone hydrogel contact lenses in the 1990s and 2000s (AOA Excel and Jobson Medical Information, 2013; Jayasimha, 2019; Lobaugh, 2020). We believe that these new technologies quickly diffused among eye care providers across the states and had similar effects on optometrist earnings and population health outcomes across states conditional on optometrist scope of practice.

[7] Ideally, we would be able to explore the effect of these changes on ophthalmologists specifically, but it is not possible to separate out ophthalmologists from other physicians in the Census or ACS data.

[8] According to the AOA Excel and Jobson Medical Information (2013), 80%–85% of optometrists have some level of involvement with medical eye care, and 18% of patient visits to optometrist offices are for medical eye care in the United States in 2012. Also, optometrists provided 85% of comprehensive eye exams.

[9] We believe that the increase in optometrist hourly wages is unlikely to be driven by stricter licensing regulations for entry to the optometry profession due to the TPA prescription authority. Although states required additional hours of education on drugs in optometry school to utilize the TPA prescription authority, the increases in mandated education were small. For example, Pennsylvania requires a minimum

100 h of education in the prescription and administration of pharmaceutical agents for therapeutic purposes and 18 h of education in glaucoma (Pennsylvania State Board of Optometry, 2003). The additional hours of education are a small part of a typical 4-year curriculum in optometry school.

10 https://www.fortunebusinessinsights.com/industry-reports/vision-care-market-101731.

11 The difference between ophthalmologists and optometrists in education and training can be summarized as the following. After obtaining an undergraduate degree, ophthalmologists attend a 4-year medical school to be a Medical Doctor (MD) and a 3-year required residency program in ophthalmology, while optometrists attend a 4-year optometry school to be a Doctor of Optometry (OD) and a year of an optional residency program.

12 Ophthalmic registered nurses usually assist in injecting medications or assisting with a hospital or office surgery, whereas ophthalmic technicians/technologists are trained medical assistants who support physicians with technical, medical tests, and minor office surgery. The role of the ophthalmic photographer is to document patient's eye conditions in photographs.

13 Minnesota was the first state to license optometrists in 1901, and by 1924 the remaining states and District of Columbia completed their licensure requirement for optometrists. Minnesota's 1901 statute defined the scope of the legal practice of optometry as "[t]he employment of subjective and objective mechanical means to determine the accommodative and refractive states of the eye and the scope of its functions in general." (Cooper, 2012 and Minnesota Senate Bill 188, Approved April 13, 1901)

14 There was an early unsuccessful attempt to permit optometrists to use both diagnostic and therapeutic medications in Pennsylvania in 1937 (Optometry Cares—The AOA foundation 2021).

15 Optometrist surgical authority expansion has been limited at the time of this writing. Only five states enable optometrists to practice with a broad range of ophthalmic surgery. Seven other states allow the excision of lumps and bumps, and several states have a provision that additional surgical procedures can be authorized by the state's board of optometry. However, 29 states and DC prevent optometrists from practicing most types of surgery, with exclusions for the most elementary procedure of inserting punctual plugs or removing foreign bodies (American Optometric Association, 2021).

16 This paragraph is heavily indebted to Cooper (2012).

17 TPA laws typically require the state Board of Optometry to specify a minimum level of education in prescription for therapeutic purposes, either as a curriculum in optometry schools or as continuing education, and pass examinations on the contents. For example, Pennsylvania requires a minimum 100 h of education in the prescription and administration of pharmaceutical agents for therapeutic purposes and 18 h of education in glaucoma (Pennsylvania State Board of Optometry, 2003). According to the Caplan (2017), optometry schools started to extend their programs to five or 6 years with an emphasis on diagnosis and treatment of eye diseases in the 1960s.

18 Fingeret (2016) commented that optometrists seem to have repeated the same procedure, but that it is simply because they are trained to conduct the procedure on one eye at a time.

19 See Bae and Timmons (2022) for a comprehensive survey of literature on scope of practice restrictions and the quality of medical service.

20 Furthermore, there are two barriers against studying the effect of the optometrist DPA prescription authority. First, 23 states adopted DPA laws in the 1970s, whose effect on hourly wages cannot be analyzed by the Census data. Next, the remaining 27 states and DC allowed DPA laws in the 1980s, but its effect is not correctly identifiable because 14 out of the 23 states that adopted the DPA law in the 1970s introduced TPA laws in the 1980s. For these reasons, we ignore the effect of the DPA prescription authority and focus our attention on the effect of TPA prescription authority. If DPA prescription authority had any positive earnings effect, then ignoring the effect of the DPA prescription authority adopted in some states in the 1980s may cause our estimates of the effect of TPA prescription authority introduced in other states in the same decadal period to be biased downwards.

21 We do not use data from the SIPP 1989 panel because of an issue of data inconsistency relevant to the panel.

22 We present empirical evidence that our results are not driven by the changes in survey questions and choices in the result section.

23 We are aware of several limitations in the 2001–2004 ACS relative to the later ACS including that people residing in group quarters are surveyed, no PUMA codes are available, and their sample size is smaller. However, they are not a concern for our study with a pooled cross-section of optometrists with state codes, none of which reside in group quarters. When we check for robustness with other healthcare workers, those in group quarters are excluded from the analysis.

24 Hurst et al. (2014) found that the share of underreported income was high in the early 1980s, declined between the late 1980s and mid-1990s, and then increased in the late 1990s and early 2000s.

25 If we include self-employed optometrists without wage and salary income into the sample, the share of self-employed optometrists gradually declined from 77% in 1980 to 42% in 2019, following a similar trend as self-employed physicians (47% in 1980 to 17% in 2019). Caplan (2017) provides a detailed account on the change in modes of optometrist practice around the 1990s as the following: "The solo practice mode, the keystone of the practice of optometry when I started in 1950 was gradually fading from the scene. The cost of furnishing, equipping, and running a solo practice had become so astronomical that it was no longer feasible to be a solo practitioner. Many private practices were purchased by ophthalmology and optometry group practices, referral centers and multi-disciplinary practices."

26 Optometry schools extended their programs to five or 6 years with an emphasis on diagnosis and treatment of eye diseases in the 1960s (Caplan, 2017). This increase in education may have provided a foundation for optometrists to pursue an expanded role in eye care in the

following decades. As a result, many optometrists in the 1980 Census obtained postgraduate education, and also optometrists without postgraduate education rapidly diminished in the 1980s and 1990s and almost disappeared by the 2000 Census.

27 The applicability is determined based on our model, data, computer programs, and computing power. For example, our data have uneven gaps in data years, and Callaway and Sant'Anna (2021) and de Chaisemartin and D'Haultfoeuille (2022) methods are not applicable. The Sun and Abraham (2021) estimator is established without covariates, which is not the case of our analysis.

28 In fact, the Borusyak et al. method estimates group-by-time average treatment effects as a building block for aggregated treatment effects. Once we aggregate estimates by relative periods since the event, the resulting estimates are the same as what we find using Gardner's methodology.

29 Our results do not change substantially if we include education controls in the regression.

30 If we estimate the effect of the first TPA law in some states without accounting for concurrent amplification laws in other states, the effect of the first TPA law would be underestimated. For example, there are 13 states that passed the first TPA law in the 1980s, and that expanded the TPA prescription authority by allowing glaucoma medications through amplification laws in the 1990s. If an estimation does not account for the amplification law in the 13 states, the effect of the first TPA law passed in 27 other states in the 1990s would be underestimated.

31 The event study requires parallel trend between treated and control states but not the random timing of policy change (Gardner, 2021). To mitigate concern on the potential endogeneity in the timing of the policy, we show that the timing of glaucoma law is not systematically associated with state demographics and vision impairment outcome in 1984 (the initial year of the sample period) in Appendix Table A1.

32 The baseline estimates are obtained from regressions that are not weighted by population weight on each sample individual. However, as shown in Appendix Table A2, estimates from weighted regressions are not that different from our baseline estimates: for example, the weighted estimate of 5–9 years lagged effect is slightly larger and more significant, that of 10–14 years lagged effect and the overall ATE estimate are slightly smaller and less significant than the baseline, unweighted estimate.

33 According to the AOA Excel and Jobson Medical Information (2013), 80%–85% of optometrists have some level of involvement with medical eye care, and 18% of patient visits to optometrist offices are for medical eye care in the United States in 2012.

34 We would expect that our calculation is conservative for two reasons. First, it does not account for the possibility that optometrist scope of practice expansion led to an increase in the number of optometrists in states with the policy relative to state without. Second, it does not address the possibility that a growing proportion of optometrists provide primary eye care over time. Both would accelerate the expansion of the primary eye care workforce after the policy.

35 Among 38 states and DC in the sample, 22 passed controlled substance TPA laws years after glaucoma TPA laws, 12 passed the two laws in the same year, and 5 passed controlled substances TPA laws before glaucoma TPA laws.

36 The test with randomly assigned placebo laws is similar to that of Anderson et al. (2013) and Shakya and Plemmons (2022).

37 Despite the SOP expansion and positive earnings effect, we find little evidence of an increase in the supply of optometrists after the policy change with the Census and ACS data. This additional result is available upon request.

38 Opticians are identifiable as a standalone occupation in the Census and ACS data while ophthalmologists are not and are lumped together with other physicians.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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APPENDIX A

TABLE A1 1984 state characteristics and the timing of optometrist TPA expansion.

State characteristics	Estimates
Vision impairment	−20.6
	(32.7)
Age	0.2
	(0.5)
Female	20.2
	(49.3)
Black	−9.5
	(14.3)
Hispanic	13.5
	(8.2)
Other race/ethnicity	6.3
	(4.2)
High school diploma	−8.7
	(17.5)
Some college education	−33.9
	(30.7)
College degree	18.6
	(26.1)
Constant	1983.0***
	(39.5)
Observations	37
R-squared	0.14

Note: Outcome variable is the year of glaucoma law being passed in a state. The sample consists of 38 states and DC that are consistently identifiable in SIPP panels. Two states, North Carolina and Oklahoma, that are already treated in 1984 are excluded from the sample. State characteristics are the weighted average of individual characteristics among individuals aged 15 or above in the 1984 SIPP Wave 3. Standard errors are robust to heteroscedasticity and presented in parentheses.

*, **, *** represent statistical significance at the 10%, 5%, and 1% level, respectively.

TABLE A2 Optometrist TPA prescription authority aggregated treatment effects on vision impairment: Robustness to weighted regression.

	(1)	(2)	(3)	(4)	(5)	(6)
	Partially aggregated					
Model specification	0–4 years	5–9 years	10–14 years	Overall ATE	Mean outcome	Sample size
Baseline (unweighted)	−0.0010 (0.0017)	−0.0047 (0.0030)	−0.0083*** (0.0028)	−0.0052** (0.0023)	0.0435	615,296
Weighted	−0.0013 (0.0019)	−0.0049* (0.0030)	−0.0072** (0.0029)	−0.0046* (0.0024)	0.0431	615,199

Note: Each cell reports aggregated treatment effect estimates by the period since the treatment specified in the column header by the model specified in the row header. The first two rows present our baseline estimates from an unweighted regression, and the next two rows show robustness estimates from a weighted regression with personal survey weights. The sample consists of individuals aged 15 or above in 38 states and DC that are consistently identifiable in SIPP panels. Two states, North Carolina and Oklahoma, that are always treated in the sample period are excluded from the estimation. Overall ATEs in Column (4) means aggregated effects for 0–14 years since the treatment. All aggregations are done by simple average of treatment effects by periods since the treatment. The model with covariates includes age, age squared, female, black, Hispanic, and other race and ethnicity dummy. Standard errors are clustered by state and presented in parentheses.

*, **, *** represent statistical significance at the 10%, 5%, and 1% level, respectively.

TABLE A3 Optometrist TPA prescription authority aggregated treatment effects on vision impairment: Robustness to placebo TPA expansions.

	(1)	(2)	(3)	(4)
	Partially aggregated			
Method	0–4 years	5–9 years	10–14 years	Overall ATE
Baseline	−0.0010 (0.0017)	−0.0047 (0.0030)	−0.0083*** (0.0028)	−0.0052** (0.0023)
Placebo estimates				
Average of placebo estimates	−0.0000	−0.0001	−0.0000	−0.0001
Minimum of placebo estimates	−0.0019	−0.0017	−0.0020	−0.0012
Maximum of placebo estimates	0.0021	0.0016	0.0024	0.0017
Number of trials	100	100	100	100
Placebo estimates <0	46	55	50	56
Placebo estimates <0 and significant at 5% level	5	1	3	3

Note: The first two rows present our baseline estimates of aggregated treatment effect estimates and their standard errors by the period specified in the column header, mean outcome of vision impairment, and sample size. The next three rows show statistics on placebo estimates when we randomly assign the timing of glaucoma laws between 1977 and 2021 for each state in the sample. The sample consists of individuals aged 15 or above in 38 states and DC that are consistently identifiable in SIPP panels. Two states, North Carolina and Oklahoma, that are always treated in the sample period are excluded from the baseline estimation. In the placebo estimation, states treated before 1985 are excluded from the estimates because they are always treated in the placebo dataset. Due to the randomness in placebo estimation, mean outcome and sample size slightly differs across placebo estimations, which are not presented in the table. Overall ATEs in Column (4) means aggregated effects for 0–14 years since the treatment. All aggregations are done by simple averages of treatment effects by periods since the treatment. All estimates are obtained from a model with covariates including age, age squared, female, black, Hispanic, and other race and ethnicity dummy under the assumption of conditional parallel trends. Standard errors are clustered by state and presented in parentheses.

*, **, *** represent statistical significance at the 10%, 5%, and 1% level, respectively.