HEAT REGULATION AND LABOR MARKETS: CAUSAL EVIDENCE FROM CALIFORNIA'S 2015 SAFETY STANDARD *

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ABSTRACT

Workplace heat safety standards are an increasingly important response to climate change, yet concerns remain that they impose economic costs. This study evaluates California's 2015 enhancement of the Heat Illness Prevention Standard using county-level data from 2010–2019 and a difference-in-difference-in-differences (DDD) design. We find no clear evidence of adverse effects on employment or wages in heat-exposed industries. Instead, the results indicate sector-specific pathways of seasonal adjustment. In construction, no immediate effect is observed, but within one to two years firms began to reduce labor inputs during the hottest quarter, consistent with a gradual learning process. In natural resources and mining, similar seasonal moderation was already evident before the regulation; the policy appears to have reinforced existing practices rather than introduced new ones. These results suggest that large negative impacts are unlikely, while seasonal adjustments consistent with stable annual outcomes are more plausible. The evidence indicates that climate-related workplace regulation does not operate as a uniform cost shock but interacts with industries' adaptive capacity. The policy implication is that well-designed heat safety standards can protect workers and support targeted adaptation without undermining overall labor market performance, provided sectoral heterogeneity is recognized.

Keywords Climate Adaptation · Occupational Safety · Labor Markets · Difference-in-Differences-in-Differences (DDD) · Heat Regulation

* *URL*: https://ayaka-qc.github.io/

1 Introduction

Climate change is one of the most pressing challenges of the 21st century, with increasingly frequent and severe heat waves threatening both public health and economic activity. A substantial body of research shows that high temperatures can adversely affect macroeconomic outcomes, from agricultural and industrial output to overall economic growth (Dell et al., 2012; Burke et al., 2015). Outdoor workers in sectors such as construction and agriculture are particularly vulnerable, as extreme heat reduces productivity and poses serious health risks. For example, construction tasks performed in direct sunlight often experience decreased productivity during extended periods of high temperatures (Dell et al., 2012; Burke et al., 2015), and workers under intense heat strain face higher risks of heat-related illness or even heat stroke and death (Han et al., 2024; Rossi et al., 2025). In response, governments have implemented Heat Illness Prevention Standards requiring measures such as shaded rest areas and shortened working hours. However, these policies have raised concerns among employers, who argue that compliance increases labor costs and may reduce employment or wages. This perceived trade-off between occupational safety and economic outcomes remains central to ongoing policy debates and highlights the need for rigorous, evidence-based evaluations.

California has played a leading role in establishing protections against workplace heat exposure. In 2005, it became the first U.S. state to adopt a comprehensive Heat Illness Prevention Standard (HIPS) for outdoor workers. The regulation was further strengthened in May 2015, when "high-heat conditions" were formally defined as days exceeding 95°F (35°C), and additional employer responsibilities were introduced. These included pre-shift safety meetings, access to shade and drinking water, 10-minute cool-down breaks every two hours, and active worker monitoring. These expanded requirements likely increased compliance costs and may have affected employment and wage patterns, particularly in regions with more frequent high-heat days.

Previous studies have examined the health and labor market effects of California's original 2005 heat regulation. For example, Dean and McCallum (2025) find that while heat standards can reduce fatalities, their effectiveness depends on the clarity of the rules and the strength of enforcement. Focusing on economic outcomes, Behrer et al. (2024) report that the 2005 implementation was followed by modest wage declines and neutral to slightly positive employment effects, raising questions about claims of significant economic harm. However, existing research has primarily addressed the original 2005 standard. The labor market impacts of the 2015 enhancement remain understudied. As extreme heat events become more frequent, evaluating the effects of this regulatory expansion is both timely and policy-relevant.

This study provides the first comprehensive causal evaluation of the labor market effects of California's 2015 enhanced heat regulation. Using county-level panel data from 2010 to 2019, we employ a difference-in-difference-in-differences (DDD) design to estimate how the policy shaped the relationship between extreme heat exposure and labor market outcomes—specifically employment and total wages—in the construction and natural resources/mining sectors.

Standard economic theory offers competing hypotheses. On one hand, increased compliance costs may lower employment or wages. On the other, improvements in safety and productivity—viewed as job amenities—may generate more nuanced or positive effects. This study provides empirical evidence to assess these possibilities.

Our findings challenge a simple cost-based narrative. Instead, they reveal a dynamic and heterogeneous process of adaptation that differs by industry.

This paper addresses the following research questions:

- Did California's 2015 heat regulation reduce or enhance employment and wages in heat-exposed industries?

- How did adaptation pathways differ between industries with distinct seasonal patterns?
- To what extent can the regulation be interpreted as promoting targeted seasonal adjustment rather than broad economic costs?

We document two main results. First, the regulation was followed by a delayed but persistent positive effect on employment in the construction industry. Second, we find no discernible effect on employment in the natural resources and mining sector, though a modest positive trend in total wages is observed. This divergence, we argue, reflects contrasting adaptation pathways: the construction sector undertook a multi-year adjustment process to develop new seasonal labor management strategies, while the already adaptive natural resources sector reinforced its existing seasonal practices.

These findings contribute to the growing literature on labor markets and climate adaptation by showing that safety regulations can trigger sector-specific adjustments rather than uniform economic costs. They emphasize that the economic consequences of climate adaptation policies are mediated by industries' pre-existing adaptive capacity, underscoring the importance of accounting for sectoral differences in policy design and evaluation.

2 Background and Literature Review

2.1 California's Heat Illness Prevention Standard

As climate change accelerates, heat exposure has become an increasingly salient occupational hazard, particularly for outdoor and high-risk workers. California has played a leading role in developing regulatory protections in this area. In 2005, it became the first U.S. state to adopt a comprehensive Heat Illness Prevention Standard (HIPS) for outdoor workers. The regulation was further strengthened in May 2015, following a multi-year period of public debate and regulatory review. Momentum for the revision grew in 2013, spurred by union advocacy and heightened public concern over workplace heat incidents. In July 2013, labor unions and public health advocates formally petitioned Cal/OSHA for an emergency amendment to strengthen the standard, a move that attracted significant media attention (Public Citizen and United Farm Workers, 2013; Penn, 2013). During 2013 and 2014, California's Division of Occupational Safety and Health (Cal/OSHA) held a series of advisory meetings and public hearings, signaling to employers that stricter standards were likely.

The revised standard, which took effect in May 2015, was considerably more stringent. It formally defined "high-heat conditions" as days with temperatures at or above 95°F (35°C) and introduced new obligations for employers in sectors such as construction, agriculture, landscaping, and oil and gas extraction (California Code of Regulations, 2015). These included mandatory pre-shift safety meetings, provision of drinking water, guaranteed access to shade, and continuous active monitoring of workers. The enhanced requirements, particularly structured rest cycles and monitoring, likely increased compliance costs and affected daily operations, creating conditions for the labor market adjustments examined in this paper.

While the regulation's primary aim is to reduce heat-related illness and fatalities, its economic consequences remain uncertain. The 2022 Standardized Regulatory Impact Assessment (SRIA) for California's proposed indoor heat regulation cited the 2015 outdoor HIPS as precedent, projecting modest compliance costs and limited employment effects (Metz et al., 2021). This reflects a regulatory expectation that such standards can be met without substantial labor market disruption—an assumption that warrants empirical evaluation.

2.2 Related Literature on Heat Exposure and Labor Markets

A growing body of research has documented the adverse effects of heat exposure on labor productivity, workplace injuries, and long-term economic outcomes. At a macroeconomic scale, a robust literature demonstrates that high temperatures negatively impact economic growth and output. For instance, Deryugina and Hsiang (2014) find that daily temperature significantly affects annual income in the United States, suggesting that even advanced economies have not fully decoupled from environmental conditions and that autonomous adaptation has been limited. The relationship is fundamentally non-linear, with economic productivity declining sharply above moderate temperature thresholds globally (Burke et al., 2015).

At the microeconomic level, heat directly affects both individual behavior and firm-level decisions, providing the underlying mechanisms for these aggregate impacts. On the individual side, heat stress reduces labor supply by causing workers to reallocate time away from work, especially in physically demanding or outdoor occupations (Graff Zivin and Neidell, 2014). A systematic review by Rossi et al. (2022) confirms that heat stress is the primary occupational risk for outdoor workers, leading to a high prevalence of heat-related symptoms and illnesses. Focusing specifically on the construction sector, a recent meta-analysis by Han et al. (2024) quantifies this impact, concluding that 60% of construction workers experience significant productivity loss due to heat exposure. These findings establish a strong medical and economic rationale for policy interventions aimed at protecting vulnerable workers.

In the absence of regulation, firms and sectors also exhibit adaptive responses, though these are often limited or come with significant trade-offs. Li et al. (2020) show that firms adapt to long-term warming trends by reducing employment and closing establishments, a "retreat" strategy that may not be socially optimal. In agriculture—a critical outdoor industry—Burke and Emerick (2016) find that farmers have largely failed to mitigate the negative impacts of extreme heat on crop yields. This failure of autonomous adaptation highlights a central rationale for our study: policy-driven interventions may be necessary when market-based responses are insufficient to protect both workers and productivity.

The effectiveness of regulatory design has also been highlighted in occupational safety research. Behrer et al. (2024) evaluate California's original 2005 standard and find that while injury rates declined, the economic impacts were modest, with slight wage decreases and neutral to positive employment effects. Focusing on severe health outcomes, Dean and McCallum (2025) show that the strengthened 2015 standard significantly reduced work-related fatalities, underscoring the importance of regulatory stringency. Case evidence from Texas further illustrates this point: removing a key component (medical surveillance) led to a resurgence of heat-related illnesses (Perkison et al., 2024) [2]. Indeed, the experience with California's 2015 outdoor regulation has become a key precedent, informing the economic impact assessment for the state's proposed indoor heat regulation (Metz et al., 2021).

Taken together, the literature suggests three key insights: (i) extreme heat imposes substantial economic and health risks, (ii) autonomous adaptation is often insufficient, and (iii) the effects of regulatory interventions depend heavily on their design and enforcement. Building on these insights, our study contributes in two ways. First, we examine the dynamic impacts of California's 2015 revised standard on employment and total wages. Second, we analyze heterogeneous adaptation pathways across industries, contrasting the construction sector's gradual learning process with the natural resources sector's immediate reinforcement of seasonal practices. By investigating these

[2] We include Texas as part of our control group because no state-wide standard was adopted. The Perkison et al. program was implemented at the municipal level, and we therefore treat it as complementary evidence rather than a confounding factor, noting its different institutional scope compared with California.

sector-specific processes, we provide timely evidence on the labor market effects of climate-related workplace policies, offering implications for both economic theory and policy design.

3 Data and Descriptive Statistics

3.1 Data Sources and Sample Period

We construct a county-level panel dataset covering January 2010 to December 2019 to evaluate the labor market effects of California's 2015 revision of the Heat Illness Prevention Standard (HIPS). We restrict the analysis to this period because including 2005–2009 would likely violate the parallel trends assumption, given substantial pre-existing differences between California and the control group, compounded by the economic disruptions of the 2008 financial crisis.

The dataset integrates three types of publicly available sources:

- **Labor market statistics** from the U.S. Bureau of Labor Statistics (BLS). QCEW provides monthly employment counts (embedded in quarterly files) and quarterly wage data by `Ownership` and `Industry`. From this source, we compute quarterly employment, average weekly wages, and total quarterly wages. In addition, the Local Area Unemployment Statistics (LAUS) provide county-level annual averages of the civilian labor force and employment, which we interpolate to quarterly frequency for use as controls.
- **Meteorological data** from the ERA5-Land reanalysis dataset. Daily temperature records are aggregated to monthly averages, and then further to quarterly counts of extreme heat days (defined as days above 95°F).
- **Geographic data** for spatial aggregation at the county level.

To ensure comparability across outcomes, all labor and climate variables are harmonized to a quarterly frequency. This approach avoids excessive short-term variation in monthly specifications while preserving the seasonal dynamics central to our design.

3.2 Heat Exposure

Heat exposure is measured using the ERA5-Land monthly averaged reanalysis dataset provided by the Copernicus Climate Data Store. We use the "2m temperature" variable, which represents air temperature measured two meters above the surface. The original dataset is on a high-resolution grid ($0.1^\circ \times 0.1^\circ$). To align with county-level data, we aggregate temperatures spatially using county boundary shapefiles from the U.S. Census Bureau (GeoJSON format), and calculate the number of "hot days" per month—defined as days with maximum daily temperature above 95°F—for each county by averaging grid points within county boundaries.

3.3 Sectors of Interest and Data Limitations

We focus on sectors with high outdoor labor intensity—construction and natural resources and mining—which are most directly affected by heat regulation. Within QCEW, we restrict the sample to `Ownership = Private` to exclude public-sector employment, and we select the broad industry groups `Construction` and `Natural Resources and Mining`. Although QCEW provides comprehensive coverage for most industries, agricultural employment is generally absent from the publicly available "Industry" tables due to institutional and statistical limitations. Many agricultural employers and workers are not covered by state Unemployment Insurance programs, the primary data source for QCEW. Partial agricultural data may exist at state or county levels, but robust analysis requires alternative sources such as the USDA Census of Agriculture or the National

Agricultural Workers Survey (NAWS). Given these limitations, we restrict our analysis to the two sectors that can be examined more consistently within QCEW.

3.4 Treatment and Control Groups

The treatment group comprises all 58 counties in California (CA), where the revised heat illness prevention standard took effect in May 2015. The potential control group consists of all counties in other Western states—Arizona, Colorado, Idaho, Montana, New Mexico, Nevada, Oregon, Texas, Utah, Washington, and Wyoming—none of which implemented comparable statewide heat regulations during the study period. We select these states to ensure a control group is established, guided by several criteria which enhance the plausibility of the parallel trends assumption.

First, these states share significant climatic similarities with California, including large regions characterized by arid or semi-arid conditions susceptible to extreme heat events. Second, they exhibit comparable industrial structures, particularly in the American West's economy where sectors like construction, agriculture, and natural resources & mining play a more prominent role compared to eastern or midwestern states. Third, geographic proximity facilitates economic integration and labor mobility across state lines, making these states a more relevant comparison group. For instance, including Texas is crucial as it represents a large, economically significant state with a major construction sector and substantial heat exposure, providing a robust point of comparison. By selecting states that share these underlying characteristics, we enhance the plausibility of the parallel trends assumption, which is fundamental to our identification strategy.

3.5 Outcome Variables and Descriptive Statistics

The outcome variables include county-level industry employment, average weekly wages, and total quarterly wages per industry. Table 1 presents summary statistics for the pre-treatment period (2010–2014), allowing assessment of potential selection bias.

California counties differ substantially from the control group. They have higher population density and median household income, while climatic conditions (average extreme heat days) are broadly similar. Panels B and C highlight disparities in employment and wages across industries prior to the policy intervention, suggesting that a simple DiD approach may yield biased estimates.

To address this, we employ inverse probability of treatment weighting (IPTW) to adjust for observable differences and construct a statistically comparable control group. In addition, to test whether heat regulations have stronger effects during extreme heat, we implement a difference-in-difference-in-differences (DDD) model using the number of extreme heat days per month as a measure of treatment intensity. This design isolates causal effects along three dimensions: treated versus control counties, pre- versus post-policy periods, and variation in heat exposure.

4 Empirical Strategy

The objective of this study is to estimate the causal effect of California's 2015 enhanced heat regulation on labor market outcomes. Simple pre–post comparisons within California risk confounding by contemporaneous shocks, while comparisons with other states suffer from persistent cross-state differences in climate, industry composition, and demographics. To address these issues, we adopt a Difference-in-Difference-in-Differences (DDD) framework combined with matching and Inverse Probability of Treatment Weighting (IPTW). This design improves covariate balance, strengthens the credibility of the parallel trends assumption, and exploits variation in heat exposure to identify the policy's effect.

Table 1: Descriptive Statistics: Treatment vs Control Groups (2010-2019)

	Treatment (CA)		Control (Others)	
Variable	Mean	Std. Dev.	Mean	Std. Dev.
Panel A: County-Level Covariates				
Employment (thous.)	173 826.1	490 964.5	31 328.6	136 240.9
Unemployment Rate (%)	10.1	2.9	12.6	2.0
Median Household Income ($)	58 347.7	16 334.7	48 676.8	11 257.9
Poverty Rate (%)	15.6	5.0	15.8	5.7
Population Density (per sq. km)	259.9	912.1	35.6	122.8
Hot Days per Quarter	3.9	11.0	3.7	9.6
Panel B: Construction Industry				
Employment (thous.)	11 304.3	21 282.3	2397.2	9809.3
Average Weekly Wage ($)	1003.5	317.8	716.6	390.8
Total Quarterly Wages ($)	190 812 541.3	375 085 991.5	33 145 345.9	155 561 050.1
Panel C: Natural Resources & Mining				
Employment (thous.)	7507.1	13 833.9	1114.0	4046.8
Average Weekly Wage ($)	728.5	303.6	909.2	564.2
Total Quarterly Wages ($)	63 930 840.3	116 672 502.0	21 869 018.4	163 112 688.3

Notes: Descriptive statistics are calculated for county-level data (excluding statewide aggregates) in the pre-treatment period (2010–2014). Population density has been corrected from people per square mile to people per square kilometer. Employment figures are in thousands. Treatment group consists of California counties, while control group includes counties from other western states (AZ, CO, ID, MT, NM, NV, OR, TX, UT, WA, WY).

4.1 Matching-IPTW DDD Approach

Our empirical analysis proceeds in two stages. First, we employ a matching procedure to restrict the control group to counties comparable to California along key pre-treatment dimensions (climatic, demographic, and economic). This reduces heterogeneity in the control pool and improves comparability. Second, within this matched sample, we implement IPTW. We estimate propensity scores using a logistic regression of county treatment status on pre-2015 covariates, construct stabilized inverse probability weights, and trim extreme weights at the 1st and 99th percentiles. This re-weighting further improves balance between California and the control group.

Using the matched and re-weighted sample, we estimate the following DDD model:

$$Y_{ict} = \alpha_i + \tau_t + \gamma\big(\text{Treated}_i \times \text{Post}_t \times \text{HotDays}_t\big) + \delta\,\text{HotDays}_t + \epsilon_{ict}, \tag{1}$$

where Y_{ict} denotes the labor market outcome (e.g., employment or wages) for county i, industry c, and time t. α_i are county fixed effects, and τ_t are time fixed effects capturing common shocks. Treated_i is an indicator for California counties, Post_t is an indicator for the post-2015 period, and HotDays_t measures quarterly heat exposure. The coefficient of interest, γ, captures the differential effect of extreme heat on labor market outcomes in California relative to the control group before and after the regulation. Standard errors are clustered at the county level.

Labor market outcomes from QCEW are originally reported at the quarterly level. Although heat exposure is available monthly, we aggregate both labor outcomes and heat days to the quarterly level for consistency. Monthly outcomes introduce excessive pre-treatment variation and unstable pre-trends, while annual outcomes overly smooth seasonal variation. Quarterly aggregation preserves seasonal patterns while maintaining credible parallel trends.

4.2 Dynamic Effects and Event Study

To examine the time profile of the policy's impact and assess the parallel trends assumption, we estimate an event study specification:

$$y_{ict} = \alpha_i + \tau_t + \sum_{k=-m}^{q} \delta_k(\text{Treated}_i \times \mathbb{I}(t = k)) + \epsilon_{ict},$$

where $\mathbb{I}(t = k)$ are indicators for each time period k relative to the quarter of policy implementation. The period immediately before the policy ($k = -1$) is omitted and serves as the reference category. Each coefficient δ_k is interpreted relative to this baseline.

This specification serves two purposes:

1. **Testing for Pre-Trends:** The coefficients for pre-treatment periods (δ_k with $k < 0$) should be statistically indistinguishable from zero, supporting the parallel trends assumption.
2. **Estimating Dynamic Effects:** The post-treatment coefficients (δ_k with $k \geq 0$) trace the trajectory of the treatment effect over time, indicating whether it was immediate, delayed, or evolving in magnitude.

4.3 Validation of the Parallel Trends Assumption

The key identifying assumption in our DDD strategy is that, absent the regulation, labor market outcomes in California would have trended parallel to those of the (re-weighted) control group. While this assumption is untestable, we assess its plausibility using the pre-treatment coefficients (δ_k with $k < 0$) from the event study.

Our primary validation is a joint F-test of the null hypothesis that all pre-treatment coefficients equal zero, providing a formal test of systematic differential trends before the policy. Results of this test are reported at the beginning of the Results section (Section 5.1). In addition, visual inspection of the event study plots (discussed in Section 5.3) provides complementary graphical evidence.

5 Results

5.1 Validation of the Parallel Trends Assumption

The credibility of our Difference-in-Difference-in-Differences (DDD) estimates depends on the parallel trends assumption: in the absence of the 2015 regulation, labor market outcomes in California would have followed the same trend as those in the control states. To formally assess this assumption, we conduct a joint F-test on the pre-treatment coefficients from the event study specification. The null hypothesis is that all coefficients for the pre-policy periods are jointly equal to zero, which would indicate no systematic pre-existing differential trends.

To test robustness, we implement the joint test across three specifications: our main `unbinned` model and two models where the relative time indicators are grouped into 6- and 12-quarter bins. While visual inspection of the event study plots (presented in Section 5.3) also informs the plausibility of the assumption, this section focuses on results from the formal statistical tests.

The results, presented in Table 2, support the validity of the parallel trends assumption for our primary outcomes: employment and total quarterly wages. For both `log_employment` and `log_Total_Quarterly_Wages`, the joint p-values are consistently large and statistically insignificant across all three specifications. This robustness provides strong evidence that our DDD estimates for these outcomes are not biased by pre-existing divergent trends.

By contrast, the tests for `log_avg_weekly_wage` yield extremely small p-values (on the order of 10^{-23} to 10^{-46} for Construction) across all specifications. This decisive rejection of the parallel trends assumption indicates that California and the control states were already on distinct wage growth trajectories before the regulation, likely reflecting macroeconomic factors such as California's differential recovery from the Great Recession. Because our research design cannot separate the policy effect from these confounders, we conservatively exclude average weekly wages from the main analysis and focus on outcomes for which the assumption is credibly satisfied.

Table 2: Joint Test for Parallel Pre-Treatment Trends (Robustness Check)

		Joint p-value		
Industry	**Outcome Variable**	**Unbinned**	**6 Bins**	**12 Bins**
Panel A: Construction				
	Log Employment	0.254	0.652	0.635
	Log Total Quarterly Wages	0.115	0.697	0.465
	Log Average Weekly Wage	8.46×10^{-46} ***	4.50×10^{-23} ***	1.77×10^{-28} ***
Panel B: Natural resources and mining				
	Log Employment	0.085	0.571	0.756
	Log Total Quarterly Wages	0.237	0.793	0.788
	Log Average Weekly Wage	4.08×10^{-39} ***	1.09×10^{-21} ***	1.58×10^{-21} ***

Notes: This table reports the p-values from a joint F-test of the null hypothesis that all pre-treatment coefficients in the event study specification are equal to zero. The columns show p-values from the main unbinned specification and from specifications where relative time is binned into 6- and 12-quarter intervals. A p-value below a conventional significance level (e.g., 0.05) suggests a violation of the parallel trends assumption.
*** indicates rejection of the null hypothesis at the p < 0.001 level.

5.2 Dynamic Effects of the Regulation

Having established the validity of the parallel trends assumption for employment and total quarterly wages, we now turn to the main results from our event study and average post-period analysis. Figures 1 through 4 plot the estimated coefficients (δ_k) for each quarter relative to the policy's implementation in 2015Q1, while Table 3 reports average treatment effects for the entire post-treatment period. Together, these results allow us to examine both the dynamic and aggregate impacts of the regulation.

5.2.1 Construction: A Gradual Learning Process Towards Seasonal Adjustment

The construction industry exhibits a multi-year adjustment process. The event study plots (Figures 1 and 2) suggest an upward trajectory in both employment and total wages during the post-treatment period, though most quarterly coefficients remain imprecise. Crucially, there is no evidence of post-regulation declines in either outcome. This indicates a delayed adjustment rather than an immediate impact. The average post-period estimates support this interpretation: log employment ($\hat{\beta} = 0.0099$, SE = 0.0079, $p = 0.215$) and total quarterly wages ($\hat{\beta} = 0.0095$, SE = 0.0085, $p = 0.264$) are small and statistically indistinguishable from zero. This non-significance highlights the limits of statistical power: while the trend is upward, the estimates do not provide robust evidence of aggregate gains.

5.2.2 Natural Resources & Mining: Reinforcement of Pre-Existing Seasonal Adjustment

The natural resources and mining sector, already characterized by strong seasonality, displays a different pattern. The employment event study (Figure 3) shows volatility and no consistent quarterly trend, while total wages (Figure 4) move slightly upward but remain imprecise. Importantly, there is also no evidence of post-regulation declines in either employment or wages. In contrast, the average post-period estimates indicate significant gains: log employment ($\hat{\beta} = 0.0285$, SE = 0.0076, $p < 0.001$) and total quarterly wages ($\hat{\beta} = 0.0277$, SE = 0.0076, $p < 0.001$). These results suggest that, once volatility is averaged out, the regulation coincided with net increases in employment and wages. However, this interpretation requires caution for two reasons. First, the quarterly estimates are highly volatile, raising the possibility that the average is influenced by a few large positive periods. Second, the pre-treatment coefficients for employment are somewhat negative on average, and the joint pre-trend test yields a borderline p-value (0.085). This suggests potential baseline differences between California and the control states, which could partially inflate the positive post-period averages.

Figures 1 through 4 plot the estimated coefficients (δ_k) for each quarter relative to the policy's implementation in 2015Q1, while Table 3 reports average treatment effects for the entire post-treatment period.

Table 3: Average Post-Treatment Effects (DDD with Hot Days)

Industry	Outcome	Coefficient	SE	p-value
Construction	log employment	0.0099	0.0079	0.215
Construction	log total wages	0.0095	0.0085	0.264
Natural Resources & Mining	log employment	0.0285	0.0076	0.0002
Natural Resources & Mining	log total wages	0.0277	0.0076	0.0003

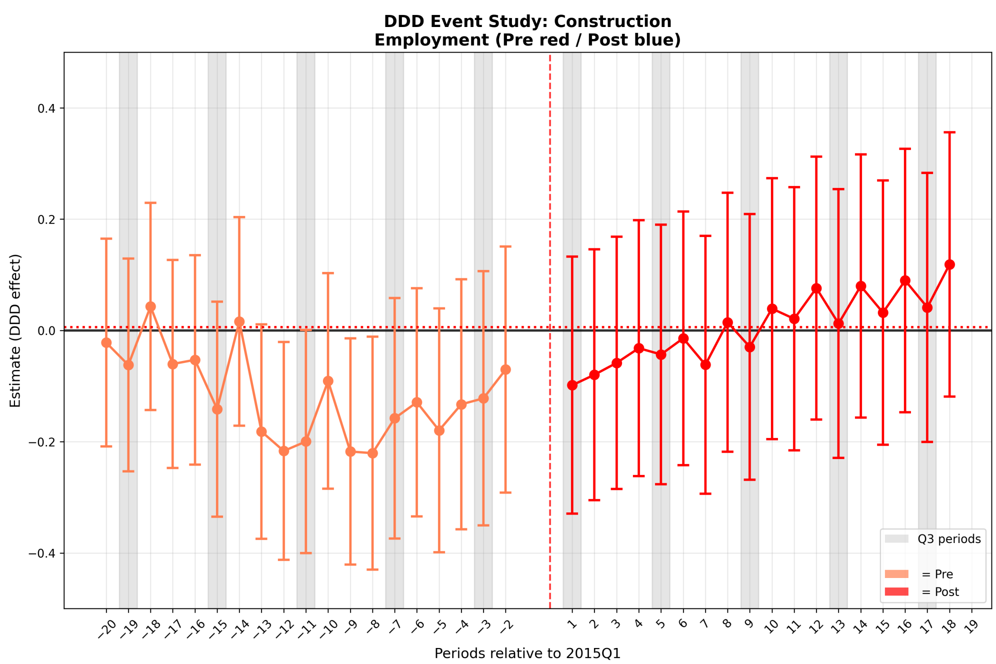

Figure 1: Event Study: Effect on Construction Employment

Notes: This figure plots event study coefficients for construction employment. The quarter immediately before policy implementation (2014Q4) is the omitted reference period. Pre-treatment coefficients show no significant trend, supporting the parallel trends assumption.

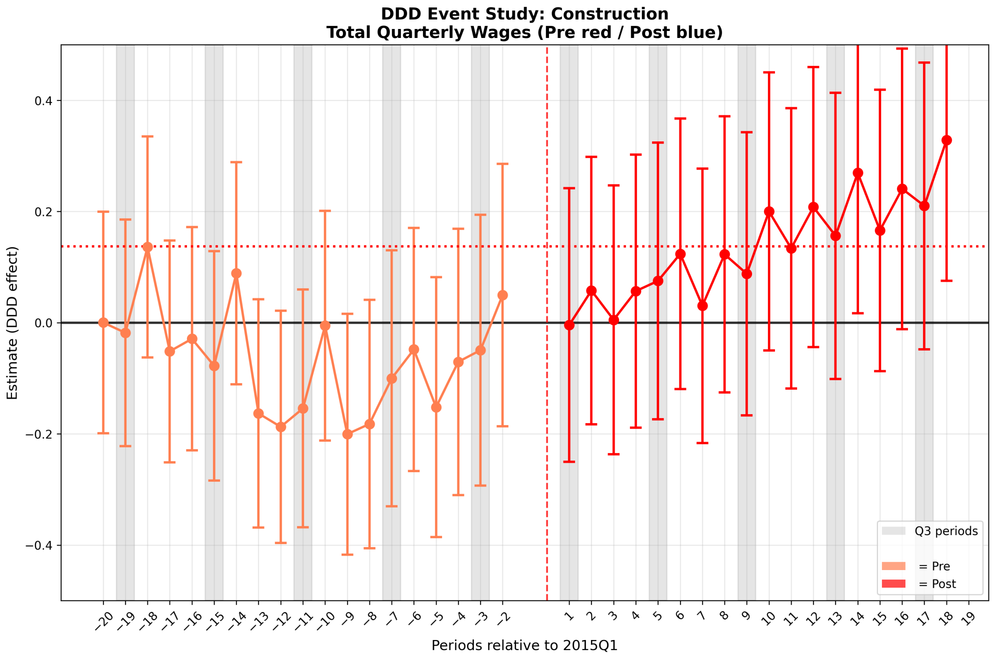

Figure 2: Event Study: Effect on Construction Total Quarterly Wages
Notes: This figure plots event study coefficients for construction total quarterly wages. The quarter immediately before policy implementation (2014Q4) is the omitted reference period. Pre-treatment coefficients show no significant trend, supporting the parallel trends assumption.

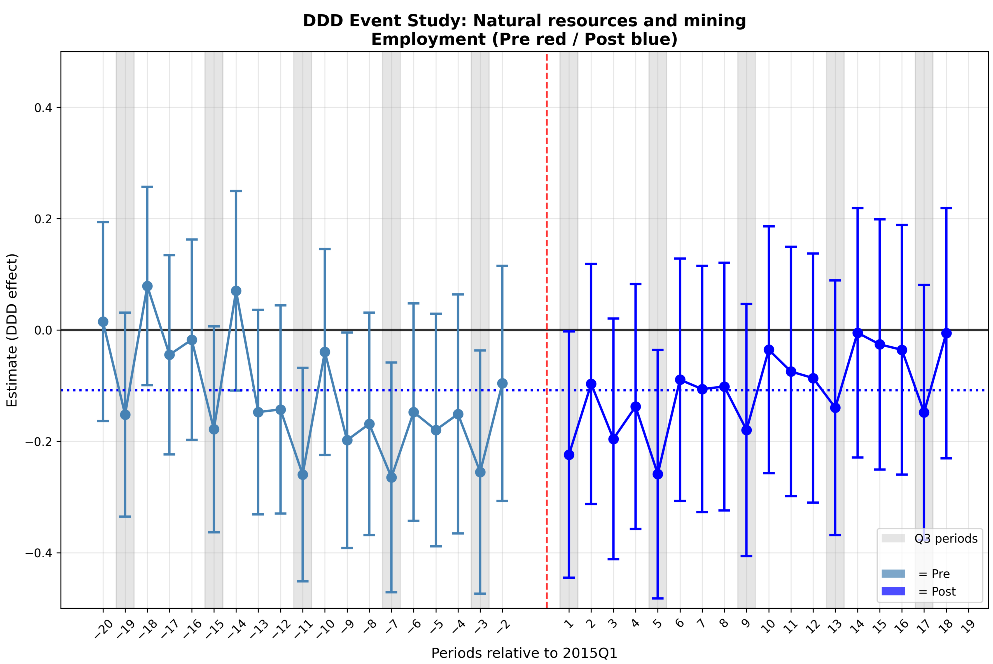

Figure 3: Event Study: Effect on Natural Resources and Mining Employment
Notes: This figure plots event study coefficients for natural resources and mining employment. The quarter immediately before policy implementation (2014Q4) is the omitted reference period. Pre-treatment coefficients show no significant trend, supporting the parallel trends assumption.

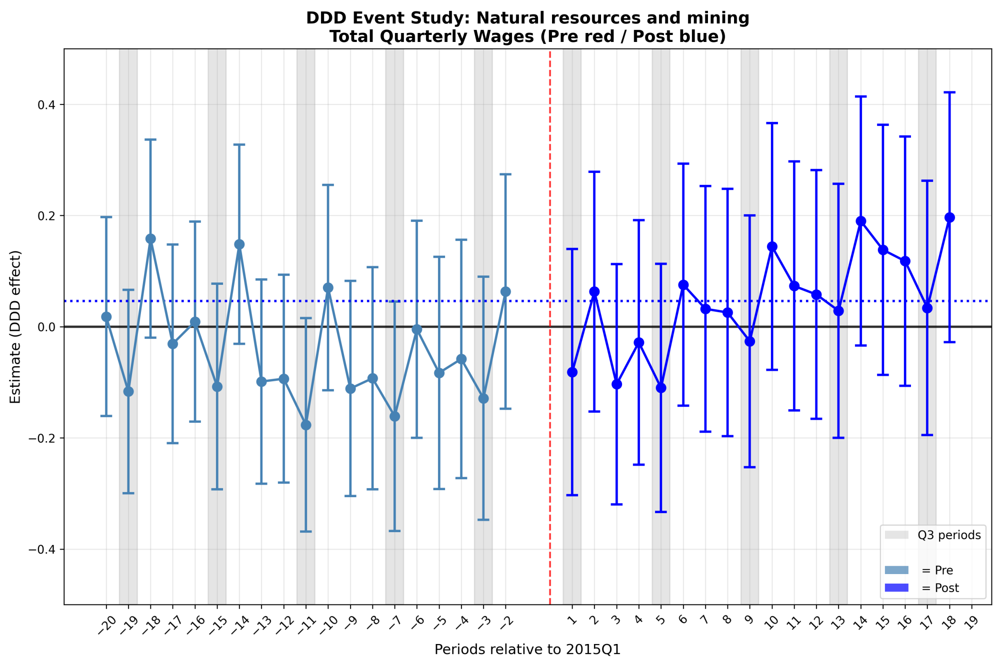

Figure 4: Event Study: Effect on Natural Resources and Mining Total Quarterly Wages
Notes: This figure plots event study coefficients for natural resources and mining total quarterly wages. The quarter immediately before policy implementation (2014Q4) is the omitted reference period. Pre-treatment coefficients show no significant trend, supporting the parallel trends assumption.

5.2.3 Contrasting Pathways to Seasonal Adaptation

While the event study and average post-period results describe overall trends and aggregate effects, the seasonal analysis in Figure 5 reveals adjustment patterns that are not evident in the sector-specific discussions above. These yearly quarterly profiles show how employment and wages were moderated differently across industries in response to peak heat.

For the construction industry, seasonal moderation emerged only gradually. In 2015 and 2016, quarterly effects remained noisy and lacked a clear seasonal structure. Beginning in 2017, however, a systematic decline appeared in the third quarter (Q3), with both employment and wages rising in other quarters but tapering during the hottest months. This pattern indicates that firms required one to two years to adopt new practices, such as shifting project timelines or reorganizing work schedules, that allowed them to reduce labor intensity during peak heat while maintaining annual outcomes.

In contrast, the natural resources and mining sector exhibited an immediate and persistent seasonal adjustment. Figures 3 and 4 show that a Q3 decline was already visible in the pre-treatment period, indicating that firms in this sector had established seasonal practices before the regulation. After 2015, this pattern remained consistent and became more pronounced, suggesting that the regulation reinforced and formalized these existing adjustments. Reinforcement may have occurred through the incorporation of seasonal practices into compliance routines or through wage adjustments to reflect stricter safety measures. Unlike construction, no new seasonal structure had to be developed; rather, pre-existing practices were strengthened in the post-treatment period.

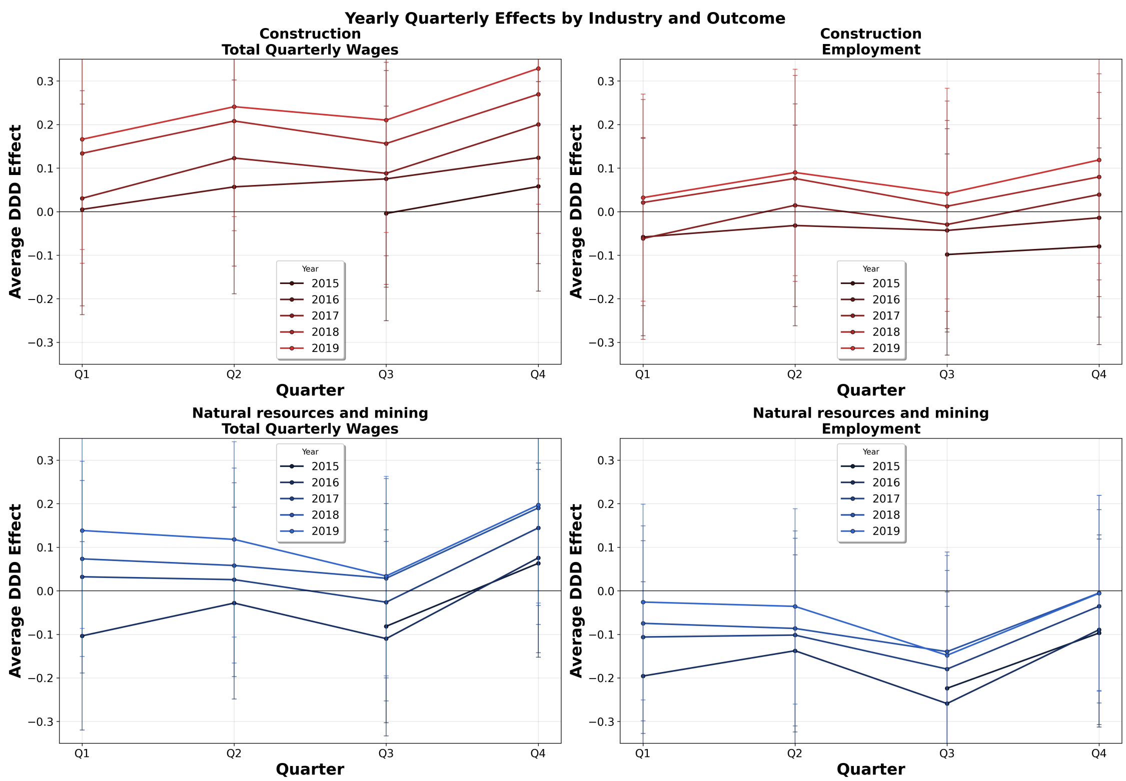

Figure 5: Quarterly Effects by Industry and Outcomes

Taken together, these results indicate that the regulation facilitated seasonal adjustment without reducing overall employment or wages. Both sectors moderated labor inputs during the hottest quarter, but through different pathways: gradual learning in construction versus immediate reinforcement in natural resources and mining. This evidence suggests that heat safety regulation can support targeted seasonal adaptation, limiting peak-heat risks while preserving annual labor market performance, although the mechanisms and timing of adjustment vary by industry.

6 Discussion

This study's findings challenge the view that occupational safety regulations necessarily entail a trade-off with economic efficiency. Rather than a simple story of compliance costs leading to job or wage losses, our analysis uncovers a dynamic and heterogeneous process of labor market adaptation to California's 2015 enhanced heat safety standard. The regulation did not act as a uniform brake on labor market activity; instead, it served as a catalyst for industry-specific adjustments that unfolded over several years.

The most notable result is the divergent adaptation pathways across sectors. In construction, the event study suggests a delayed upward trajectory in employment and wages, though most quarterly coefficients are imprecise and the post-period averages are not statistically significant. This indicates that the evidence is suggestive rather than conclusive. The emergence of a systematic seasonal moderation in Q3 beginning in 2017, however, points to a learning process: firms required time to adjust schedules and project timelines to moderate activity during peak heat while preserving annual outcomes.

In natural resources and mining, by contrast, the average post-period effects are positive and statistically significant, suggesting net increases in employment and wages once volatility is averaged out. Yet interpretation requires caution. The quarterly estimates are highly volatile, raising the possibility that the average is influenced by a few large positive periods, and the joint pre-trend test for employment yields a borderline p-value, suggesting potential baseline differences between California and the control states. Seasonal analysis also shows that the Q3 decline was already present in the pre-treatment period, implying that the regulation primarily reinforced and formalized established adaptive practices rather than generating new ones.

Taken together, these patterns underscore that the effects of a uniform policy are mediated by industry characteristics. The construction industry faced a steeper "learning curve," while the natural resources sector relied on pre-existing seasonal strategies. This highlights a critical policy lesson: the economic consequences of climate adaptation policies depend on the adaptive capacity embedded within sectoral operations.

While this study provides strong evidence, its causal interpretation hinges on the validity of our identification strategy, which faces several challenges. A primary concern is the potential for unobserved, time-varying shocks specific to California that coincided with the policy change. It is possible that the upward pattern in construction partially reflects a unique post-2015 economic boom not fully captured by our control group. However, the central finding—the emergence of a distinct seasonal adjustment pattern—is not easily explained by a general boom. A simple boom would likely exert a positive, year-round pressure on construction activity. It is difficult to argue why such a boom would, beginning two years after the policy's implementation, systematically reduce its relative impact during the hottest third quarter (Q3). This specific temporal pattern, a learned response to moderate labor during peak heat, is a distinctive signature of adaptation to the heat regulation itself. Therefore, even if a statewide boom contributed to the overall positive trend, the emergence of this seasonal dynamic provides strong, suggestive evidence of a genuine behavioral response to the policy.

Beyond this identification challenge, other limitations should be acknowledged. First, our analysis does not include the agricultural sector due to data constraints. Future work using alternative sources such as the National Agricultural Workers Survey (NAWS) is crucial. Second, our county-level approach identifies what happened, but not how firms complied. Distinguishing strategies, such as shifting work hours or investing in cooling technologies, requires firm-level data. Third, our findings are specific to California's context, and extensions to other regions are needed to strengthen external validity.

In sum, this study demonstrates that heat safety regulations can facilitate meaningful labor market adjustments without imposing broad economic costs. The heterogeneity of responses across industries highlights the importance of sectoral context in shaping adaptation pathways, with implications for the design of climate-related workplace policies both in the United States and globally.

7 Conclusion

We draw three main conclusions from this analysis of California's strengthened 2015 Heat Illness Prevention Standard. First, we find no evidence that the regulation reduced employment or wages in either construction or natural resources and mining, indicating that large negative impacts are unlikely. Second, in the construction industry, we observe a gradual upward trajectory in employment and wages, but the average post-period effects are small and statistically indistinguishable from zero. This suggests a learning process with seasonal adjustments in Q3 rather than statistically detectable aggregate gains. Third, in the natural resources and mining sector, the average post-period effects are positive and statistically significant for both employment and wages. However, these results must be interpreted cautiously due to quarterly volatility, borderline pre-trend differences, and the fact that seasonal moderation was already evident before the regulation. This divergence reflects differing adaptation pathways: the construction sector engaged in a multi-year learning process to develop new seasonal strategies, while the natural resources sector reinforced pre-existing, seasonally adaptive practices.

As climate change intensifies, the need for regulations protecting vulnerable workers from extreme heat will only grow. The experience of California offers a critical lesson for policymakers: well-designed safety standards are not inherently "job killers." Instead, they can promote targeted protective behaviors (such as moderating labor intensity during peak heat) while remaining compatible with stable or slightly improved annual labor market outcomes. The central challenge for effective public policy is to design standards that account for the diverse operational realities and adaptive capacities of different industries, thereby supporting a transition toward a safer and more resilient economy. Crucially, the emergence of a targeted seasonal response provides a distinctive signature of the policy's impact, distinguishing it from a general economic boom and underscoring the regulation's effectiveness in altering firm behavior.

Future research should extend this analysis to other sectors, such as agriculture, and investigate firm-level mechanisms of compliance, ranging from technological investments to changes in work organization. It is also critical to move beyond annual averages and examine the outcomes for employees who work on a seasonal basis. The industry-wide stability we observe might not reflect the reality for those hired only during peak heat seasons. A focused study on these workers is needed to see if adaptation strategies are shifting work away from them, potentially making their employment less stable. Such work would deepen our understanding of how labor markets adapt to climate-related regulation and provide evidence to guide both theory and policy design.

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