Journal of Agricultural and Applied Economics (2025), 1–14
doi:10.1017/aae.2025.15

CAMBRIDGE UNIVERSITY PRESS

RESEARCH ARTICLE

The Effects of Class-Action Lawsuits on California Glyphosate Usage

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Abstract
A slate of class action lawsuits has been filed in California against Monsanto (and now Bayer), alleging that exposure to glyphosate, an active herbicide, has caused non-Hodgkin's Lymphoma in people. The current litigation may create liability risks for stakeholders continuing to use glyphosate. We estimate the impact of litigation on glyphosate use in California by leveraging the court rulings awarding damages as a natural experiment. Our findings suggest that glyphosate usage in California has fallen substantially in the wake of these lawsuits. Decisions in the courtroom regarding glyphosate users' health risks are already having a decreasing effect on pesticide use decisions in the real world.

Keywords: Class action lawsuit; glyphosate; liability; pesticide use

AMS subject classifications: Q12; K13

1. Introduction

In March 2015, the International Agency for Research on Cancer (IARC) formed a working group of experts and specialists to evaluate the carcinogenic risk of five insecticides and herbicides, including glyphosate. Glyphosate is an active herbicide in many weed-killing products (e.g., Roundup) developed by Monsanto in the 1970s. The IARC categorizes chemicals into one of five risk groups – Group 1: carcinogenic, Group 2a: probably carcinogenic, Group 2b: possibly carcinogenic, Group 3: not classifiable, or Group 4: probably not carcinogenic. While the working group noted limited evidence for the carcinogenicity of glyphosate in humans, they also noted a positive association had been observed for non-Hodgkin's lymphoma (International Agency for Research on Cancer, IARC). Ultimately, they concluded glyphosate is probably carcinogenic to humans (Group 2a). Product liability lawsuits were soon filed after the IARC findings were announced.

A landmark court decision was reached in 2018 when a California jury ordered Monsanto to award a plaintiff $289 Million for allegations that glyphosate, the active ingredient in Roundup, caused non-Hodgkin's Lymphoma. Since then, a series of lawsuits have resulted in similar rulings, and as of 2022, damage awards totaled over $11 billion (Gaines, 2024). With glyphosate still in use, a question looming over manufacturers, consumers, and agricultural producers involves potential risk and liability moving forward.

It is unclear how court rulings will affect production decisions and the use of glyphosate in California or across the U.S. It is plausible that the ongoing litigation spurs potential risk, or at least perceived risk, for continued on-farm use of glyphosate. For example, agricultural producers

could perceive there to be health risks associated with exposure to what has been deemed carcinogenic in the court system, production risk associated with the future availability of glyphosate to maintain current production practices, or liability risk associated with personal claims of damage to others.

We estimate the impact of litigation on glyphosate use in California by leveraging the court rulings awarding damages as a natural experiment. The findings from our analysis provide a better understanding of current changes in glyphosate usage and potential liability awareness, which will be relevant to glyphosate users, manufacturers, industry groups, and policymakers.

2. Background

Glyphosate is one of the most used non-selective herbicides in agriculture due to its application in growing crops genetically engineered to resist glyphosate, generally called herbicide-tolerant crops (Dill et al., 2010). Herbicide-tolerant crops allow farmers to control weeds without harming their crops. Economically, herbicide use provides substantial societal benefits, including lower production costs and higher yields, which result in lower food costs (Fernandez-Cornejo, Jans, and Smith, 1998).

Monsanto filed for a patent for glyphosate in 1971, and the patent was granted in 1974 (Székács and Darvas, 2012). Generic versions of glyphosate began production outside of the U.S. when the patent rights limitedly expired in 1991, which reduced the price by an estimated 30% in year one and 40% by year two (Székács and Darvas, 2012). The patent rights expired in the U.S. a decade later, and production and sales of generic versions became widespread, although Monsanto was still the lead producer of glyphosate-based herbicides (Székács and Darvas, 2012). In 2018, Bayer acquired Monsanto along with liability for glyphosate, which led Bayer to remove glyphosate as the active ingredient in Roundup sold to the residential market. Glyphosate is still available for use in agricultural production.

In the U.S., approximately 90% of corn, cotton, soybeans, sugar beets, and canola are grown using herbicide-tolerant seeds (Hellerstein, Vilorio, and Ribaudo, 2019), and glyphosate is applied to many of these acres. The adoption of herbicide-tolerant seeds increased the use of glyphosate in agricultural production. It has been estimated that in 2014, U.S. producers sprayed glyphosate at a rate equivalent to applying 0.8 pounds to every acre of cultivated cropland (Benbrook, 2016). The increased use prompted the evolution of glyphosate-resistant weeds beginning in 2000 (Van Deynze, Swinton and Hennessy, 2022), and 18 glyphosate-resistant weed species were reported in U.S. cropland as of 2024 (Heap, 2024). Glyphosate resistance has reduced the herbicide's effectiveness and increased agricultural production costs (Lambert et al., 2017; Livingston et al., 2015).

California agriculture: California is the largest agricultural producer in the U.S. It produces half of all fruit and vegetables grown in the U.S. Glyphosate is key in the production of these specialty crops. Most agricultural production occurs in the Central Valley region of the state.[1] Over part of the period of analysis for this study, California faced extreme drought conditions. From 2011 to 2017, exceptional drought levels covered up to 60% of the state, with the height of the drought occurring between Fall 2014 and December 2016 (NIDIS, 2024). The historic drought subsided in early 2017. Periods of prolonged drought affect crop and weed growth and also reduce the amount of water allocated to crop production.

California glyphosate litigation: To date, there have been three major court decisions regarding the cancer-causing properties of glyphosate: *Johnson v. Monsanto Co.*, *Hardeman v. Monsanto Co.*,[2] and *Pilliod et al v. Monsanto Co.* Juries found for the plaintiffs (and against

[1]Appendix Figure B1 shows the number of farms and the percentage of land area devoted to farm acres for each county in California as of 2017.

[2]While the Hardeman case was tried in federal court, its implications were largely confined to California. Although federal courts adjudicate cases involving parties from different states under diversity jurisdiction, they apply state law in doing so. The

https://doi.org/10.1017/aae.2025.15 Published online by Cambridge University Press

Monsanto) in all cases, and awarded damages ranged from $80 million to over $2.5 billion across the three trials. Table 1 presents an overview of this litigation, and Appendix A presents further details on each case.

The precedent set in this litigation has the potential to create liability for farms whose workers apply glyphosate and subsequently contract NHL.[3] As stakeholders react to their perceived risks associated with glyphosate application, shifts in overall usage levels may occur. The empirical analysis that follows seeks to investigate how glyphosate usage in California has evolved in light of this litigation.

3. Data

To empirically investigate the impacts of litigation on glyphosate use, we compile a dataset from the U.S. Geological Survey (USGS) on county-level pesticide usage from 2013 to 2019 for California and other U.S. states. The USGS pesticide use estimates are based on surveys, proprietary agricultural chemical sales data, and reported pesticide use records (Baker and Stone, 2015; Stone, 2013; Thelin and Stone, 2013). The dataset presents three constructed estimates of pesticide usage – a "low" estimate, an "average" estimate, and a "high" estimate – for each county and year.[4]

The final dataset includes seven years of observations for 3,063 U.S. counties. Of the 57 California counties in our sample, median usage of glyphosate was 7,818 kg over the full sample period (7,054 during the pre-treatment period and 7,825 during the post-treatment period). The median county outside of California used 14,067 kg of glyphosate over the full sample period (14,560 during the pre-treatment period and 13,279 during the post-treatment period). Panels (a), (b), and (c) of Figure 1 summarize the distribution of "low," "average," and "high" estimates of county-level glyphosate use in California counties versus counties in other states, both in the pre-treatment period and in the treatment period. Additional summary statistics are reported in Appendix Table B1.

Hardeman decision was based on California law, meaning it did not establish a binding legal precedent for courts in other states. Furthermore, while Monsanto sought to appeal the ruling to the Supreme Court on the grounds that federal pesticide labeling law (FIFRA) preempted state law claims, the Supreme Court declined to hear the case. This left the lower court ruling intact but did not create a nationwide precedent that would automatically expose glyphosate users in other states to similar liability risks. Beyond legal considerations, California's agricultural and regulatory landscape further distinguishes it from other states. The Proposition 65 requirement that glyphosate products be labeled as carcinogenic heightened both public awareness and legal risks in California, making it a more favorable venue for plaintiffs. Additionally, California's agricultural sector is more reliant on hired labor for pesticide application, compared to mechanized row crop production in the Midwest, increasing the likelihood of worker exposure claims. These factors suggest that the litigation-induced changes in glyphosate use were most pronounced in California, supporting our empirical strategy.

[3]Agricultural producers have faced pesticide liability claims in the past for groundwater contamination and chemical drift. Producers question the fairness of holding them liable for practices that have government approval, such as pesticide use. However, arguments for producer liability could be made if label instructions for use were not followed or if there was negligence when spraying (Blomquist, 1995; Raccio, 1993). In the 1990s, groundwater contamination from pesticide use prompted Connecticut to enact the Potable Water Act, which required manufacturers and producers to share the cost of damages and responsibility to find alternative drinking sources for citizens affected (Raccio, 1993). For pesticide drift claims, courts have found producers liable for damages to crops and livestock but have generally been hesitant to award damages for cases involving personal injury from exposure (Blomquist, 1995). Producers could also incur liability for work performed by an independent contractor on their farm; the New Mexico Supreme Court upheld a ruling that a landowner was liable for negligent pesticide application performed by an independent contractor (Blomquist, 1995). While agricultural producers have not yet been found liable for cases related to glyphosate, producers and landowners using pesticide applications could be advised to add indemnity contract provisions with renters or applicators (Centner, 2021).

[4]The "low" estimate and the "high" estimate differ in their treatment of missing observations from Crop Reporting Districts (CRDs). The "low" estimate assumes zero use in CRDs where pesticide usage is not reported. The "high" estimate treats unreported use as missing data and imputes missing use rates using data from neighboring CRDs or other CRDs within the same region. The "average" estimate is the simple average of the "low" and "high" estimates.

https://doi.org/10.1017/aae.2025.15 Published online by Cambridge University Press

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Table 1. Overview of glyphosate litigation

	Johnson v. Monsanto	Hardeman v. Monsanto	Pilliod v. Monsanto
File Date	January 2016	February 2016	June 2017
Trial Date	July–August 2018	February–March 2019	March–May 2019
Court	California State Court	U.S. District Court, Northern District of California	California Superior Court of Alameda
Claim	Negligence; Product Liability	Negligence; Product Liability	Design Defect; Failure to Warn
Verdict	For Plaintiffs	For Plaintiffs	For Plaintiffs
Jury-Awarded Damages	$289 Million	$80 Million	$2.55 Billion
Appeal	First District Court of Appeal upheld verdict, reduced damages to $20.5M.	Ninth U.S. Circuit Court of Appeals upheld verdict. SCOTUS denies Monsanto petition for certiorari.	California Appellate Court, California Supreme Court, and SCOTUS reject requests for appeal.

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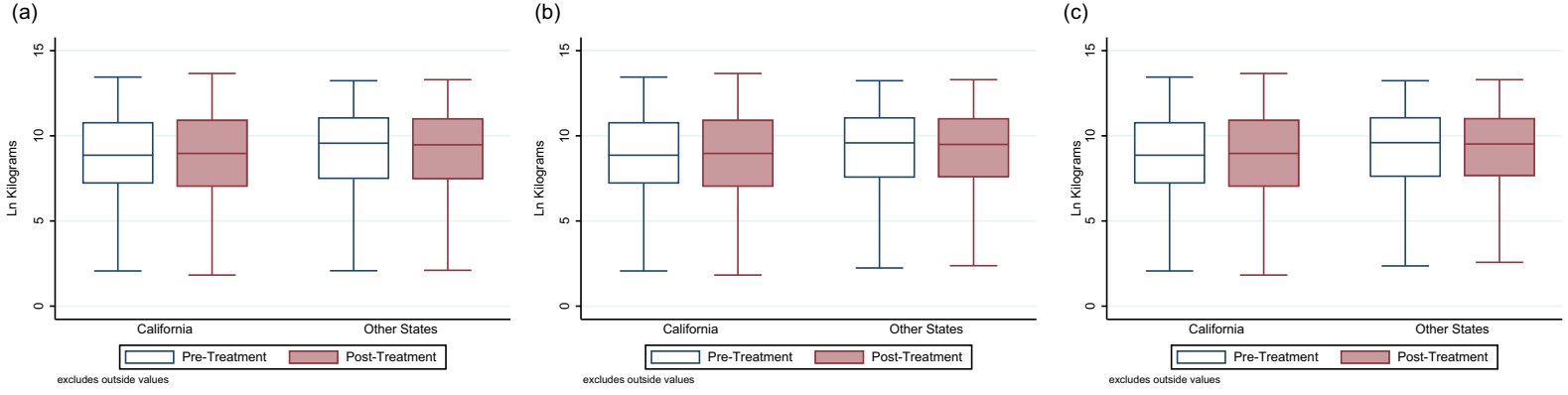

Figure 1. Summary statistics for county-level glyphosate use.
Notes: Figure summarizes the distribution of "low," "average," and "high" estimates of county-level glyphosate and chlorpyrifos use in California counties versus counties in other states in the pre-treatment period and in the treatment period.

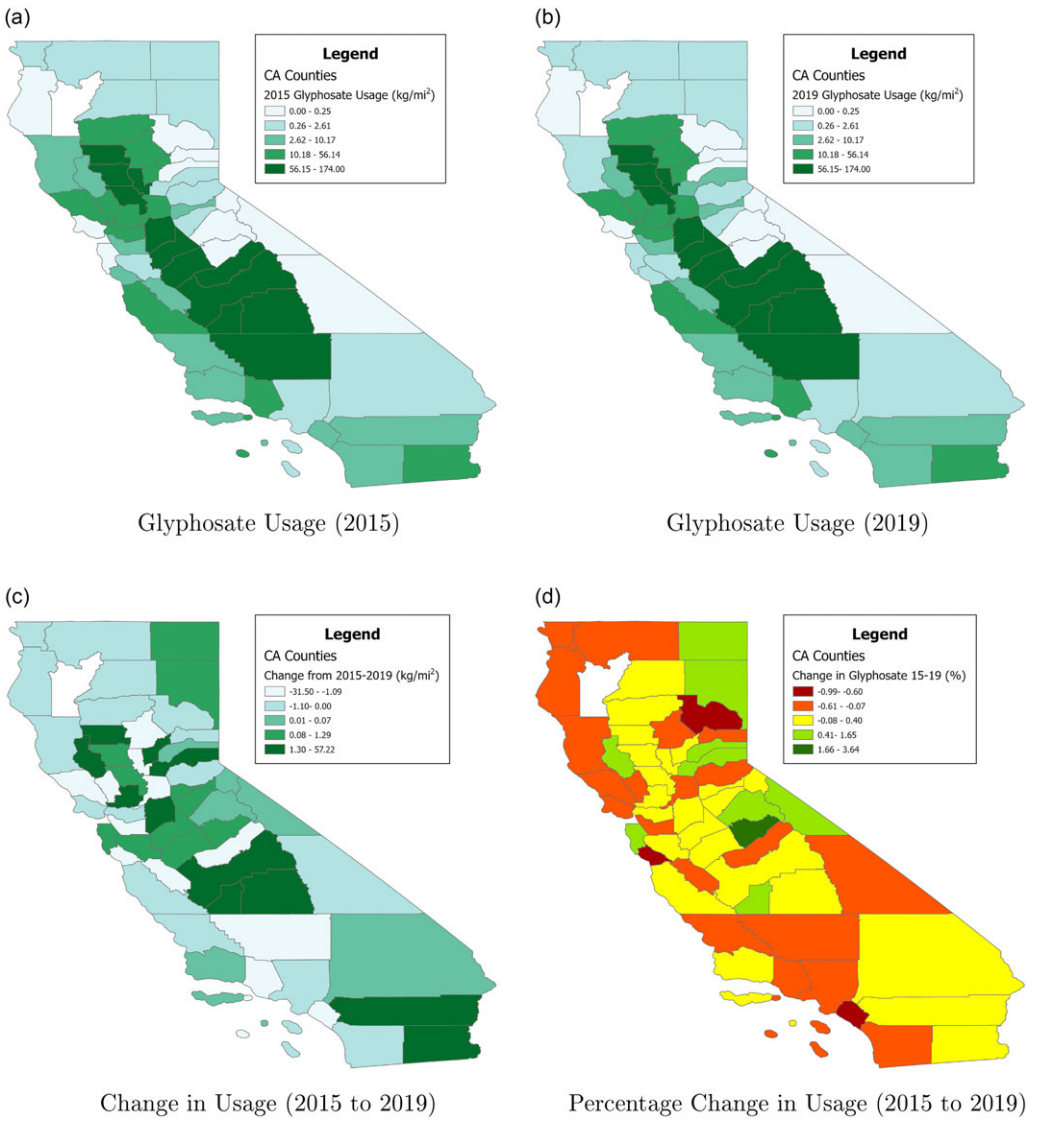

Figure 2. County-level glyphosate usage (2015 vs 2019).
Notes: These maps disaggregate California glyphosate use in 2015 and 2019 by county and show the change in usage from 2015 to 2019. Underlying data obtained from USGS NAWQA.

The maps in Figure 2 disaggregate California glyphosate use in 2015 and 2019 by county and show the change in usage from 2015 to 2019. As shown in panels (*a*) and (*b*), a majority of glyphosate usage in California is contained to the Central Valley. Notably, the counties with the largest decrease in glyphosate usage are either very urban areas or counties with low population densities. A majority of the Central Valley, where most agricultural production occurs, has not seen a total decrease in usage values. However, there are large sections in California that have decreased usage. Outside of Napa Valley, which is a large player in California grape production, the area of Northern California where the glyphosate trials have occurred have seen a decrease in usage.

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4. Methodology

We use a natural experiment design to analyze the impacts of the class action lawsuits on glyphosate use in California. We consider two alternative approaches to identify these impacts:

- **Triple-difference model:** First, we employ a triple-difference (TD) model, in which we compare both glyphosate usage in California counties "treated" by the litigation relative to glyphosate usage in counties outside of California (i.e., control counties), and also usage of the treated pesticide (i.e., glyphosate) and a control pesticide (i.e., chlorpyrifos) that was not the subject of the litigation in California.
- **Dynamic treatment model:** Second, we analyze parallel pre-treatment trends assumptions and investigate treatment dynamics using the multi-period estimator developed by Callaway and Sant'Anna (2021).

Treatment date: For all specifications, we use year 2017 as the treatment date. This date is chosen because (as summarized in Table 1) the first lawsuits were filed in 2016. Agricultural producers face lags concerning input decisions due to annual or semi-annual production cycles. This restricts their ability to substantially alter pesticide inputs in the year the litigation was initiated. The dynamic treatment model allows us to further investigate the prudence of our chosen event date.

4.1. Triple-differences model

To test whether the class-action litigation had statistically measurable effects on glyphosate usage in California, we employ a triple-difference (TD) model, which compares the average change in glyphosate usage in California, not only with usage outside of California, but also with usage of all other compounds – that were was not the subject of the litigation – as control products both inside and outside of California.

Our TD specification is as follows:

$$U_{jit} = \mu_i + \mu_t + \mu_j + \lambda_1 G_j \times CA_i \times T_t + \lambda_3 CA_i \times T_t + \varepsilon_{it} \tag{1}$$

where dependent variable U_{jit} is the log-transformed kilograms of pesticide j used in a given county i in a given year t. We estimate specifications where this variable is alternatively defined using the "low" usage estimate, the "average" usage estimate, and the "high" usage estimate.

On the right-hand side of equation (1), variables μ_i, μ_t, and μ_j are fixed effects, which control for time-invariant factors in each county, such as agronomic and climatic factors and location, time-invariant factors for each chemical compound, and time-variant factors that affect all counties in the U.S., such as the rise of glyphosate-resistant weeds and the overall prices for agricultural commodities.

This specification includes two interaction terms: $CA_i \times T_t$, which measures the total difference in all pesticide usage in California during the treatment period, and $G_j \times CA_i \times T_t$ (the TD treatment), which measures the difference in glyphosate usage in California both relative to glyphosate usage outside California and relative to chlorpyrifos usage inside (and outside) California. Variable CA_i denotes treated counties (i.e., counties within California), and indicator T_t, takes value one for all years from 2017 to 2019, and is otherwise equal to zero. Variable G_j is a dummy variable which takes value one for glyphosate.

Our coefficient of interest in (1) is λ_1, which measures the treatment effect of the litigation on glyphosate usage in "treated" California counties. Treatment effects are reported as percent changes using the following transformation: $e^{\hat{\lambda}_1} - 1$.

Equation (1) is estimated using ordinary least squares with standard errors clustered at the state level. All data analysis is conducted using Stata 16M software.

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Table 2. Estimated impacts of glyphosate litigation using triple-differences model

Variables	(1) "Low" usage estimate	(2) "Average" usage estimate	(3) "High" usage estimate
Glyph × California × Treatment Period	−1.357***	−1.037***	−1.360***
	(0.141)	(0.119)	(0.117)
California × Treatment Period	−0.260***	−0.284***	−0.281***
	(0.026)	(0.023)	(0.016)
Constant	3.065***	3.443***	3.174***
	(0.002)	(0.002)	(0.001)
Observations	1,578,469	1,609,266	2,354,985
R-squared	0.247	0.269	0.242

Standard errors reported in parentheses are clustered at the state level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

A potential concern with our approach is whether the litigation effects were confined to California or had broader national spillover effects. While the *Hardeman* case was a federal lawsuit, it applied California law, meaning its direct legal implications were limited to the state. Additionally, California's unique regulatory environment – including Proposition 65 carcinogen labeling requirements and a history of large plaintiff-friendly product liability rulings – created conditions that made glyphosate litigation more concentrated in California than in other states.

4.2. Model robustness

We consider two robustness checks on this specification. First, we re-estimate the model restricting the control units to only neighboring states (Oregon, Nevada, and Arizona). Counties in these states may provide a more comparable counterfactual given their geographic proximity, shared climate conditions, and similar agricultural markets with California.

Second, we re-estimate the model using an outcome variable where the quantity (KG) of glyphosate used in a county is normalized by the county's land mass (i.e., KG per sq. mile). This allows us to more directly account for differences in county size and agricultural production scale. Results of these analyses are reported in Appendix Table B2 and B3. The results of these robustness checks are generally consistent with our baseline estimates – with respect to sign and statistical and economic significance.

4.3. Dynamic treatment model

Parallel pre-treatment trends between glyphosate usage in California counties versus counties in other states is a necessary condition for the causal interpretation of estimated treatment effects in our baseline models. While this assumption cannot be tested directly, an analysis of outcome trends in the pre-treatment period provides important evidence regarding its validity (Freyaldenhoven, Hansen, and Shapiro, 2019).

Further, the full impact of the litigation may not be immediate and has the potential to compound over time. To examine both pre-treatment trends and the evolution of treatment effects, we employ the DiD-with-multiple-periods estimator developed by Callaway and Sant'Anna (2021):

$$U_{Glyph,it} = \mu_i + \mu_t + \sum_{e=-k}^{-1} \delta_e^{anticip} L_{it}^e + \sum_{e=0}^{L} \beta_e L_{it}^e + \nu_{it} \tag{2}$$

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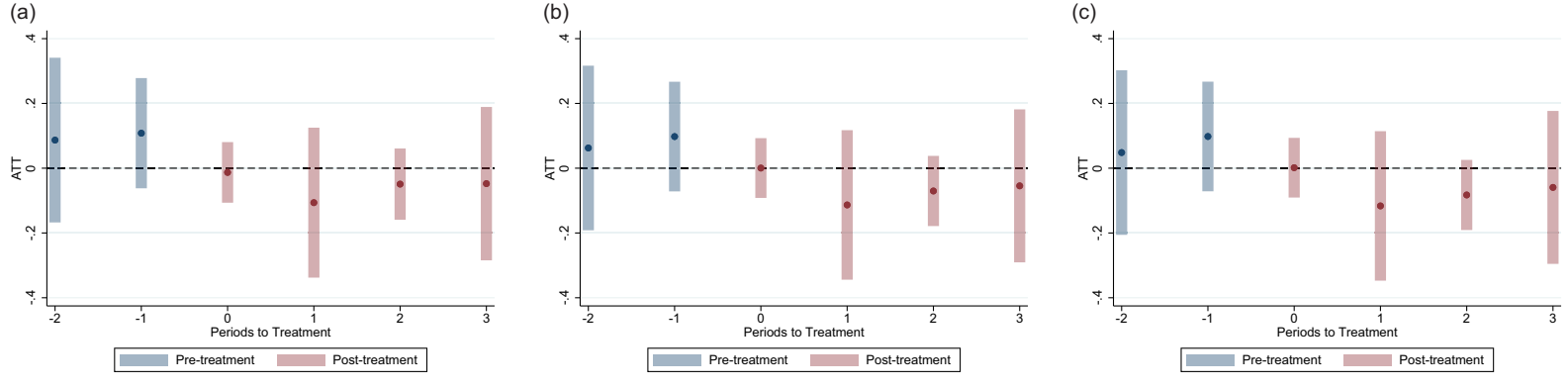

Dynamic "Low" Results | Dynamic "Average" Results | Dynamic "High" Results

Figure 3. Estimated impact dynamics of class-action lawsuits on california glyphosate usage.
Notes: Panel (*a*), (*b*), and (*c*) report results from the dynamic treatment specifications described in Section 4.3.

where the dependent variable $U_{Glyph,\,it}$ is the log-transformed kilograms of glyphosate used in county i in year t (as defined in equation (1)). Also as above, variables μ_i and μ_t are county and time fixed effects, which control for time-invariant factors at the county level and time-varying factors that affect all counties.

Variable L_{it}^{e} is an event-time indicator variable, taking a value of 1 if county i is observed in period e relative to the treatment year (2017) and 0 otherwise, where k represents the number of years before the treatment event (i.e., negative values of e correspond to pre-treatment periods, while positive values correspond to post-treatment periods).

Parameter $\delta_e^{anticip}$ captures anticipatory effects of litigation before the treatment year (i.e., whether any behavioral adjustments occurred prior to 2017). The pre-treatment parallel trends assumption is evaluated through the coefficients $\delta_e^{anticip}$, which estimate differences in glyphosate use prior to the litigation event. If these coefficients do not exhibit a systematic trend, this supports the assumption that pre-treatment glyphosate use evolved similarly in treated and control counties.

Finally, our coefficient of interest in equation (2) is β_e, which measure the effects of the litigation on the "treated" counties over time.

5. Results

Baseline results: Table 2 reports the results of our baseline empirical analysis. As explained in Section 4, the coefficient estimates reported in the table can be interpreted as percent changes using the following transformation: $e^{\hat{\lambda}_1} - 1$, where $\hat{\lambda}$ is the estimated coefficient on our variables of interest in equations (1). Estimated treatment effects in the TD analysis are consistently negative and range in magnitude from a 65% reduction in glyphosate usage in the "average" usage estimate specification to a 74% reduction in glyphosate usage in the "high" usage estimate specification. These treatment effects are statistically significant at the 1% level in each usage specification.

Model robustness: Results of our robustness checks which limit the control units to only neighboring states (Oregon, Nevada, and Arizona) and using an outcome variable is normalized by the county's land mass (i.e., KG per sq. mile) are reported in Appendix Table B2 and B3. Respectively, these analyses allows us to more directly account for differences in county size and agricultural production scale. The results of these robustness checks are generally consistent with our baseline estimates – with respect to sign and statistical and economic significance.

Parallel trends and treatment dynamics: Panel (*a*), (*b*), and (*c*) of Figure 3 report results from the dynamic treatment specifications described in Section 4.3. We find no evidence of significant pre-trends in this analysis. These pre-treatment results present strong evidence that our coefficients can be interpreted causally. Further, looking at the point estimates on the post-treatment effects, we see that – consistent with our baseline results – California class-action lawsuits appear to have persistently reduced glyphosate usage over the subsequent three years, though these post-treatment effects are not statistically significant on an individual basis.

6. Conclusion

Our analysis suggests that glyphosate usage in California has declined in light of litigation surrounding the product. There are multiple mechanisms by which this effect could occur. One could imagine these results are supply-driven as pesticide manufacturers and distributors or pesticide applicators operating in the California market charge a higher price to insure against future liability risks (Carter and Schaefer, 2019; Scheitrum, Schaefer, and Saitone, 2023). On the other hand, the effects could be demand-driven as producers weigh the perceived benefits of weed reduction versus the potential liability risks. Regardless of the precise mechanism, if the precedent set in California courts is accepted in other jurisdictions, one may see a reduction in glyphosate usage on a national level.

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Reductions in glyphosate usage may positively affect environmental and human health outcomes as potential exposure to the pesticide falls. However, there may be perverse trade-offs as well. Producers who shift away from glyphosate will likely transition towards tillage or another pesticide. Each of these options has its own negative effects. Tillage has negative impacts on soil health and structure, each of which can impact yields. Tillage also has a larger environmental impact than pesticide application, both with respect to loss of sequestered carbon and additional use of fossil fuel (Duke, 2020). Moreover, while studies have found negative health impacts associated with glyphosate, other herbicides used for weed management have also been associated with adverse health effects. Additionally, glyphosate has a lower environmental impact than many other synthetic herbicides on the market.

Finally, we acknowledge several caveats with respect to our results. One potential confounder we were unable to fully control for is the expansion of organic agriculture, which prohibits glyphosate use. County-level organic acreage data from the USDA Census of Agriculture (2012, 2017) would have been a useful control variable, but a significant proportion of this data is undisclosed at the county level due to confidentiality restrictions. Future research could explore alternative data sources or indirect proxies to further investigate the relationship between organic adoption and glyphosate use trends.

Additionally, three other factors may have contributed to changes in glyphosate use independent of litigation effects. First, California experienced severe drought conditions from 2011 to 2017, which likely affected both cropping decisions and pesticide application practices. The timing of the drought's end in 2017 coincides with the beginning of our treatment period, making it difficult to fully disentangle the effects of water availability from litigation-driven changes in glyphosate use.

Second, the rise of glyphosate-resistant weeds may have contributed to shifts in weed management strategies. In response to increasing resistance, some producers may have reduced glyphosate use in favor of alternative herbicides (e.g., dicamba, glufosinate) or mechanical tillage, both of which could partially explain declining glyphosate application rates.

Third, ongoing regulatory changes in California may have signaled additional future restrictions on glyphosate use. The California Department of Pesticide Regulation began considering additional regulatory actions in 2017, independent of the litigation. If agricultural producers perceived that state-level restrictions on glyphosate were imminent, they may have preemptively adjusted their pesticide use, contributing to the observed reductions.

While our robustness checks help mitigate some of these concerns, we acknowledge that these additional factors may have played a role in shaping observed usage trends. Future research could build on this analysis by incorporating more detailed county-level agronomic data, additional pesticide usage records, or farm-level decision-making surveys to further isolate the causal impact of litigation on glyphosate use.

Supplementary material. For supplementary material accompanying this paper visit https://doi.org/10.1017/aae.2025.15

Data availability statement. All data and programs necessary to replicate the analyses and results in this manuscript are available from the authors upon request.

Financial support. This project was partially funded under USDA NIFA Multistate Hatch Project S-1072.

Competing interests. The authors report no conflicting interests relevant to this work.

Ethics committee approval. This project did not involve human subjects research.

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https://doi.org/10.1017/aae.2025.15 Published online by Cambridge University Press

Appendix A. Overview of glyphosate class-action lawsuits

Johnson v. Monsanto Co.: This was the first glyphosate lawsuit and was tried in California State Court. Plaintiff and Respondent Dewayne Johnson was the grounds manager for the Benicia Unified School District in Benicia, California, beginning in June 2012. Johnson used Monsanto's glyphosate-containing products Roundup Pro and Ranger Pro to control weeds on school properties and sued Monsanto after contracting NHL. Johnson was a certified herbicide applicator and followed protective measures while utilizing the products. Johnson used a truck-mounted sprayer when applying the chemical mix on the school districts properties, while also wearing a full-body Tyvek suit, chemical-resistant gloves, boots, eye goggles, and a mask during application. Johnson normally sprayed up to 150 gallons of Ranger Pro for two to three hours each school day and occasionally on weekends and summer days for four to five hours per day.

Johnson experienced extreme exposure to Ranger Pro for the first time in June 2014. While spraying, the hose of his truck-mounted sprayer broke and began spouting the chemical mix, soaking his body and face inside his protective suit. In late July, Johnson sought his physician after developing a rash, which persisted and worsened despite topical treatment. Referred to a dermatologist in October 2014, Johnson was diagnosed with NHL, and suffered from the mycosis fungoides subclassification, a rare form of NHL. Johnson called the Monsanto hotline in November 2014 to determine if his condition was related to his exposure to Ranger Pro. His statement was taken by a representative with no further communications occurring.

In January 2015, Johnson was further diagnosed with squamous cell cancer, developing "nodules, plaques, and painful lesions" all over his body. When raising his concerns with his supervisor about the connection between his cancer and the Ranger Pro incident, his supervisor expressed shock that Johnson had not previously known about the cancer-causing nature of the products. Johnson continued to spray Ranger Pro after his diagnosis and had a second direct exposure when a backpack sprayer leaked through his clothes and onto his back. Johnson last used Roundup and Ranger Pro in January 2016, shortly before quitting his job with the Benicia School District. Johnson filed his product liability lawsuit in January 2016, and the trial began in June 2018.

In trial court, Johnson sought recovery claiming that Monsanto's Roundup products contained a design defect and provided inadequate warnings. A large portion of the testimony was based on IARCs monograph, with Dr Christopher Portier, who served on IARCs glyphosate panel, testifying for Johnson. On the third day of deliberations, the jury reached a verdict and ruled in Johnsons favor on all three liability theories: that Monsanto failed to adequately warn on the product's potential dangers, both strict liability and for negligently failing to warn, and that Monsanto's products have design defects. The jury awarded Johnson $39.3 million in compensatory damages and $250 million in punitive damages. The judge later reduced the punitive damages awarded to $78.5 million. Monsanto appealed the decision in April 2019 and the appellate trail began in June 2020. Monsanto lost the appeal, but damages were reduced to $20.5 million.

Hardeman v. Monsanto Co.: The second trial, and first federal trial, was held in the Northern California District Court. The case was the first out of the bellwether trial of federal cases consolidated in a multidistrict litigation. Edwin Hardeman, who used Roundup beginning in the 1980s through 2012, sued Monsanto alleging a connection between his Roundup usage and his diagnosis of NHL in 2015. The Hardeman case was one of approximately 5,000 federal cases alleging that Roundup causes NHL. The Judicial Panel on Multidistrict Litigation consolidated the cases for pretrial proceedings in the Northern District of California, with Hardeman's case was the first to go to trial.

The jury found Hardeman's exposure to Roundup as a substantial factor in causing his NHL, and awarded approximately $80 million, which would later be reduced to $20 million. Monsanto appealed the decision to the 9th Circuit Court of the United States, arguing that Hardeman's claims were preempted by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), given the Environmental Protection Agency's (EPA) registration of glyphosate, approval of the Roundup label, and classification of glyphosate as non-carcinogenic. This topic arose in the trial court as a motion to deny, which was denied by the court.

For a pesticide to be used in the United States, it must be registered with the EPA. The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) mandates that pesticides must pass safety and health standards. To be approved, a pesticide manufacturer performs product tests addressing toxicity, human health, and environmental impact data that must be submitted to the EPA.

In the appellate trial, the court upheld the lower court verdict, finding that Roundup was a substantial factor in Hardeman's contraction of NHL, and concluded that FIFRA does not preempt state law claims. Monsanto petitioned the Supreme Court to review which the Court denied. Since Hardeman was a bellwether trial, this denial brought major implications to further cases since failure-to-warn claims under state law are one of the only avenues for legal relief for Monsanto (Motz, 2023).

Pilliod et al., v. Monsanto Co.: In the third major case, a couple, Alva and Alberta Pilliod, each developed NHL after years of utilizing Monsanto's Roundup products. The Pilliods used Roundup on four residential properties, beginning with their primary residence in 1982. The Pilliods estimated they sprayed a gallon of Roundup on their primary property each week, for nine months of the year, until 2011. Concerning the three other properties; one was sprayed with two gallons every week for nine months of the year for a total of two years, another was sprayed with one gallon a month nine times a year for ten years, and the final was sprayed with a total of nine gallons over the course of two years. In 2011, Alva was diagnosed with stage IV

https://doi.org/10.1017/aae.2025.15 Published online by Cambridge University Press

large B-cell lymphoma in his bones, a common but aggressive type of NHL. In 2015, Alberta was diagnosed with large B-cell lymphoma, which had presented in her central nervous system.

In 2017, the Pilliods sued Monsanto alleging use of the companies Roundup products caused their development of NHL. The couple sued for compensatory and punitive damages and asserted claims for design defect and failure to warn, based on Monsanto's labeling, marketing, and promotion of Roundup. Monsanto denied the claims that their product can cause NHL and further denied there was a basis to warn consumers. The trial occurred from March through May of 2019 and addressed two primary issues: whether Monsanto knew or should have known that Roundup causes cancer at the time the Pilliods used the products, and whether Roundup played a substantial part in causing the Pilliods development of cancer. The jury decided in favor of the Pilliods and awarded Alva over $18 million and Alberta over $37 million in compensatory damages and awarded each $1 billion in punitive damages. After judgment, Monsanto filed a motion for a new trial claiming the weight of the evidence did not support the verdicts, that the damages awarded were excessive, and that there had been procedural irregularities. The trial court conditionally granted the motion for a new trial unless the Pilliods accepted a reduced judgment. The reduced judgment was accepted and the Pilliods reserved the right to appeal the reduction if Monsanto appealed the case. Monsanto appealed and the Pilliods cross-appealed regarding the judgment reduction. The California Court of Appeals, California Supreme Court, and the Supreme Court of the United States all rejected Monsanto's appeal petition.

Cite this article: Rosselle, M., K.A. Schaefer, H. Shear, and B. McFadden (2025). "The Effects of Class-Action Lawsuits on California Glyphosate Usage." *Journal of Agricultural and Applied Economics*. https://doi.org/10.1017/aae.2025.15