Adaptation to Climate-induced Regulatory Risk Through Technological Progress

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Abstract

We investigate the impact of climate-induced labor regulations on technology adoption at the plant level, focusing on the Heat Illness Prevention Standard (HIPS) implemented in California in 2005. This standard, designed to protect outdoor workers from heat-related risks, varies in impact across occupations and industries. Employing a triple-difference design, we find that following the implementation of HIPS, the gap in IT adoption between high- and low–heat-exposure plants in California expands significantly relative to the corresponding gap in other states, accompanied by a reduction in employment. The effects are more pronounced in plants where automation is more feasible, labor costs constitute a larger share of production costs, local heat risk is more severe, and firms have greater financial capacity to absorb adjustment costs. The effects are also stronger when firms are more exposed and have limited alternative adaptation options, making IT investment a key adaptation strategy. Overall, our findings highlight the critical role of technological progress in mitigating climate-induced regulatory risk.

Keywords: Climate Change; Climate Adaptation; Heat Risk; Heat Illness Prevention Standard (HIPS); Information Technology (IT); Employment.

JEL Codes: D22, G30, J30, J63, O33, Q54.

"I am mobilizing an all-of-government effort to protect workers...from extreme heat. The Department of Labor, the Department of Health and Human Services, the Environmental Protection Agency, and other agencies will work together to help ensure that the American people have safe and healthy working conditions, provide cooling assistance to homes and neighborhoods, and coordinate with state and local officials to bolster their resilience and address the impacts of this threat."

- Joe Biden, Sep 2021

1 Introduction

The global response to climate change is increasingly recognizing extreme heat as one of its most immediate and consequential threats to human health and productivity. This recognition was underscored at the 2023 United Nations Climate Change Conference (COP28), which introduced its first "Health Day" to highlight the need to integrate climate resilience into labor and public health system. A growing scientific literature documents the rising health and safety risks associated with extreme heat (e.g., Luber and McGeehin, 2008; Mora et al., 2017; Park et al., 2021; Gibb et al., 2024), prompting policymakers to consider stronger workplace protections, particularly for outdoor workers. Yet, despite growing research in climate finance, little is known about how firms adapt to climate-induced labor regulations and, specifically, how such regulations reshape production inputs and operational decisions. We address this gap by studying how firms respond to the United States' first heat-related outdoor workplace safety regulation – the Heat Illness Prevention Standard (HIPS), implemented in California in 2005 – which provides a sharp and policy-relevant setting to analyze adaptation in labor-intensive environments.[1]

HIPS mandates essential safety measures for outdoor workers to mitigate heat-related risks. However, its implementation raises important questions about the economic and operational effects on affected firms. Specifically, the requirements to enhance protections for outdoor workers may increase labor costs, thereby reducing the efficiency of human capital as a production input. Furthermore, HIPS introduces litigation risks and

[1]The *Asunción Valdivia Heat Illness and Fatality Prevention Act (2021)* highlights federal efforts to establish heat safety standards. Yet, as of Nov 2025, no federal standard has been finalized. For institutional backgrounds and perspectives from various regulators, see Section 2 and Internet Appendix Section A.

the possibility of reputational damage for firms.[2] To better understand firms' strategic adaptation to these challenges, we investigate how plants in California utilize information technology (IT) to mitigate the labor costs and production inefficiencies, aligning with broader trends towards automation and technology-enhanced production processes (e.g., Karabarbounis and Neiman, 2014; Acemoglu and Restrepo, 2019).

We define IT investment as encompassing various technological components that enhance operational processes and reduce dependency on labor. Specifically, IT investment includes hardware investments (such as computers, sensors, and related infrastructure), software investments (including systems for workflow automation, enterprise resource planning (ERP), and AI-driven tools), network and monitoring tools (used for real-time monitoring, data collection, and analysis), and process automation (replacing manual tasks and decision-making with IT-driven solutions). While traditional equipment investments may appear as a more direct response to regulatory pressures like HIPS, we argue that IT investments offer a more scalable and flexible alternative.

Through IT investments, firms can effectively reduce reliance on labor-intensive tasks, manage compliance and litigation risks, and enhance operational efficiency within regulatory constraints. Technologies like real-time monitoring, automated workflows, and data-driven resource management allow firms to track operational metrics, adjust schedules, and optimize resource allocation with minimal manual oversight. Under HIPS, such IT solutions reduce the need for manual labor in compliance tasks, such as monitoring heat exposure, scheduling breaks, and maintaining safety protocols. This substitution not only lowers labor costs but also promotes consistent regulatory compliance, providing firms with resilience against potential labor shortages and mitigating the risk of non-compliance in climate-sensitive environments.

Our empirical strategy employs a difference-in-difference-in-differences (DDD) de-

[2]California has been rigorously enforcing HIPS since its implementation, as evident by 45,889 heat-related inspections and 20,947 violations cited between 2005 and 2019, which impose significant operating costs and legal liabilities on firms. Non-compliance with HIPS may result in severe repercussions such as criminal charges, imprisonment, financial penalties, barring managers and safety supervisors from the industry, and damage to firm reputation. We discuss these aspects in detail in Section 2 and Internet Appendix Section C.

sign over the 2002 – 2009 period to estimate the causal impact of California's HIPS implementation on plant-level IT adoption. Our identification comes from comparing changes in IT intensity between high- and low-exposure plants in California before and after HIPS, relative to the corresponding changes among plants in non-California states that were not subject to the regulation. The analysis relies on detailed plant-level data from the Computer Intelligence Technology Database (CiTDB), which provides information on IT capital, employment, location, industry classification, and parent company affiliation. Following prior research, we focus on computers (desktop and laptop PCs) and measure plant-level IT intensity as the natural logarithm of the number of computers per employee (e.g., Bloom et al., 2012, 2014; Tuzel and Zhang, 2021; Ouimet et al., 2025).

The applicability of HIPS to each plant is determined by its production process and geographic location, since the regulation primarily targets outdoor workers in California. We identify each plant' location using county and ZIP code information from the CiTDB. To quantify each plant's labor exposure to heat risk and thus its relevance under HIPS, we draw on industry and occupation-level data on the prevalence of outdoor work. Specifically, following Xiao (2021), we construct the labor exposure measure using data from the Occupational Employment and Wage Statistics (OEWS) and the Occupational Information Network (O*NET). The OEWS provides the number of employees in each occupation within four-digit NAICS (NAICS4) industries, while O*NET assigns work context scores from 1 to 5 to reflect the frequency and intensity of outdoor activity for each occupation. We calculate a weighted average outdoor intensity score for each NAICS4 industry, using occupational employment shares as weights. This composite index serves as our measure of labor exposure to heat risk and enables us to assess each plant's potential exposure to HIPS based on its industry classification.

Using the DDD framework, our analysis shows that the gap in IT adoption between high- and low-exposure plants in California widens significantly after HIPS implementation, relative to the corresponding gap in non-California states. This pattern suggests that the HIPS regulation prompted a relative increase in IT adoption among California plants more heavily exposed to the regulation through their labor composition. The effect is also

economically meaningful: a one-standard-deviation increase in labor exposure is associated with a 1.7% higher increase in IT intensity. These findings are robust to the inclusion of state-by-year and NAICS2-by-year fixed effects, which account for time-varying differences across states and NAICS2 industries. The results also hold under a stronger set of controls, including county-by-year and NAICS4-by-year fixed effects that absorb more granular local and industry-level heterogeneity. Finally, the estimates remain consistent after introducing firm-by-year fixed effects, allowing within-firm comparisons and confirming that the results are not driven by firm-level differences.

Our DDD analysis rests on the assumption that, prior to the implementation of HIPS, trends in IT intensity were similar across high- and low-exposure plants in both California and non-California states, after accounting for heterogeneity across plants, industries, states, and counties. To validate this parallel trends assumption, we examine the dynamics of IT intensity around the HIPS adoption. We find that, before HIPS implementation, IT intensity evolved similarly between high- and low-exposure plants across both groups of states, lending support to the identification strategy. After the policy's enactment, however, the gap in IT intensity between high- and low-exposure plants widens significantly in California, relative to non-California states. Moreover, we observe a second notable increase in 2008, which aligns with the surge in HIPS enforcement actions (e.g., inspections and citations) and outreach efforts during that year. This pattern underscores the importance of regulatory enforcement and communication in amplifying policy effectiveness and prompting adaptation actions.

Furthermore, we decompose the change in IT intensity to examine whether it is driven by adjustments in IT capital, employment, or both. Our analysis shows that the observed increase in IT intensity is the result of both a rise in IT capital and a decline in employment. Specifically, HIPS implementation leads to a 0.8% increase in IT capital and a 0.9% decrease in employment for treated plants with a one-standard-deviation higher labor exposure. These results suggest that firms respond to rising labor-related compliance costs by substituting IT for labor, reinforcing the interpretation of technology adoption as a key adaptation strategy under HIPS.

To better understand the economic mechanisms driving increased IT adoption in response to HIPS implementation, we conduct a series of cross-sectional analyses examining how the effect varies across industries, locations, and firm characteristics. First, we assess the role of automation potential by leveraging measures of occupational automation probability and skill intensity. We find that the positive effect of HIPS on IT adoption is concentrated in industries where substitution between labor and technology is more feasible – namely, industries with higher automation potential and a greater share of low-skilled workers. Second, the effect is more pronounced in labor-intensive industries, where labor accounts for a larger share of total production costs, suggesting that the incentive to automate in response to HIPS-induced labor cost increases is stronger in such settings. Third, we examine the moderating role of local climate conditions and find that the IT response is driven by plants located in counties with greater heat risk, as measured by both historical temperature extremes and projected increases in extremely hot days. This supports the view that the salience and stringency of HIPS enforcement vary geographically, creating differential incentives for employers to adjust production inputs. Fourth, we explore the role of financial constraints and find that the IT response is concentrated among firms with greater financial flexibility, while financially constrained firms exhibit more limited adjustment, highlighting the importance of internal resources in shaping firms' ability to invest in labor-substituting technology. Collectively, these analyses show that the impact of HIPS on IT adoption is not uniform but depends on the feasibility of automation, the importance of labor costs in production, the severity of local heat risk, and firms' capacity to absorb adjustment costs. These cross-sectional patterns provide compelling evidence that the observed increase in IT adoption is a strategic response to regulation-induced labor costs.

In the final part of our paper, we explore whether the observed increase in IT adoption reflects a deliberate adaptation strategy, particularly when other responses are less feasible. While our main analysis highlights technological progress as a response to increased labor-related compliance costs under HIPS, firms may consider alternative strategies such as adjusting work schedules, outsourcing, relocating, or modifying supply chains. While

some of these alternatives may be viable in certain contexts, they are not universally applicable across all business types. For example, shifting work schedules may be a feasible strategy in agriculture but is often impractical in service industries, where operating hours are rigid and customer-facing activities constrain flexibility. We provide supporting evidence that the IT response is concentrated among firms with greater business exposure to heat-exposed industries in California. These firms face stronger incentives to adapt through technology, as other mitigation strategies may be costly or difficult to implement. For example, long-standing ties to local customers, suppliers, and financial partners make relocating operations less viable. Moreover, the strategic importance of their operations in heat-exposed industries reduces the likelihood of exiting or scaling back. These patterns suggest that when firms are more exposed and face limited alternatives, adopting IT becomes a key channel of compliance. This analysis complements our main results and provides further insight into how firm characteristics shape adaptation choices under climate-related labor regulations.

Our study makes several important contributions to the literature. First, it enriches the rapidly expanding field of climate finance (e.g., Bernstein et al., 2019; Hong et al., 2020; Giglio et al., 2021; Stroebel and Wurgler, 2021), particularly the discussions on temperatures (e.g., Addoum et al., 2020; Acharya et al., 2022; Addoum et al., 2023; Acharya et al., 2023; Ponticelli et al., 2023; Pankratz and Schiller, 2024) and regulatory risks associated with climate change (e.g., Ilhan et al., 2021; Seltzer et al., 2025; Bartram et al., 2022; Ivanov et al., 2024). While existing research primarily focuses on carbon-related regulations, our study offers a novel perspective by examining climate-induced regulations targeting extreme heat and associated workplace safety issues. Specifically, we investigate the implementation of HIPS in California that safeguards outdoor workers from climate-induced heat risks, which has been effective in reducing workplace injuries (Park et al., 2021). Our paper extends the discussion by investigating the effects of climate regulations on human capital management at the plant and firm levels, revealing that firms respond to HIPS by substituting IT for labor to mitigate rising compliance costs.

Second, our paper contributes to the literature on adaptation and mitigation strategies

adopted by economic agents in response to climate challenges, as highlighted in studies such as Fankhauser (2017), Dillender (2021), and Lai et al. (2023), which offer valuable insights for businesses adapting to an era of increasing temperatures. More relatedly, Pankratz and Schiller (2024) show that customers terminate existing supplier relationships when suppliers experience heat shocks. Somanathan et al. (2021) finds that onsite climate controls, such as air conditioning, can alleviate heat-induced productivity losses in India. Recent works by Xiao (2021) and Xiao (2023a) examine automation as an adaptation strategy to mitigate the physical risks of extreme heat, i.e., the direct damages of extreme heat to labor and corporate performance. Our research distinguishes itself by closely examining regulatory responses to extreme heat and the impact on the efficiency of human capital as a production input. Moreover, we specifically analyze plant-level technology investments in automation, contrasting with the broader discussions of firm-level capital-labor substitution or general disclosures of automation-related news in their studies. Furthermore, Xiao (2023b) shows that prospective entrepreneurs respond to both physical and regulatory heat risks by reducing entry, leading to an overall contraction in macroeconomic activity. Our analysis reveals that U.S businesses adapt to climate-induced labor regulations by substituting IT for labor to address challenges to their human capital and improve production efficiencies.

Third, this research enhances our understanding of the micro-foundations of production functions, emphasizing the increasing importance of technology in driving automation and shaping the modern capital-intensive economy (e.g., Brozen, 1957; Jones, 2005; Acemoglu and Restrepo, 2019). Our findings corroborate the notion that technological substitution is partly a response to elevated labor costs, which are in turn a consequence of enhanced climate risks and the ensuing regulatory mandates. This insight sheds light on the dynamic relationship between technological advancement and labor economics in the context of climate change and adaptation strategies.

Overall, our study not only provides empirical evidence to theoretical frameworks within these literature but also highlights the practical implications for policymakers and businesses confronting the multifaceted challenges of climate change, technological trans-

formation, and job creation.

The remainder of this paper is structured as follows: Section 2 provides the institutional background; Section 3 details the data, measures, and sample for empirical analysis; Section 4 presents the main results and conducts some robustness checks; Section 5 explores cross-sectional heterogeneity in the effects; Section 6 discusses some additional issues and provides broader insights; and Section 7 concludes.

2 Institutional Background

This section delineates the regulatory landscape governing heat illness prevention in the workplace, starting with the history of the Occupational Safety and Health Administration (OSHA), its approach to heat-related hazards, and the evolution of federal and state-level regulations, with a focus on California rules and their enforcement.[3]

2.1 The Occupational Safety and Health Administration

The Occupational Safety and Health Administration, established under the Occupational Safety and Health Act of 1970 by the U.S. Department of Labor, is mandated to ensure safe and healthy working conditions. Despite its comprehensive safety standards, OSHA lacks a specific mandate for heat illness prevention, a gap underscored by the National Institute for Occupational Safety and Health (NIOSH)'s recommendations since 1972.[4] In the absence of specific standards for heat risks, OSHA can cite the General Duty Clause of the Occupational Safety and Health Act (OSH Act) when dealing with heat-related

[3]We also present views from various regulators on heat-related issues in Internet Appendix Section A, including the House and Senate, the Biden Administration, the Environmental Protection Agency, the Department of Labor, and the National Institute for Occupational Safety and Health.

[4]NIOSH has been recommending OSHA to establish heat stress standards since 1972, but OSHA didn't act on these recommendations. Despite subsequent updates and further suggestions from NIOSH, OSHA has remained unresponsive. Examples of these recommendations are: "*Criteria for a recommended standard: Occupational exposure to hot environments, 1972*," "*Criteria for a Recommended Standard: Occupational Exposure to Hot Environments (Revised Criteria 1986)*," and "*Criteria for a Recommended Standard: Occupational Exposure to Heat and Hot Environments, 2016*." Meanwhile, various public interest groups have made significant efforts to urge OSHA to implement a standard for heat-related workplace safety, yet all have been unsuccessful. Notable is the petition led by Public Citizen available here. OSHA's response is available here.

incidents in the workplace.[5] However, its enforcement is primarily reactive, offering remedies only after incidents of illness or death have already occurred. This enforcement process is lengthy, frequently dependent on the availability of critical documents such as death certificates, autopsy reports, and additional evidence. Additionally, the Occupational Safety and Health Review Commission (OSHRC) imposes stringent criteria for applying the General Duty Clause to heat-related cases, as evidenced in *Secretary of Labor v. A.H. Sturgill Roofing, Inc*.[6] The ruling of this case sets a precedent and significantly limits OSHA's ability to penalize employers for insufficient protections against heat risks in the workplace. Consequently, the application of the General Duty Clause to heat-related cases is severely limited, nearly non-existent. Furthermore, an internal OSHA study conncludes that the General Duty Clause fails to effectively incentivize employers to implement preventive measures against heat-related illness (Arbury et al., 2016).

2.2 Federal Regulations on Heat Illness Prevention

Amidst a growing public health crisis exacerbated by extreme heat, the *Asunción Valdivia Heat Illness and Fatality Prevention Act* was introduced in 2021, compelling OSHA to develop heat-specific safety standards.[7] This legislative push, coupled with the Biden Administration's initiatives following record-setting temperatures in 2021,[8] signaled a

[5] See "*OSH Act of 1970*".

[6] *A.H. Sturgill Roofing, Inc.*, a Dayton, Ohio-based commercial roofing company, faced an OSHA inspection and citation after an employee collapsed and died from heat exposure while working on a roof. The citation included two serious violations: first, for exposing employees to excessive heat under the General Duty Clause of the Occupational Safety and Health Act (29 U.S.C. § 654(a)(1)), and second, for failing to train employees on recognizing and avoiding heat-related illness risks (29 C.F.R. § 1926.21(b)(2)). However, OSHRC overturned both citations (for more details, see *OSHRC Docket No. 13-0224*). OSHRC reversed OSHA's verdicts against Sturgill Roofing, ruling that OSHA failed to establish the existence of heat hazards or feasible means of abatement. OSHRC further criticized OSHA's use of the General Duty Clause in this case. The Commission wrote: *"While practical considerations may have led OSHA, over the years, to rely on the general duty clause in lieu of setting standards, the provision seems to have increasingly become more of a "gotcha" and "catch all" for the agency to utilize, which as a practical matter often leaves employers confused as to what is required of them."*

[7] See "*S.1068 - Asuncion Valdivia Heat Illness and Fatality Prevention Act of 2021*" and *H.R.4443 - Asunción Valdivia Heat Illness, Injury, and Fatality Prevention Act of 2025*. This bill is named after Asunción Valdivia, a farmworker who succumbed to heatstroke in 2004 after working 10 hours in temperatures reaching 105°F.

[8] See "*FACT SHEET: Biden Administration Mobilizes to Protect Workers and Communities from Extreme Heat*" and "*Statement by President Joe Biden on Mobilizing the Administration to Address Extreme Heat*."

proactive shift towards establishing concrete federal regulations for heat illness prevention. However, the rulemaking process, initiated by OSHA's publication of an *Advance Notice of Proposed Rulemaking (ANPRM) for Heat Injury and Illness Prevention*, is intricate and lengthy, reflecting the challenges of translating broad health concerns into actionable workplace standards.[9] As a result, as of May 2025, no federal-level heat illness prevention standards have been established in the U.S.

2.3 State Regulations on Heat Illness Prevention

In the absence of federal standards, states like California, Minnesota, Oregon, and Washington have led the way in establishing heat illness prevention regulations. For instance, Minnesota enacted a heat illness standard in 1997 that exclusively governs indoor workplaces. California was the first to set a standard for outdoor workers through emergency action in August 2005, becoming permanent in July 2006. Washington issued an emergency standard for outdoor workers in 2006 and 2007, solidifying it permanently in 2008. Oregon enacted rules for both indoor and outdoor workers in response to the 2021 summer emergencies, formalizing them in May 2022. Our paper focuses on the risks of heat exposure for outdoor workers due to climate change by analyzing California's heat standards.[10] These standards mandate accessible water and cooling, training for supervisors and workers, and comprehensive risk control and symptom response plans. California's heat standard, due to its pioneering role and impact, serves as the basis for our discussing of regulation, enforcement, and compliance in the next section.[11]

[9] Additional guidance can be found on the *Federal Register*. The rule-making process also involves a legal process that requires the agency to establish that there is significant risk, a standard that is difficult to meet. Marc Freedman, a vice president at the U.S. Chamber of Commerce, said that "*It's very difficult to regulate something like heat exposure...We can all say there's a hazard there, but reducing that to a question of a standard and when an employee is going to be in trouble and what that threshold of exposure is going to be for an employer to protect against is very vexing.*"

[10] Indoor heat can arise from production processes like steel making and cooking. These risks are beyond the scope of our paper because they are endogenous to firms' production processes and are not necessarily caused by climate change.

[11] In Internet Appendix Section B, We review recent updates to heat standards in California and examine state-level developments in heat illness prevention across the United States beyond California.

2.4 California Heat Illness Prevention Standard

2.4.1 Origins of California HIPS

California has been a leader in ensuring employee safety and health, particularly in recognizing heat hazards as significant risks for workers. This recognition led to the state's pioneering move to adopt the first standard for outdoor workplace heat risks in 2005, as outlined in the *California Code of Regulations Title 8, Section 3395*.

The campaign for a heat standard began in 1984 when the Los Angeles Librarians' Guild, joined by over twenty union locals and the Los Angeles Committee on Occupational Safety and Health, petitioned California OSHA (Cal/OSHA) for a statewide heat stress standard. This request emerged from incidents of librarians suffering from heat illnesses in inadequately insulated and cooled libraries. After years of inaction, Cal/OSHA revisited the heat standard issue in the late 1990s, establishing an Advisory Committee with diverse stakeholders to formulate a draft for public commentary. The proposed 2002 standard aimed to protect both indoor and outdoor workers from heat illness. Yet, the board did not advance the standard further.

In 2005, the United Farmworkers (UFW) union and the California Rural Legal Assistance Foundation championed Assembly Bill 805, advocating for a comprehensive heat illness prevention standard. Before the Senate's approval, a severe heat wave causing multiple worker fatalities prompted the state to enact an emergency temporary standard for outdoor workers, later made permanent in 2006.

Overall, this historical oscillation between action and inaction underscores the unpredictable and reactive nature of California's approach to heat illness prevention, culminating in the sudden adoption of HIPS in 2005. More importantly, the emergency use of HIPS represents a significant and plausibly exogenous policy shock impacting exposed California firms and plants.

2.4.2 Requirements of California HIPS

The California Code of Regulations outlines comprehensive requirements for employers to protect outdoor workers from heat exposure. We summarize some key points below.[12]

[1] **Provision of water**. Employers must ensure access to fresh, pure, and suitably cool drinking water at no cost to employees at all times.

[2] **Access to shade**. When the temperature exceeds 80°F, the employer shall maintain enough areas with shade at all times that are either open to the air or provided with ventilation or cooling. Timely access to shade should be available upon an employee's request when the temperature is below 80°F.

[3] **Cool-down rest**. Employees shall be allowed and encouraged to take preventative cool-down rests in the shade to prevent overheating, with no pressure to return to work until they have recovered from any signs of heat illness.

[4] **High-heat procedures**. At temperatures of 95°F or higher, employers must implement specific high-heat procedures, including but not limited to frequent and effective communication between onsite employees and supervisors, a mandatory buddy system, and close monitoring of employee health conditions.

[5] **Emergency Response Procedures**. Effective emergency response procedures shall be implemented, ensuring that clear and precise directions are available for emergency responders, including contacting emergency medical services and arranging for employee transport to medical providers.

[12] More details can be found in "*§3395. Heat Illness Prevention in Outdoor Places of Employment*" and "Heat Illness Prevention Enforcement Q&A." Cal/OSHA has continually revised and increased the stringency of these rules since their initial implementation. Notably, the high-heat procedures were adopted in 2010 and only apply to the following industries: agriculture, construction, landscaping, oil and gas extraction, and transportation and delivery of agricultural products and of construction or other heavy materials (e.g., furniture, lumber, freight, cargo, cabinets, industrial or commercial materials). The temperature threshold for access to shade was 85°F in the 2005 standard and decreased to 80°F in the 2015 revision. Emergency response procedures and acclimatization protocols were more explicitly outlined in distinct clauses in 2015, although the core concepts had already been incorporated into the 2005 version. Since the implementation of HIPS, Cal/OSHA has also undertaken multiple outreach and education campaigns, particularly notable ones in 2010 and 2012.

[6] **Acclimatization**. A new employee in high-heat areas must be closely monitored by a supervisor or designee for the first 14 days of employment.

[7] **Prevention and Training**. Employers must develop and maintain effective heat illness prevention plans and training programs that educate employees about heat hazards, heat illness, abatement measures, and their rights.

2.4.3 Enforcement of California HIPS

Cal/OSHA has rigorously enforced HIPS since its introduction. Figure 1 presents annual inspections, enforcement actions, and outreach activities during our sample period from 2000 to 2009. Values are assumed to be zero prior to the implementation in 2005. In the first year of enforcement, 2005, only 39 heat-related site inspections were conducted, resulting in 2 violations. During 2006 and 2007, Cal/OSHA conducted 1,252 inspections, with 60% resulting in citations. Enforcement intensity rose sharply beginning in 2008, with the number of inspections increasing to 2,586 and then further to 3,574 in 2009.[13] This contrasts sharply with federal OSHA's 142 nationwide inspections resulting in heat-related citations under the General Duty Clause between 2013 and 2017.[14]

Importantly, enforcing HIPS has significantly increased operational costs for businesses. Employers face challenges in maintaining compliance, such as providing sufficient water and shade, as well as medical support and training. For instance, one respondent in the "*Final Performance and Evaluation Report*" of the *California Heat Illness Prevention Campaign* in 2012 complained that - *"Having to follow the buddy rule when the job really only needs one employee, but because they are outdoors and working in field, they have to have a buddy. That costs the company."* Another employer mentioned that supplying enough water was a challenge and the operating costs had increased - *"I have 500 workers and having to keep water within reach and filled to at least half way has made it so that I hire three extra people to just*

[13] For more details, refer to Internet Appendix Section C and Figure C.1.

[14] See "*Extreme Heat and Unprotected Workers*" by Public Citizen. Further, an internal OSHA study by Arbury et al. (2016) finds that federal OSHA had 84 heat enforcement cases in 2012 to 2013 and over 80% employers did not rely on national standard approaches to heat illness prevention.

focus on monitoring and moving water up so that it is within reach of workers."[15]

Additionally, HIPS introduces significant litigation risks and potential reputation damages for employers. Non-compliance can lead to substantial civil and criminal penalties, with fines varying widely based on the severity of the violation, from minor amounts to several million dollars. Noteworthy cases underscore the serious repercussions of failing to adhere to these standards. For example, Merced Farm Labor Contractor was penalized $262,700 due to a worker's heat-related death in 2008.[16]

Furthermore, managers and safety supervisors may be subject to criminal charges, fines, and imprisonment. In the Merced case, the owner Maria De Los Angeles Colunga was sentenced to 40 hours of community service and three years of probation. The safety coordinator pleaded guilty to a felony count of violating a health or safety regulation that requires 480 hours of community service and five years probation.

Survey feedback from Californian employees highlights the positive impacts of strict enforcement of HIPS, noting improved training, communication, and overall treatment by employers. Recent research by Park et al. (2021) indicates a significant decrease in workplace injuries in California following HIPS implementation, with annual injuries reducing from approximately 6,100 to 4,250. This shift is attributed to the fear of legal consequences, demonstrating the efficacy of HIPS in promoting safer working condition.[17]

3 Data, Measures, and Summary Statistics

3.1 Labor Exposure to Heat Risk and HIPS

As discussed in Section 2, the HIPS adopted in California are designed to mitigate heat-related workplace risks for outdoor workers, thereby affecting industries variably based

[15] See more in "California Heat Illness Prevention Campaign - Final Performance and Evaluation Report."
[16] See Internet Appendix Section C.2 for more details.
[17] These substantial litigation risks associated with non-compliance strongly incentivize employers' adherence to HIPS. Several examples of feedback from respondents in the "*Final Performance and Evaluation Report*" include: (1) "*Now [employers] provide training, take care of their people. They want them to feel well and healthy.*"; (2) "*I have seen more communication, that workers are listened to more now. I think it's because of fear of the consequences.*"; (3) "*Now employers are afraid. Before they didn't care, and since many were undocumented they took advantage of them. Now there isn't so much abuse.*"; (4) "*At first they didn't like us to teach this, but after Cal/OSHA fined them they've been helping a little more.*"

on their reliance on outdoor labor in production. Industries employing a higher proportion of outdoor workers are more significantly impacted by HIPS compared to those with fewer outdoor workers. Following Xiao (2021), we construct an index to quantify the intensity of outdoor work required across different industries at the NAICS4 industry level. We then map this index to each plant according to its NAICS4 industry classification, since each plant has its own industry classification and that can be different from the parent firm's main industry classification.

We start by collecting industry-specific occupational data from the Occupational Employment and Wage Statistics (OEWS) provided by the U.S. Bureau of Labor Statistics (BLS). This data includes occupations needed in each industry, the number of employees working in each occupation, and wage estimates for each occupation. Next, we gather information on outdoor intensity for each occupation, both current and historical, from the Occupational Information Network (O*NET) program of the U.S. Department of Labor, focusing on the working context of "*Outdoors, Exposed to Weather*". In this context, O*NET assigns a score to each occupation based on the question - "*How often does this job require working outdoors, exposed to all weather conditions?*" This score captures the frequency of outdoor activities required for workers in each occupation to perform their duties under extreme heat and other weather conditions. The scoring system ranges from 1 (*no exposure*) to 5 (*daily exposure*).[18] A higher score indicates a greater degree of an occupation's exposure to changing climates when performing job duties, meaning that workers in these occupations are more adversely affected by extreme heat and thus benefit more from HIPS protection.

Utilizing the OEWS and O*NET data, we construct an index of labor exposure to heat risk and, consequently, to HIPS in the following way.

$$Exposure_{i,t} = \sum_{o=1}^{O_{i,t}} \left(\frac{Emp_{i,o,t}}{Emp_{i,t}} \times Score_{o,t} \right) \tag{1}$$

[18]Specifically, a score of "1" indicates that workers in this occupation are *never* exposed to any weather conditions during the working process. "2" indicates "*once a year or more but not every month*." "3" indicates "*once a month or more but not every week*." "4" indicates "*once a week or more but not every day*." "5" indicates "*every day*."

where i denotes NAICS4 industry, o denotes occupation, and t denotes year. $O_{i,t}$ is the total number of occupations in industry i and year t. $Score_{o,t}$ is the occupational score of outdoor intensity from the O*NET program for occupation o in year t. $Emp_{i,o,t}$ is the number of employees working in occupation o in industry i and year t. $Emp_{i,t}$ is the total number of employees in industry i and year t. Therefore, this index is a weighted average of all occupations' outdoor scores in a NAICS4 industry, with the weight being the percentage of employees working in a given occupation within an industry.

Table 1 presents selected examples of 30 industries with varying exposure values to heat risk and the implemented HIPS.[19] First, consistent with prior expectations, industries with more blue-collar workers generally exhibit higher levels of outdoor work, such as transportation and freight industries compared to legal and financial industries. Second, high-exposure industries are distributed across a wide range of sectors, including mining, transportation and warehousing, waste management, and various service industries. This pattern underscores the broad impact of high temperatures on the overall economic landscape.[20]

3.2 Plant-level IT Intensity

We obtain plant-level data on IT capital and employment from the Computer Intelligence Technology Database (CiTDB), provided by Aberdeen (previously known as "Harte Hanks"). This dataset include detailed information of each plant's name, location, industry, IT adoption, employment, sales, and parent company. IT adoption covers many IT-related equipment, such as computers, servers, terminals, printers, storage devices, telecommunication platforms, and wide-area network (WAN) equipment. CiTDB collects and maintains the data's accuracy and timeliness through monthly extensive interviews, surveys, and web scraping. This data has became a crucial source of information on IT usage and investment among U.S. firms and is extensively used by large technology firms for sales

[19] The mean is 2.2. The 25^{th} percentile, the median, the 75^{th} percentile are 1.8, 2.0, and 2.4 separately.

[20] For further details on the measure, see Xiao (2021) for a more detailed discussion of the data, the rationale for selecting working contexts, additional examples of occupations and industries with varying exposure levels, the validation process, and the distribution of exposure across labor skill levels, sectors, and counties.

and marketing purpose, which exerts a strong market discipline on data quality. Additionally, it also has been widely used in academic studies on corporate IT investment, including Brynjolfsson and Hitt (2003); Bloom et al. (2012, 2014, 2016); Tuzel and Zhang (2021); Dai and Qiu (2024); Pierri and Timmer (2022); Jiang et al. (2022); Ouimet et al. (2025).

We construct our sample from CiTDB and apply several carefully selected criteria to ensure a robust analysis. First, we focus primarily on HIPS in California due to the regulation's significance, its pioneering nature, and the substantial representation of plants from the state in our sample. Accordingly, we exclude plants located in Washington to avoid confounding effects from the HIPS adopted there in 2006 for emergency use. We also drop plants in non-contiguous U.S. states and territories, as well as those in Washington, D.C. Second, we restrict the sample period to 2002–2009, allowing for a difference-in-difference-in-differences (DDD) analysis around the adoption of HIPS in California in 2005. Third, we exclude plants operating in elementary and secondary education services, finance and insurance, non-profit, public administration, utility, and unclassified industries to maintain the focus and relevance of our sample. This filter helps mitigate concerns related to data imputation, as larger plants tend to have substantially lower levels of imputed data. Finally, we exclude plants with incomplete data on location, industry classification, employment, or IT capital over the sample period, which helps mitigate coverage and survivorship bias.[21] This methodical approach to sample construction aims to create a coherent and representative dataset for analyzing the impact of HIPS on plant-level IT adoption and employment within the targeted industries and regions.

Following prior research, we focus on computers (desktop and laptop PCs) and measure plant-level IT intensity as the natural logarithm of the number of computers per employee (e.g., Bloom et al., 2012, 2014; Tuzel and Zhang, 2021; Ouimet et al., 2025). The advantage of this measure is that the number of computers is consistently available over the sample period and represents a physical input that can be measured uniformly across

[21] Our results are robust to less strict requirements, such as each plant having at least one observation in the pre-HIPS period, one in the post-HIPS period, and one in the HIPS adoption year, 2005.

plants and over time. We also demonstrate the robustness of our results using alternative measures, including scaling the number of computers by sales and counting the number of computers and servers to capture a broader concept of IT use.[22]

3.3 Additional Data

We collect county-level data on total labor force and income from the Bureau of Economic Analysis (BEA), and unemployment rates from the BLS. Daily temperature and precipitation data are obtained from the PRISM Climate Group, covering 481,631 4×4 km grids across the U.S., which we aggregate to the county level. Additionally, we use county-level temperature projections from the CDC, capturing changes in extreme hot days (above 90°F) between the 1976–2005 baseline and the 2016–2045 projection period. To measure industry-level automation potential, we use occupational automation probabilities from Frey and Osborne (2017) and skill measures from the O*NET program. For public firms, firm-level accounting and financial information is obtained from Compustat.

3.4 Summary Statistics

Table 2 reports the summary statistics of key variables used in our empirical analysis. The sample is at the plant-year level and includes 17,375 plants across 10,206 firms from 2002 to 2009.[23] These plants are distributed across 47 states and 2,048 counties, with about 10% located in California. *Log(IT/Emp)* measures plant-level IT intensity and has a mean of -0.707, a median of -0.730, and a standard deviation of 0.561, indicating substantial variation across plants. Furthermore, the median plant's standardized exposure to heat risk (*Exposure*) and thus to HIPS is -0.208, with the upper 95th percentile at 2.145 and the lower 5th percentile at -1.255, highlighting a considerable range in exposure levels across plants.

[22] Another commonly used proxy for IT investment is the plant-level annual IT budget; however, this information is only available from 2007 onward.

[23] We end our sample in 2009 to avoid inconsistencies in the CiTDB data starting in 2010, which may bias our estimation. CiTDB made significant changes to its data construction methodology, including expanding coverage from fewer than 0.5 million to more than 3 million records.

4 HIPS Implementation and Plant-level IT Intensity

4.1 Empirical Methodology

To identify the causal impact of the implementation of HIPS on plant-level IT intensity, we estimate the following empirical models:

$$Y_{p,s,c,i,j,t} = \mu_p + \pi_{j,t} + \beta_1 CA_s \times Post_t + \beta_2 CA_s + \beta_3 Post_t + \delta \boldsymbol{X}_{c,t-1} + \varepsilon_{p,s,c,i,j,t} \tag{2}$$

$$\begin{aligned} Y_{p,s,c,i,j,t} = &\mu_p + \tau_{s,t} + \pi_{j,t} + \beta_1 CA_s \times Post_t + \beta_2 CA_s \times Exposure_i \times Post_t + \beta_3 Exposure_i \times Post_t \\ &+ \beta_4 CA_s \times Exposure_i + \beta_5 CA_s + \beta_6 Exposure_i + \beta_7 Post_t + \delta \boldsymbol{X}_{c,t-1} + \varepsilon_{p,s,c,i,j,t} \end{aligned} \tag{3}$$

where p denotes plant, s denotes state of a plant, c denotes county of a plant, i denotes NAICS4 industry of a plant, j denotes NAICS2 industry of a plant, and t denotes year. $Y_{p,s,c,i,j,t}$, the dependent variable, represents a plant's IT intensity, defined as the natural logarithm of the total number of computers (desktop and laptop PCs) per employee (*IT/Emp)*). As a robustness check, we also use an alternative measure scaled by sales. $Exposure_i$ represents the standardized pre-HIPS average exposure to heat and thus to HIPS of a NAICS4 industry, as defined in Equation (1). $CA_{s,t}$ is an indicator variable set to one for plants located in California, and zero otherwise. $Post_t$ is an indicator variable set to one for years 2005 and after, and zero otherwise. $X_{c,t}$ is a vector of controls at the county level, including the natural logarithm of a county's total laborforce (*Log(Laborforce)*), the natural logarithm of a county's total income (*Log(Income)*), unemployment rate (*Unemployment Rate*), a county's average temperature from May to September (*Temperature*), and a county's average precipitation from May to September (*Precipitation*).

Additionally, we include various fixed effects to control for unobserved heterogeneity in the analysis. Specifically, μ_p denotes plant fixed effects, $\tau_{s,t}$ represents state-by-year fixed effects, and $\pi_{i,t}$ denotes NAICS2 industry-by-year fixed effects. In robustness checks, we replace state-by-year fixed effects with county-by-year fixed effects and substitute NAICS2-by-year fixed effects with NAICS4-by-year fixed effects to achieve finer

granularity. Furthermore, to enable within-firm comparisons, we incorporate firm-by-year fixed effects.

Our empirical strategy leverages the HIPS implementation in California to examine its causal impact on plant-level utilization of IT capital. Model (2) estimates the average differences in IT utilization between plants in California and those outside California, before and after HIPS implementation. Model (3) further incorporates the labor channel by interacting per-HIPS exposure to heat risk and thus to HIPS at the plant level. Our key coefficient of interest is β_2 in Model (3), which captures the triple-differences estimate. Specifically, it reflects the difference in IT intensity between high- and low-exposure plants in California due to the HIPS implementation, relative to the corresponding difference between high- and low-exposure plants in non-California states without HIPS implementation. Our causal inference relies on the parallel trends assumption, which posits that pre-HIPS trends in IT intensity were similar across high- and low-exposure plants in both California and non-California states, after accounting for heterogeneities across plants, industries, states, and counties.

Based on our hypothesis of plant adaptation through technological progress, we expect the estimated coefficient β_2 in Model (3) to be positive and statistically significant, indicating that HIPS encourages more treated plants to increase IT adoption relative to their reliance on human capital as a production input.

4.2 Plant-level IT Intensity

Panel A of Table 3 presents the main results. The dependent variables are *Log(IT/Emp)* in columns (1) - (4) and *Log(IT/Sales)* in columns (5) - (8). *Log(IT/Emp)* is the natural logarithm of the number of computers (desktop and laptop PCs) per employee, while *Log(IT/Sales)* is the natural logarithm of the number of computers per million dollars of sales. Columns (1) and (5) estimate Model (2) and show that, on average, California plants exhibit higher IT adoption relative to employment compared to non-California plants following the HIPS implementation, as indicated by the positive and statistically significant coefficient on $CA \times Post$. Columns (2) and columns (6) estimate Model (3) by further

incorporating plant-level exposure to heat risk and thus to HIPS. As shown, while the coefficient on $CA \times Post$ remains positive, the coefficient on $CA \times Exposure \times Post$ is also positive and statistically significant. This suggests that, following HIPS implementation, plants in California with greater exposure to heat risk increased IT adoption more than less exposed plants, relative to the corresponding difference in non-California states without HIPS. The results remain robust in columns (3) and (7) after the inclusion of state-by-year fixed effects to control for state-level time-varying differences. They continue to hold in columns (4) and (8) after further controlling for county-level lagged variables, including the natural logarithm of a county's total laborforce (*Log(Laborforce)*), the natural logarithm of a county's total income (*Log(Income)*), unemployment rate (*Unemployment Rate*), a county's average temperature from May to September (*Temperature*), and a county's average precipitation from May to September (*Precipitation*). The economic magnitude is also substantial: the implementation of HIPS leads to a 1.7% greater increase in IT intensity for treated plants with a one standard deviation higher labor exposure.

Panel B of Table 3 presents robustness checks using a stronger set of fixed effects. In Columns (1) and (5), we replace NAICS2-by-year fixed effects with NAICS4-by-year fixed effects to better control for time-varying industry heterogeneity. Columns (2) and (6) substitute state-by-year fixed effects with county-by-year fixed effects to incorporate more granular local controls for policy and economic conditions. Columns (3) and (7) apply both substitutions simultaneously. The results remain consistent, with similar economic magnitudes. In Columns (4) and (8), we add firm-by-year fixed effects to conduct within-firm analyses, which control for firm-level fundamentals and allow comparisons across plants within the same firm. The results continue to hold, confirming that the findings are not driven by firm-level heterogeneity.

4.3 Dynamic Effects

Our difference-in-difference-in-differences (DDD) analysis relies on the premise that pre-HIPS trends in IT intensity were similar across high- and low-exposure plants in both California and non-California states, after accounting for heterogeneity across plants, in-

dustries, states, and counties. To validate this assumption, we examine the dynamics of IT intensity around the HIPS implementation in Table 4, using year-specific indicators for periods before and after the policy enactment. *Year 2004* serves as the benchmark year and is therefore omitted from the regression. Results show that the coefficients on $CA \times Exposure \times Year\ 2002$ and $CA \times Exposure \times Year\ 2003$ are statistically insignificant, indicating no evidence of pre-treatment effects. In contrast, starting from the year of HIPS adoption, the interaction terms, $CA \times Exposure \times Year\ 2005$ through $CA \times Exposure \times Year\ 2009$, are positive and statistically significant, consistent with a post-treatment increase in IT adoption among more exposed plants in California.

Dynamic changes in IT intensity plotted around HIPS implementation corroborate these findings, as shown in Figure D.1. Prior to HIPS implementation, differences in IT intensity dynamics between high- and low-exposure plants were similar in both California and non-California states, supporting the parallel trends assumption. Following HIPS, the gap in IT intensity between high- and low-exposure plants widens significantly in California, relative to that in non-California states. Additionally, we observe a second notable increase in the effect of HIPS on IT adoption in 2008. This is consistent with Figure 1, which shows a sharp rise in HIPS enforcement activities (inspections and violations) and outreach efforts during that year. Faced with growing compliance pressures, employers were likely more incentivized to increase IT adoption. This further highlights the importance of real-time enforcement and outreach in strengthening the impact of regulations and prompting responsive firm behavior.

Collectively, these findings alleviate concerns about reverse causality or violations of the parallel trends assumption, indicating that the observed increases in IT investment relative to human capital among treated plants are attributable to the policy's introduction rather than to pre-existing trends.

4.4 Decomposition: Plant-level IT Capital and Employment

Our hypothesis posits that HIPS implementation raises labor-related costs, prompting affected plants to substitute human capital with IT capital as production inputs. Thus far,

the results on IT intensity support this conjecture. Furthermore, the hypothesis implies that IT adoption should increase while employment should decrease when IT intensity is decomposed into its two components. We test this prediction in Table 5, where the dependent variable is *Log(IT)* in Columns (1)–(3) and *Log(Emp)* in Columns (4)–(6). *Log(IT)* is the natural logarithm of the number of computers, normalized by the pre-HIPS average, and *Log(Emp)* is the natural logarithm of the number of employees, also normalized by the pre-HIPS average.

Consistent with our hypothesis, the coefficient on $CA \times Exposure \times Post$ is positive and statistically significant for IT capital in Columns (1)–(3), but negative and statistically significant for employment in Columns (4)–(6). The economic magnitudes are meaningful: HIPS implementation leads to a 0.8% increase in IT capital and a 0.9% decrease in employment for treated plants with a one-standard-deviation higher labor exposure. This evidence further supports the hypothesis that treated plants offset HIPS-induced labor costs by substituting IT for labor.

4.5 Robustness

In Internet Appendix Section D, we provide further analyses to affirm the robustness of our main findings regarding plant-level IT intensity.

4.5.1 Alternative Measures of IT Capital

In the main analysis, we measure IT as the number of computers. For robustness, we also include servers, which function as high-capacity computing stations and share similar properties with computers, to capture a broader measure of IT. The results, presented in Table D.1, remain consistent, with comparable economic magnitudes.

4.5.2 HIPS Enforcement and Outreach Activities in California

We incorporate yearly enforcement and outreach activities in California by constructing three variables: *Inspections*, *Violations*, and *Outreach*, each defined as one plus the respective annual count by Cal/OSHA divided by 1000. These variables are set to zero in all

years prior to HIPS implementation. Analysis in Table D.2 shows that Cal/OSHA's enforcement and outreach efforts under HIPS increase IT adoption in high-exposure plants, reinforcing the main findings. The evidence also helps explain the increase in the dynamic effects of HIPS implementation on IT adoption observed in 2008, as shown in Figure D.1.

4.5.3 HIPS Implementation and Firm-level Capital-labor Ratio: Validation with Compustat

To reinforce the main findings on IT adoption based on the CiTDB data, we conduct a complementary analysis using Compustat data for public firms. Specifically, we examine the impact of HIPS implementation on firm-level capital-to-labor ratios, defined as the natural logarithm of a firm's property, plant, and equipment divided by the number of employees (*Log(PPENT/Emp)*). The firm-level exposure to California HIPS is measured as the standardized pre-HIPS proportion of a firm's total employment located in California-based plants with heat exposure above the median. Plant-level exposure is defined as the pre-HIPS average heat exposure for a NAICS4 industry, based on its industry classification (Equation (1)). The difference-in-differences (DID) results (Internet Appendix Table D.3) show that more exposed firms significantly increase their capital-to-labor ratios after HIPS implementation, consistent with the plant-level findings. The estimated magnitude is comparable: a one-standard-deviation increase in labor exposure is associated with a 1.7% rise in the capital-to-labor ratio. Dynamic results (Table D.4, Figure D.1) further support the parallel trends assumption underlying the DID design. We also observe a noticeable increase in HIPS effects from 2007 to 2008, consistent with the enforcement patterns in Figure 1 and the dynamics in Figure D.1.

It is worth highlighting that the analysis uses an extended sample covering 2002 to 2011, although the results remain nearly identical when restricting the sample to 2002–2009, the period used in the main analysis. We use the extended sample to further demonstrate that the findings are not purely driven by the 2008 crisis.

4.5.4 HIPS Implementation and Plant Employment: Validation with Quarterly Census of Employment and Wages (QCEW)

In Internet Appendix Table D.5, we validate the employment effects using QCEW data at the county by NAICS4 level and find consistent results: HIPS implementation leads to a greater reduction in employment in high-exposure industries in California relative to less exposed industries, compared to the corresponding difference in non-HIPS states. The estimated effect is similar in magnitude, with a 0.9% decline in employment for treated industries with one-standard-deviation higher labor exposure.

5 Cross-sectional Heterogeneities

In this section, we conduct several cross-sectional analyses to better understand the underlying mechanisms driving the increased adoption of IT relative to human capital among high-exposure plants in California following HIPS implementation.

5.1 Automation Potential

We argue that the increased adoption of IT is driven by substitution for heat-exposed workers, whose costs rise due to the implementation of HIPS mandates. However, the degree of substitutability between IT and human capital likely depends on the nature of the business. If this mechanism holds, the impact of HIPS implementation on IT adoption should be significantly stronger in industries where such substitution is more feasible.

Following Bates et al. (2025), we first test this conjecture using an occupation-level automation probability measure proposed by Frey and Osborne (2017). We aggregate the occupation-level data to the NAICS4 level, consistent with our exposure measure in Equation (1). The results are presented in Table 6, Columns (1) and (2). As shown, the coefficient on $CA \times Exposure \times Post$ is statistically significant primarily among plants in industries with high automation probability, supporting our conjecture.

In addition, we measure automation potential using occupational skill requirements (Ghaly et al., 2017), given the documented shift away from low-skilled labor due to au-

tomation (e.g., Graetz and Michaels, 2018). Based on this, we hypothesize a weaker effect of HIPS on IT intensity in plants that primarily employ high-skilled workers. This hypothesis is supported in Columns (3) and (4) of Table 6, where the coefficient on $CA \times Exposure \times Post$ is statistically significant only among plants with a high share of low-skilled labor.

5.2 Labor Cost Share

To further explore the mechanism behind the impact of HIPS on IT adoption, we examine whether the effect varies with the importance of labor costs in an industry's cost structure. The incentives to adopt cost-saving technologies in response to HIPS are likely stronger in industries where labor accounts for a larger share of total production costs. If rising labor adjustment costs are driving the observed increase in IT adoption (as shown in Table 3), we would expect the effect of HIPS to be more pronounced in these labor-intensive industries.

We test this idea in Table 7, using two proxies for industry-level labor cost share. The results show that the positive effects of HIPS on IT adoption are concentrated in industries where labor costs represent a larger share of total production costs. Specifically, the coefficient on $CA \times Exposure \times Post$ is statistically significant only among plants in industries with an above-median labor cost share, while it is not significant for those in below-median industries.

5.3 Heat Risk

As discussed in Section 2, the passage of HIPS was primarily aimed at mitigating workplace safety issues arising from heat risk. In regions where extremely high temperatures occur more frequently, heat-related risks are more severe, leading to greater health concerns. Consequently, the binding effects of HIPS are stronger in these areas, imposing higher compliance costs on employers. As a result, firms are more incentivized to reduce their reliance on heat-exposed labor as a production input and instead adopt technological solutions. We therefore expect the effect of HIPS on IT adoption to be stronger in

counties with higher heat risk.

To test this expectation, we construct two measures of county-level heat risk, following previous studies (e.g., Addoum et al., 2020; Xiao, 2021; Pankratz and Schiller, 2024). The first is based on historical temperature data: we define abnormally hot days as days between May and September with temperatures exceeding the 90^{th} percentile of historical daily temperatures for the same county and month, using temperature data from 1981 to year $t-1$. The second measure uses forward-looking temperature projections: specifically, the projected increase in extremely hot days (above 90°F) between the historical reference period (1976 – 2005) and the projected period (2016 – 2045), based on data from the Centers for Disease Control and Prevention (CDC). Both variables are constructed as binary indicators equal to one for counties with heat risk above the median and zero otherwise. Both variables are then transformed into binary indicators, equal to one for counties with heat risk above the median and zero otherwise. Table 8 presents the results. Consistent with our expectation, the positive and statistically significant coefficient on $CA \times Exposure \times Post$ is observed only in counties with heat risk above the sample median, whether measured using historical temperature data or forward-looking projections.

5.4 Financial Constraints

The adoption of IT and adjustments to production processes often involve significant costs. In particular, replacing labor with technology can require both upfront capital investment and substantial financial compensation for displaced workers. These costs may constrain firms with limited financial resources from responding effectively to regulatory changes. Accordingly, we hypothesize that the effect of HIPS implementation on IT adoption to be stronger among firms with greater financial flexibility, as they are better equipped to absorb adjustment costs and finance the transition toward more technology-intensive operations.

We test this hypothesis in Table 9 using text-based measures of financial constraints developed by Hoberg and Maksimovic (2015). These measures identify firms' self-reported

liquidity constraints that hinder or delay investment, based on textual analysis of 10-K filings. Prior research has shown that they more accurately capture firms' financial conditions than traditional accounting-based indicators. This measure is well suited to our context, given our focus on firms' capacity to invest in technology. Our analysis indicates that the increase in IT investment following HIPS implementation is concentrated among firms with above-median financial flexibility, while those with lower liquidity show more limited responses. Further analysis reveals that constraints in equity and debt markets are the primary factors limiting investment, whereas private placement constraints appear to have a minimal effect.

In summary, the effects of HIPS on IT adoption are stronger in industries with higher automation potential and labor cost shares, and among firms with greater financial flexibility. These findings provide strong evidence that labor costs resulting from compliance with heat-related workplace safety regulations are a key driver of increased IT adoption relative to human capital among high-exposure plants in California. However, the ability to respond through IT investment depends not only on regulatory pressure but also on firms' financial capacity to absorb adjustment costs. Overall, these cross-sectional patterns offer consistent support for our core hypothesis.

6 Discussions

In this section, we discuss several issues that may affect the interpretation of our findings and complement the main analysis with additional empirical results. These extensions contribute to reinforcing the robustness of our results and offer deeper insight into the mechanisms underlying the observed effects.

6.1 Adaptation Choices

Throughout the paper, we focus on firms' adaptation to HIPS implementation through technological progress in response to increased labor-related compliance costs. In practice, however, firms may adopt a range of alternative strategies to mitigate heat-related

risks, such as adjusting work schedules, relocating operations, outsourcing, modifying supply chains, or changing business scope and industry focus (e.g., Graff Zivin and Neidell, 2014; Acharya et al., 2023; Pankratz and Schiller, 2024). For example, Acharya et al. (2023) finds that multi-location firms in the U.S. respond to heat-related damages by reallocating employment from affected to unaffected areas. Ponticelli et al. (2023) shows that high-temperature shocks raise energy costs and reduce productivity for small plants, with little effect on large plants. Consequently, hotter commuting zones experienced a decline in small plants, a shift in labor toward large plants, and increased labor market concentration. However, while some of these alternatives may be viable in specific contexts, they are not universally applicable across all business types. For instance, shifting work schedules may be feasible in agriculture but is often impractical in service industries, where rigid operating hours and customer-facing activities limit flexibility. Although examining the full spectrum of these responses is important, it presents substantial empirical challenges and falls outside the scope of this study. Importantly, if firms were primarily relying on non-technological adaptations, we would not expect to observe systematic increases in IT investment following HIPS implementation. The presence of such increases highlights the important role of IT as a strategic response to regulation-induced labor costs associated with heat exposure, reinforcing our interpretation of technology adoption as a key channel of adaptation.

To further support our interpretation, we examine whether the effect of HIPS on IT adoption is concentrated among firms with greater business exposure to heat-exposed industries in California. These firms have stronger incentives to adapt through technological means, as other mitigation strategies may be less feasible or scalable given the nature of their operations. In particular, firms with deep business exposure in the state often face higher costs of relocating out of California due to their entrenched local presence. For instance, long-standing ties to major customers and creditors, local suppliers, and distribution networks create significant frictions that make relocation less viable or economically meaningful. Additionally, these firms are less likely to scale back or exit their operations in heat-exposed industries, given the strategic importance of these busi-

ness lines to the overall firm.

We present the analysis in Table 10. The variable *Firm Exposure* measures the pre-HIPS proportion of a firm's total employment located in California-based plants with above-median heat exposure. Consistent with our hypothesis, the responsiveness in IT adoption to address HIPS-related compliance costs is stronger among firms with significant exposure to heat-exposed industries in California. From columns (1) to (5), both the statistical and economic significance of the effect increase. For instance, in column (5), firms with more than 30% of their operations in heat-exposed industries in California experience a 5.7% increase in IT adoption – over three times the sample average effect of 1.7%. This evidence reinforces the view that when alternative adaptation strategies are less feasible or cost-effective, firms with greater exposure to heat-exposed operations in California are more likely to respond to regulatory pressure by investing in IT, highlighting technological progress as a deliberate and strategic channel of compliance and operational adjustment.

Additionally, we directly test the relocation and industry exit hypotheses using the number of plants at the county by NAICS4 level from the QCEW data.[24] If firms significantly rely on relocation or exiting heat-exposed industries, we would expect to observe a meaningful reduction in the number of high-exposure plants in California. Internet Appendix Table D.1 presents the analysis. The dependent variable is *Log(Plants)*, defined as the natural logarithm of the annual average of quarterly plant counts for a given year at the county by NAICS4 level. The analysis shows that HIPS implementation leads to no significant change in the number of high- relative to low-exposure plants in California, compared to other states. Therefore, the evidence does not support the conjecture that firms relocated to other states or exited high-exposure industries in response to HIPS adoption in California.

[24]We do not use CiTDB data due to its limited coverage of economy-wide plant activity, which restricts its ability to reflect broader industry trends. In contrast, the QCEW offers comprehensive coverage of macro-level plant activity at the county by NAICS4 level.

7 Conclusions

Facing the escalating challenge of global warming, the emphasis of policy efforts has largely been on the reduction of carbon emissions. This focus, while vital, often overshadows the need for interventions in other critical areas, such as safeguarding human health against heat risks. The state of California has taken a leading role in addressing heat-related labor risks by enacting the HIPS as early as 2005 to protect outdoor workers from excessive heat exposure. In recent years, the federal government and several other U.S. states have begun advancing similar regulatory efforts, reflecting a growing recognition of heat as a serious workplace hazard.

In this paper, we examine how plants with varying degrees of labor exposure to heat respond to the implementation of California's HIPS by adjusting their use of IT. We find that, following HIPS implementation, plants in California with greater exposure to heat risk increased IT adoption significantly more than less exposed plants, relative to the corresponding difference in non-California states without HIPS. This response is reflected in higher IT capital investment and lower employment levels, indicating a shift toward technology as a strategic adaptation to climate-related labor regulations. These findings underscore how firms seek to mitigate the financial burden of regulatory compliance by substituting technology for labor in high-risk environments.

However, our findings also uncover a paradoxical outcome of these regulatory efforts aimed at protecting workers from heat risks. While HIPS is designed to enhance worker safety, its adoption has inadvertently led to a decrease in employment opportunities. This outcome presents a significant policy challenge: the need for a balanced approach that ensures worker safety in the face of climate change while sustaining job creation within the economy.

In conclusion, our investigation into heat-related labor regulations offers insights into the complex interplay between climate change, regulatory responses, and economic adaptation strategies. It underscores the importance of considering the broader economic implications of climate-related policies and the pivotal role of technological progress in nav-

igating the challenges posed by climate change.

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Appendix A: Variable Definitions

Variables	Description
Dependent Variables	
Log(IT/Emp)	The natural logarithm of the number of computers (desktop and laptop PCs) per employee.
Log(IT/Sales)	The natural logarithm of the number of computers per million dollars of sales.
Log(IT)	The natural logarithm of the number of computers, normalized by the pre-HIPS average.
Log(Emp)	The natural logarithm of the number of employees, normalized by the pre-HIPS average.
Key Independent Variables	
CA	An indicator variable set to one for plants located in California, and zero otherwise.
Post	An indicator variable set to one for years 2005 and after, and zero otherwise.
Exposure	Standardized the pre-HIPS average exposure to heat and thus to HIPS of a NAICS4 industry. This measure is computed using Equation (1) as the weighted average of outdoor intensity across all occupations within a NAICS4 industry. Outdoor intensity for each occupation is sourced from the O*NET program. Weights are assigned based on the percentage of employees working in each occupation within the NAICS4 industry, as reported by the Occupational Employment and Wage Statistics (OEWS) data. This measure follows the methodology of Xiao (2021).
Other Independent Variables	
High Automation Probability	An indicator set to one for NAICS4 industries with pre-HIPS automation probabilities above the median, and zero otherwise. The industry-level measure is calculated as the weighted average of automation probabilities across all occupations within a NAICS4 industry. Automation probability for each occupation is provided by Frey and Osborne (2017)). Weights are assigned based on the percentage of employees working in each occupation within the NAICS4 industry, as reported by the Occupational Employment and Wage Statistics (OEWS) data.
Low Labor Skill	An indicator set to one for NAICS4 industries with pre-HIPS labor skills below the median, and zero otherwise. The industry-level measure is calculated as the weighted average of labor skills across all occupations within a NAICS4 industry. Labor skill for each occupation is based on job zones from the O*NET program. Weights are assigned based on the percentage of employees working in each occupation within the NAICS4 industry, as reported by the Occupational Employment and Wage Statistics (OEWS) data.
High Labor Cost Share 1	An indicator set to one for NAICS4 industries with pre-HIPS labor cost share above the median, and zero otherwise. The industry-level measure is calculated as the median labor cost share in a NAICS4 industry. For each firm, dollar labor costs are computed as the Compustat number of employee's (emp) times the average wage rate in the firm's NAICS4 industry obtained from the Quarterly Census of Employment and Wages (QCEW) provided by the U.S. Bureau of Labor Statistics. Next, the dollar labor costs are divided by the firm's cost of goods sold (cogs).

Variables	Description
High Labor Cost Share 2	An indicator set to one for NAICS4 industries with pre-HIPS labor cost share above the median, and zero otherwise. The industry-level measure is calculated as the median labor cost share in a NAICS4 industry. For each firm, dollar labor costs are computed as the Compustat number of employee's (emp) times the average wage rate in the firm's NAICS4 industry obtained from the Quarterly Census of Employment and Wages (QCEW) provided by the U.S. Bureau of Labor Statistics. Next, the dollar labor costs are divided by the firm's sales (sale).
High Heat Shocks	An indicator set to one for counties with abnormal hot days from t-3 to t-1 above the median, and zero otherwise. Abnormal hot days are defined as days from May to September with temperatures above the 90th percentile of historical temperatures in the same county and month from 1981 to t 1.
High Heat Projection	An indicator set to one for counties with projected heat risk above the median, and zero otherwise. The projected heat risk is measured as the differences in extreme hot days (90F) between the reference period (1976 – 2005) and the projected period (2016 - 2045), sourced from the Disease Control and Prevention (CDC).
Financial Flexibility	The negative of the pre-HIPS 10-K text-based measure of financial constraints proposed by Hoberg and Maksimovic (2015), which identifies firms that are curtailing investment due to challenges to liquidity.
High Financial Flexibility	The negative of the pre-HIPS 10-K text-based measure of financial constraints proposed by Hoberg and Maksimovic (2015), which identifies firms that are curtailing investment due to challenges to liquidity.
Financial Flexibility (Equity)	The negative of the pre-HIPS 10-K text-based measure of equity market financial constraints.
Financial Flexibility (Debt)	The negative of the pre-HIPS 10-K text-based measure of debt financial constraints.
Financial Flexibility (Private Placement)	The negative of the pre-HIPS 10-K text-based measure of private placement financial constraints.
Firm Exposure	The standardized pre-HIPS proportion of a firm's total employment in California-based plants with heat exposure above the median level.
Controls	
Log(Laborforce)	The natural logarithm of a county's total laborforce at t-1.
Log(Income)	The natural logarithm of a county's total income at t-1.
Unemployment Rate	A county's unemployment rate at t-1.
Temperature	A county's average temperature from May to September at t-1.
Precipitation	A county's average precipitation from May to September at t-1.

Figures

Figure 1. HIPS Enforcement and Outreach Activities in California

This figure presents the annual inspections, enforcement, and outreach activities conducted by Cal/OSHA from 2000 to 2009. Values are assumed to be zero prior to the implementation of HIPS in 2005. The data are sourced from the "*FY 2020 Follow-up Federal Annual Monitoring Evaluation (FAME) Report*."

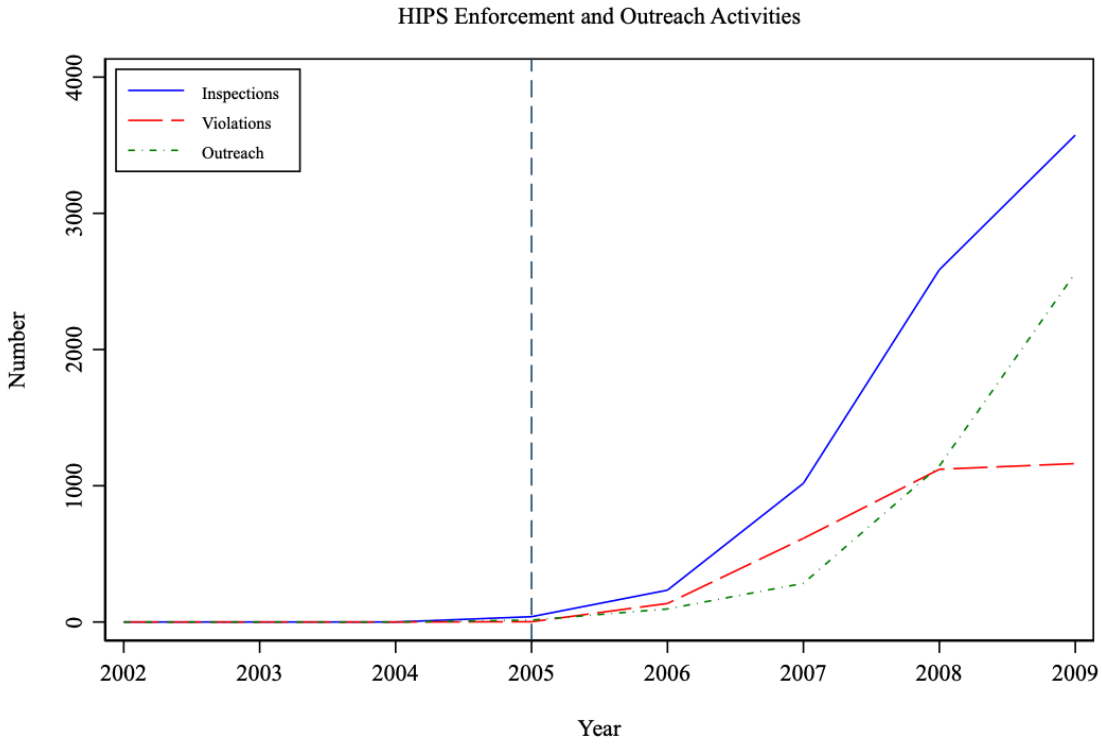
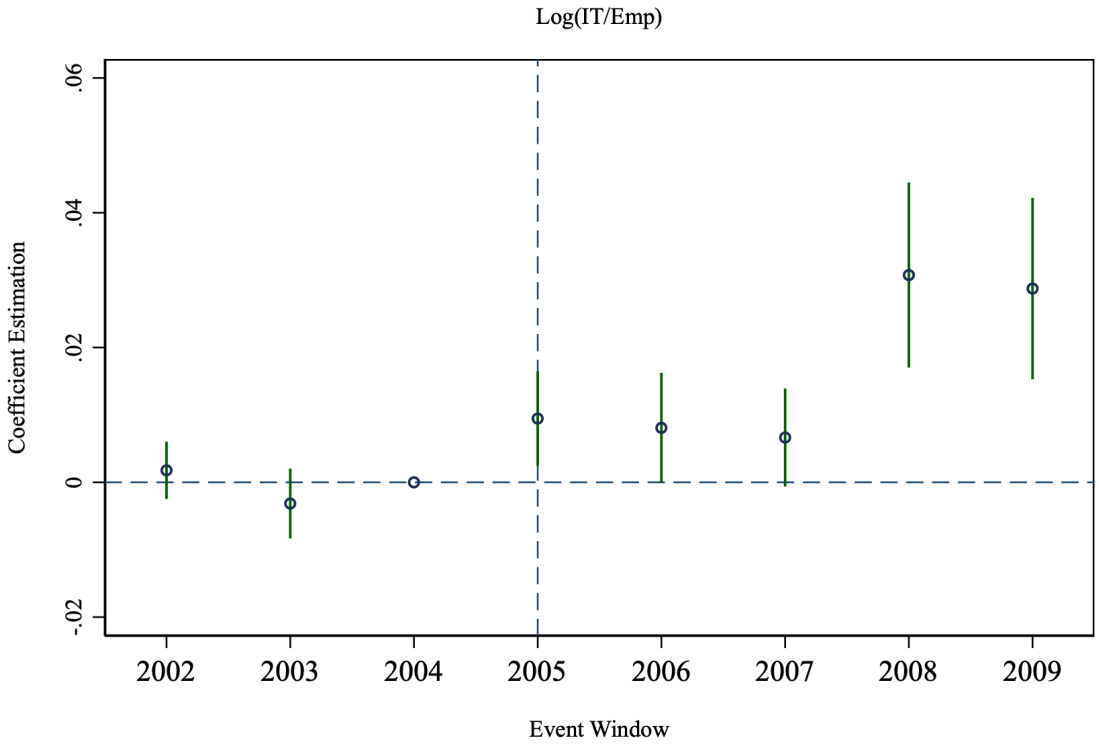


Figure 2. Dynamic Differences in Plant-level IT Intensity Around the HIPS Implementation

This figure presents dynamic differences in plant-level IT intensity around the implementation of HIPS in California. IT intensity is measured as the natural logarithm of the number of computers (desktop and laptop PCs) per employee, *Log(IT/Emp)*. The coefficients on the y-axis represent the coefficient estimate on triple interaction terms between *CA*, *Exposure*, and year dummies from 2002 to 2009. *CA* is an indicator variable set to one for plants located in California, and zero otherwise. *Exposure* is standardized the pre-HIPS average exposure to heat of a NAICS4 industry, defined in Equation (1). The estimation is based on column (2) in Table 4. See "*Appendix A: Variable Definitions*" for more detailed definitions of variables.



Table

Table 1. The Implementation of HIPS and Plant-level IT Intensity

This table presents selected examples of 30 industries with varying non-standardized exposure values to heat risk and the implemented HIPS. The raw non-standardized values range from 1 to 5.

NAICS4 Code	NAICS4 Title	Raw Exposure Value (1 - 5)
2131	Support Activities for Mining	3.6
5622	Waste Treatment and Disposal	3.3
5617	Services to Buildings and Dwellings	3.2
4821	Rail Transportation	3.1
4841	General Freight Trucking	3.0
7131	Amusement Parks and Arcades	3.0
6219	Other Ambulatory Health Care Services	2.8
3273	Cement and Concrete Product Manufacturing	2.8
8111	Automotive Repair and Maintenance	2.6
4931	Warehousing and Storage	2.5
4413	Automotive Parts, Accessories, and Tire Stores	2.4
5413	Architectural, Engineering, and Related Services	2.4
3241	Petroleum and Coal Products Manufacturing	2.4
3121	Beverage Manufacturing	2.4
3366	Ship and Boat Building	2.3
3115	Dairy Product Manufacturing	2.2
3253	Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing	2.1
3114	Fruit and Vegetable Preserving and Specialty Food Manufacturing	2.1
7211	Traveler Accommodation	2.1
8114	Personal and Household Goods Repair and Maintenance	2.0
3362	Motor Vehicle Body and Trailer Manufacturing	2.0
8112	Electronic and Precision Equipment Repair and Maintenance	1.9
5614	Business Support Services	1.9
3222	Converted Paper Product Manufacturing	1.8
4481	Clothing Stores	1.8
3162	Footwear Manufacturing	1.6
6221	General Medical and Surgical Hospitals	1.6
5415	Computer Systems Design and Related Services	1.4
5411	Legal Services	1.3
5412	Accounting, Tax Preparation, Bookkeeping, and Payroll Services	1.3

Table 2. Summary Statistics

This table presents summary statistics of key variables used in empirical analyses. *Log(IT/Emp)* is the natural logarithm of the number of computers (desktop and laptop PCs) per employee. *Log(IT/Sales)* is the natural logarithm of the number of computers per million dollars of sales. *Log(IT)* is the natural logarithm of the number of computers, normalized by the pre-HIPS average. *Log(Emp)* is the natural logarithm of the number of employees, normalized by the pre-HIPS average. *Exposure* is the standardized the pre-HIPS average exposure to heat of a NAICS4 industry, defined in Equation (1). *CA* is an indicator variable set to one for plants located in California, and zero otherwise. *Post* is an indicator variable set to one for years 2005 and after, and zero otherwise. *Log(Laborforce)* is the natural logarithm of a county's total laborforce at t-1. *Log(Income)* is the natural logarithm of a county's total income at t-1. *Unemployment Rate* is a county's unemployment rate at t-1. *Temperature* is a county's average temperature from May to September at t-1. *Precipitation* is a county's average precipitation from May to September at t-1. See "*Appendix A: Variable Definitions*" for more detailed definitions of variables. The sample period is from 2002 to 2009.

Variables	**N**	**Mean**	**P5**	**Median**	**P95**	**SD**
Log(IT/Emp)	139,000	-0.707	-1.582	-0.730	0.262	0.561
Log(IT/Sales)	139,000	1.293	-0.151	1.262	2.619	0.851
Log(IT)	139,000	-0.027	-0.753	0.000	0.673	0.438
Log(Emp)	139,000	-0.013	-0.420	0.000	0.357	0.228
Exposure	139,000	0.000	-1.255	-0.208	2.145	1.000
CA	139,000	0.097	0.000	0.000	1.000	0.297
Post	139,000	0.625	0.000	1.000	1.000	0.484
Log(Laborforce)	138,077	12.020	9.283	12.231	14.756	1.615
Log(Income)	138,077	16.252	13.273	16.452	19.092	1.773
Unemployment Rate	138,142	5.911	3.400	5.500	10.100	2.092
Temperature	139,000	21.506	16.890	21.106	27.127	3.147
Precipitation	139,000	3.085	0.121	3.144	5.563	1.570

Table 3. HIPS Implementation and Plant-level IT Intensity

This table presents the effects of HIPS implementation on plant-level IT intensity. Panel A presents the main baseline results, while Panel B reports robustness checks using a stronger set of fixed effects. The dependent variables are *Log(IT/Emp)* in columns (1) - (4) and *Log(IT/Sales)* in columns (5) - (8). *Log(IT/Emp)* is the natural logarithm of the number of computers (desktop and laptop PCs) per employee. *Log(IT/Sales)* is the natural logarithm of the number of computers per million dollars of sales. *Exposure* is the standardized the pre-HIPS average exposure to heat of a NAICS4 industry, defined in Equation (1). *CA* is an indicator variable set to one for plants located in California, and zero otherwise. *Post* is an indicator variable set to one for years 2005 and after, and zero otherwise. *Log(Laborforce)* is the natural logarithm of a county's total laborforce at t-1. *Log(Income)* is the natural logarithm of a county's total income at t-1. *Unemployment Rate* is a county's unemployment rate at t-1. *Temperature* is a county's average temperature from May to September at t-1. *Precipitation* is a county's average precipitation from May to September at t-1. Controls in Panel B include other interaction terms, *Log(Laborforce)*, *Log(Income)*, *Unemployment Rate*, *Temperature*, and *Precipitation*. See "*Appendix A: Variable Definitions*" for more detailed definitions of variables. The sample period is from 2002 to 2009. Numbers in parentheses are standard errors. Standard errors are double clustered at the state and the plant levels. ***, **, and * indicate p-values of 1%, 5%, and 10%, respectively.

Panel A. Main Results

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Log(IT/Emp)				Log(IT/Sales)			
CA x Post	0.015**	0.016***			0.017***	0.019***		
	(0.006)	(0.006)			(0.006)	(0.005)		
CA x Exposure x Post		0.018***	0.017***	0.017***		0.017***	0.018***	0.017***
		(0.004)	(0.004)	(0.004)		(0.003)	(0.003)	(0.003)
Exposure x Post		0.038***	0.038***	0.039***		0.040***	0.040***	0.041***
		(0.005)	(0.004)	(0.004)		(0.004)	(0.004)	(0.004)
Log(Laborforce)				-0.315***				-0.338***
				(0.065)				(0.066)
Log(Income)				0.078				0.089
				(0.068)				(0.075)
Unemployment Rate				0.017***				0.017***
				(0.004)				(0.004)
Temperature				-0.009*				-0.010*
				(0.005)				(0.005)
Precipitation				-0.002				-0.003
				(0.002)				(0.002)
Observations	139,000	139,000	139,000	138,077	139,000	139,000	139,000	138,077
Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
NAICS2 Industry x Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State x Year FE	No	No	Yes	Yes	No	No	Yes	Yes
Adjusted R^2	0.634	0.635	0.636	0.636	0.828	0.829	0.829	0.830

Panel B. Robustness - Additional Fixed Effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Log(IT/Emp)				Log(IT/Sales)			
CA x Exposure x Post	0.011***	0.017***	0.012***	0.012*	0.012***	0.018***	0.014***	0.011*
	(0.004)	(0.004)	(0.004)	(0.006)	(0.004)	(0.004)	(0.004)	(0.006)
Exposure x Post		0.036***		0.085***		0.038***		0.098***
		(0.005)		(0.015)		(0.005)		(0.015)
Observations	137,997	133,552	133,456	75,982	137,997	133,552	133,456	75,982
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
NAICS2 Industry x Year FE	No	Yes	No	Yes	No	Yes	No	Yes
NAICS4 Industry x Year FE	Yes	No	Yes	No	Yes	No	Yes	No
State x Year FE	Yes	No	No	Yes	Yes	No	No	Yes
County x Year	No	Yes	Yes	No	No	Yes	Yes	No
Firm x Year FE	No	No	No	Yes	No	No	No	Yes
Adjusted R^2	0.693	0.629	0.686	0.649	0.854	0.825	0.850	0.825

Table 4. HIPS Implementation and Plant-level IT Intensity: Dynamic Effects

This table presents the dynamic differences in plant-level IT intensity around HIPS implementation. The dependent variables are *Log(IT/Emp)* in columns (1) - (3) and *Log(IT/Sales)* in columns (4) - (6). *Log(IT/Emp)* is the natural logarithm of the number of computers (desktop and laptop PCs) per employee. *Log(IT/Sales)* is the natural logarithm of the number of computers per million dollars of sales. *Exposure* is the standardized the pre-HIPS average exposure to heat of a NAICS4 industry, defined in Equation (1). *CA* is an indicator variable set to one for plants located in California, and zero otherwise. *Year 2002*, *Year 2003*, *Year 2005*, *Year 2006*, *Year 2007*, *Year 2008*, *Year 2009* denote dummy variables for the corresponding years. *Year 2004* serves as the benchmark year and is therefore omitted from the regression. Controls in columns (1), (2), (4), and (5) include other interaction terms. Controls in columns (3) and (6) include other interaction terms, *Log(Laborforce)*, *Log(Income)*, *Unemployment Rate*, *Temperature*, and *Precipitation*. *Log(Laborforce)* is the natural logarithm of a county's total laborforce at t-1. *Log(Income)* is the natural logarithm of a county's total income at t-1. *Unemployment Rate* is a county's unemployment rate at t-1. *Temperature* is a county's average temperature from May to September at t-1. *Precipitation* is a county's average precipitation from May to September at t-1. See "*Appendix A: Variable Definitions*" for more detailed definitions of variables. The sample period is from 2002 to 2009. Numbers in parentheses are standard errors. Standard errors are double clustered at the state and the plant levels. ***, **, and * indicate p-values of 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
	Log(IT/Emp)			Log(IT/Sales)		
CA x Exposure x Year 2002	0.001	0.002	0.002	0.003	0.003	0.004
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
CA x Exposure x Year 2003	-0.003	-0.003	-0.003	-0.002	-0.002	-0.002
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
CA x Exposure x Year 2005	0.010***	0.009***	0.009**	0.011***	0.011***	0.010***
	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
CA x Exposure x Year 2006	0.009**	0.008*	0.008*	0.009**	0.009**	0.009**
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
CA x Exposure x Year 2007	0.007*	0.007*	0.006*	0.006*	0.006*	0.006*
	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.004)
CA x Exposure x Year 2008	0.030***	0.031***	0.031***	0.032***	0.033***	0.033***
	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
CA x Exposure x Year 2009	0.028***	0.029***	0.028***	0.030***	0.031***	0.030***
	(0.006)	(0.007)	(0.007)	(0.006)	(0.007)	(0.007)
Observations	139,000	139,000	138,077	139,000	139,000	138,077
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Plant FE	Yes	Yes	Yes	Yes	Yes	Yes
NAICS2 Industry x Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State x Year FE	No	Yes	Yes	No	Yes	Yes
Adjusted R^2	0.635	0.636	0.636	0.829	0.829	0.830

Table 5. HIPS Implementation and Plant-level IT and Employment

This table presents the effects of HIPS implementation on plant-level total IT and employment, respectively. The dependent variables are *Log(IT)* in columns (1) - (3) and *Log(Emp)* in columns (4) - (6). *Log(IT)* is the natural logarithm of the number of computers, normalized by the pre-HIPS average. *Log(Emp)* is the natural logarithm of the number of employees, normalized by the pre-HIPS average. *Exposure* is the standardized the pre-HIPS average exposure to heat of a NAICS4 industry, defined in Equation (1). *CA* is an indicator variable set to one for plants located in California, and zero otherwise. *Post* is an indicator variable set to one for years 2005 and after, and zero otherwise. Controls in columns (1), (2), (4), and (5) include other interaction terms. Controls in columns (3) and (6) include other interaction terms, *Log(Laborforce)*, *Log(Income)*, *Unemployment Rate*, *Temperature*, and *Precipitation*. *Log(Laborforce)* is the natural logarithm of a county's total laborforce at t-1. *Log(Income)* is the natural logarithm of a county's total income at t-1. *Unemployment Rate* is a county's unemployment rate at t-1. *Temperature* is a county's average temperature from May to September at t-1. *Precipitation* is a county's average precipitation from May to September at t-1. See "*Appendix A: Variable Definitions*" for more detailed definitions of variables. The sample period is from 2002 to 2009. Numbers in parentheses are standard errors. Standard errors are double clustered at the state and the plant levels. ***, **, and * indicate p-values of 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
	Log(IT)			Log(Emp)		
CA x Exposure x Post	0.009**	0.009**	0.008*	-0.008***	-0.008***	-0.009***
	(0.004)	(0.004)	(0.004)	(0.002)	(0.002)	(0.002)
Observations	139,000	139,000	138,077	139,000	139,000	138,077
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Plant FE	Yes	Yes	Yes	Yes	Yes	Yes
NAICS2 Industry x Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State x Year FE	No	Yes	Yes	No	Yes	Yes
Adjusted R^2	0.377	0.380	0.381	0.341	0.342	0.342

Table 6. HIPS Implementation and Plant-level IT and Employment: Automation Potential

This table presents the effects of HIPS implementation on plant-level IT intensity, conditional on automation potential. The dependent variable is *Log(IT/Emp)*, the natural logarithm of the number of computers (desktop and laptop PCs) per employee. *Exposure* is the standardized the pre-HIPS average exposure to heat of a NAICS4 industry, defined in Equation (1). *CA* is an indicator variable set to one for plants located in California, and zero otherwise. *Post* is an indicator variable set to one for years 2005 and after, and zero otherwise. *High Automation Probability* is an indicator set to one for NAICS4 industries with pre-HIPS automation probabilities above the median, and zero otherwise. *Low Labor Skill* is an indicator set to one for NAICS4 industries with pre-HIPS labor skills below the median, and zero otherwise. Controls include other interaction terms, *Log(Laborforce)*, *Log(Income)*, *Unemployment Rate*, *Temperature*, and *Precipitation*. *Log(Laborforce)* is the natural logarithm of a county's total laborforce at t-1. *Log(Income)* is the natural logarithm of a county's total income at t-1. *Unemployment Rate* is a county's unemployment rate at t-1. *Temperature* is a county's average temperature from May to September at t-1. *Precipitation* is a county's average precipitation from May to September at t-1. See "*Appendix A: Variable Definitions*" for more detailed definitions of variables. The sample period is from 2002 to 2009. Numbers in parentheses are standard errors. Standard errors are double clustered at the state and the plant levels. ***, **, and * indicate p-values of 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)
	Log(IT/Emp)			
CA x Exposure x Post	0.006	0.007	0.009	0.009
	(0.007)	(0.007)	(0.006)	(0.006)
CA x Exposure x Post x High Automation Probability	0.019**	0.018**		
	(0.008)	(0.008)		
CA x Exposure x Post x Low Labor Skill			0.016**	0.017**
			(0.008)	(0.008)
Observations	137,925	137,925	138,077	138,077
Controls	Yes	Yes	Yes	Yes
Plant FE	Yes	Yes	Yes	Yes
NAICS2 Industry x Year FE	Yes	Yes	Yes	Yes
State x Year FE	No	Yes	No	Yes
Adjusted R^2	0.636	0.638	0.644	0.646

Table 7. HIPS Implementation and Plant-level IT and Employment: Labor Cost Share

This table presents the effects of HIPS implementation on plant-level IT intensity, conditional on labor cost share. The dependent variable is *Log(IT/Emp)*, the natural logarithm of the number of computers (desktop and laptop PCs) per employee. *Exposure* is the standardized the pre-HIPS average exposure to heat of a NAICS4 industry, defined in Equation (1). *CA* is an indicator variable set to one for plants located in California, and zero otherwise. *Post* is an indicator variable set to one for years 2005 and after, and zero otherwise. *High Labor Cost Share 1* and *High Labor Cost Share 2* are both indicators set to one for NAICS4 industries with pre-HIPS labor cost share above the median, and zero otherwise. Controls include other interaction terms, *Log(Laborforce)*, *Log(Income)*, *Unemployment Rate*, *Temperature*, and *Precipitation*. *Log(Laborforce)* is the natural logarithm of a county's total laborforce at t-1. *Log(Income)* is the natural logarithm of a county's total income at t-1. *Unemployment Rate* is a county's unemployment rate at t-1. *Temperature* is a county's average temperature from May to September at t-1. *Precipitation* is a county's average precipitation from May to September at t-1. See "*Appendix A: Variable Definitions*" for more detailed definitions of variables. The sample period is from 2002 to 2009. Numbers in parentheses are standard errors. Standard errors are double clustered at the state and the plant levels. ***, **, and * indicate p-values of 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)
	Log(IT/Emp)			
CA x Exposure x Post	-0.007	-0.006	-0.003	-0.002
	(0.004)	(0.004)	(0.004)	(0.004)
CA x Exposure x Post x High Labor Cost Share 1	0.038***	0.036***		
	(0.006)	(0.005)		
CA x Exposure x Post x High Labor Cost Share 2			0.019***	0.017***
			(0.006)	(0.006)
Observations	134,741	134,741	134,741	134,741
Controls	Yes	Yes	Yes	Yes
Plant FE	Yes	Yes	Yes	Yes
NAICS2 Industry x Year FE	Yes	Yes	Yes	Yes
State x Year FE	No	Yes	No	Yes
Adjusted R^2	0.638	0.640	0.636	0.638

Table 8. HIPS Implementation and Plant-level IT and Employment: Local Heat Risk

This table presents the effects of HIPS implementation on plant-level IT intensity, conditional on local heat risk. The dependent variable is *Log(IT/Emp)*, the natural logarithm of the number of computers (desktop and laptop PCs) per employee. *Exposure* is the standardized the pre-HIPS average exposure to heat of a NAICS4 industry, defined in Equation (1). *CA* is an indicator variable set to one for plants located in California, and zero otherwise. *Post* is an indicator variable set to one for years 2005 and after, and zero otherwise. *High Heat Shocks* is an indicator set to one for counties with abnormal hot days from t-3 to t-1 above the median, and zero otherwise. Abnormal hot days are defined as days from May to September with temperatures above the 90th percentile of historical temperatures in the same county and month from 1981 to t-1. *High Heat Projection* is an indicator set to one for counties with projected heat risk above the median, and zero otherwise. The projected heat risk is measured as the differences in extreme hot days (90°F)) between the reference period (1976 – 2005) and the projected period (2016 - 2045), sourced from the CDC. Controls include other interaction terms, *Log(Laborforce)*, *Log(Income)*, *Unemployment Rate*, *Temperature*, and *Precipitation*. *Log(Laborforce)* is the natural logarithm of a county's total laborforce at t-1. *Log(Income)* is the natural logarithm of a county's total income at t-1. *Unemployment Rate* is a county's unemployment rate at t-1. *Temperature* is a county's average temperature from May to September at t-1. *Precipitation* is a county's average precipitation from May to September at t-1. See "*Appendix A: Variable Definitions*" for more detailed definitions of variables. The sample period is from 2002 to 2009. Numbers in parentheses are standard errors. Standard errors are double clustered at the state and the plant levels. ***, **, and * indicate p-values of 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)
	Log(IT/Emp)			
CA x Exposure x Post	-0.001	-0.001	0.004	0.007
	(0.005)	(0.005)	(0.005)	(0.005)
CA x Exposure x Post x High Heat Shocks	0.027***	0.028***		
	(0.007)	(0.007)		
CA x Exposure x Post x High Heat Projection			0.031***	0.027***
			(0.007)	(0.007)
Observations	138,077	138,077	138,077	138,077
Controls	Yes	Yes	Yes	Yes
Plant FE	Yes	Yes	Yes	Yes
NAICS2 Industry x Year FE	Yes	Yes	Yes	Yes
State x Year FE	No	Yes	No	Yes
Adjusted R^2	0.635	0.636	0.635	0.636

Table 9. HIPS Implementation and Plant-level IT and Employment: Financial Flexibility

This table presents the effects of HIPS implementation on plant-level IT intensity, conditional on firm-level financial constraints. The dependent variable is *Log(IT/Emp)*, the natural logarithm of the number of computers (desktop and laptop PCs) per employee. *Exposure* is the standardized the pre-HIPS average exposure to heat of a NAICS4 industry, defined in Equation (1). *CA* is an indicator variable set to one for plants located in California, and zero otherwise. *Post* is an indicator variable set to one for years 2005 and after, and zero otherwise. *Financial Flexibility* is the negative of the pre-HIPS 10-K text-based measure of financial constraints proposed by Hoberg and Maksimovic (2015), which identifies firms that are curtailing investment due to challenges to liquidity. *High Financial Flexibility* is an indicator set to one for firms with financial flexibility above the median, and zero otherwise. *Financial Flexibility (Equity)* is the negative of the pre-HIPS 10-K text-based measure of equity market financial constraints. *Financial Flexibility (Debt)* is the negative of the pre-HIPS 10-K text-based measure of debt market financial constraints. *Financial Flexibility (Private Placement)* is the negative of the pre-HIPS 10-K text-based measure of private placement financial constraints. Controls include other interaction terms, *Log(Laborforce)*, *Log(Income)*, *Unemployment Rate*, *Temperature*, and *Precipitation*. *Log(Laborforce)* is the natural logarithm of a county's total laborforce at t-1. *Log(Income)* is the natural logarithm of a county's total income at t-1. *Unemployment Rate* is a county's unemployment rate at t-1. *Temperature* is a county's average temperature from May to September at t-1. *Precipitation* is a county's average precipitation from May to September at t-1. See "*Appendix A: Variable Definitions*" for more detailed definitions of variables. The sample period is from 2002 to 2009. Numbers in parentheses are standard errors. Standard errors are double clustered at the state and the plant levels. ***, **, and * indicate p-values of 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)	(5)
	Log(IT/Emp)				
CA x Exposure x Post	-0.014	-0.003	-0.005	-0.014**	-0.002
	(0.009)	(0.006)	(0.006)	(0.006)	(0.006)
CA x Exposure x Post x High Financial Flexibility	0.035**				
	(0.014)				
CA x Exposure x Post x Financial Flexibility		0.323***			
		(0.065)			
CA x Exposure x Post x Financial Flexibility (Equity)			0.391***		
			(0.080)		
CA x Exposure x Post x Financial Flexibility (Debty)				0.891***	
				(0.138)	
CA x Exposure x Post x Financial Flexibility (Private Placement)					0.097
					(0.110)
Observations	30,539	30,539	30,539	30,539	30,539
Controls	Yes	Yes	Yes	Yes	Yes
Plant FE	Yes	Yes	Yes	Yes	Yes
NAICS2 Industry x Year FE	Yes	Yes	Yes	Yes	Yes
State x Year FE	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.523	0.523	0.523	0.522	0.522

Table 10. HIPS Implementation and Plant-level IT and Employment: Firm Exposure and Adaptation Choices

This table presents the effects of HIPS implementation on plant-level IT intensity, conditional on firm-level business exposure to heat-exposed industries in California. The dependent variable is *Log(IT/Emp)*, the natural logarithm of the number of computers (desktop and laptop PCs) per employee. *Exposure* is the standardized pre-HIPS average exposure to heat of a NAICS4 industry, defined in Equation (1). *CA* is an indicator variable set to one for plants located in California, and zero otherwise. *Post* is an indicator variable set to one for years 2005 and after, and zero otherwise. *Firm Exposure* is the standardized pre-HIPS proportion of a firm's total employment in California-based plants with heat exposure above the median level. Controls include other interaction terms, *Log(Laborforce)*, *Log(Income)*, *Unemployment Rate*, *Temperature*, and *Precipitation*. *Log(Laborforce)* is the natural logarithm of a county's total laborforce at t-1. *Log(Income)* is the natural logarithm of a county's total income at t-1. *Unemployment Rate* is a county's unemployment rate at t-1. *Temperature* is a county's average temperature from May to September at t-1. *Precipitation* is a county's average precipitation from May to September at t-1. See "*Appendix A: Variable Definitions*" for more detailed definitions of variables. The sample period is from 2002 to 2009. Numbers in parentheses are standard errors. Standard errors are double clustered at the state and the plant levels. ***, **, and * indicate p-values of 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
	Log(IT/Emp)					
CA x Exposure x Post	0.036***	0.014***	0.022***	0.011***	0.011***	0.010**
	(0.005)	(0.004)	(0.004)	(0.003)	(0.003)	(0.004)
CA x Exposure x Post x Firm Exposure > 0.05	0.003					
	(0.008)					
CA x Exposure x Post x Firm Exposure > 0.10		0.027***				
		(0.008)				
CA x Exposure x Post x Firm Exposure > 0.15			0.037***			
			(0.013)			
CA x Exposure x Post x Firm Exposure > 0.20				0.050**		
				(0.022)		
CA x Exposure x Post x Firm Exposure > 0.30					0.057*	
					(0.030)	
CA x Exposure x Post x Firm Exposure						0.016**
						(0.006)
Observations	137,840	137,840	137,840	137,840	137,840	137,840
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Plant FE	Yes	Yes	Yes	Yes	Yes	Yes
NAICS2 Industry x Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State x Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.637	0.637	0.637	0.637	0.637	0.637

Internet Appendix to

“Adaptation to Climate-induced Regulatory Risk Through Technological Progress"

A Legislative and Regulatory Responses to Extreme Heat and Workplace Safety

In this section, we highlight some discussions from various regulators to demonstrate the increasing attention to climate-induced health risks faced by outdoor workers in the U.S. These authorities are progressively adopting measures to mitigate heat risks, thereby strengthening labor protections.

A.1 House and Senate[1]

"Heat illness affects workers in our nation's fields, warehouses, and factories, and climate change is making the problem more severe every year. This legislation will require OSHA to issue a heat standard on a much faster track than the normal OSHA regulatory process. Workers deserve no less."

- House Committee on Education and Labor Chairman, Bobby Scott, 2021

"I will never forget Asuncion Valdivia or how his tragic death could have been avoided...Whether on a farm, driving a truck, or working in a warehouse, workers like Asuncion keep our country running while enduring some of the most difficult conditions, often without access to water or rest. According to a 2015 study by OSHA, this has led to 37 work-related deaths and thousands of injuries and illnesses. And it has only gotten worse as climate change has led to dangerously high temperatures in parts of the country not accustomed to high heat. Every worker deserves to be protected from preventable death, and we know that requiring breaks, shade, and water can save lives.

- Representatives Judy Chu, 2021

"As climate change brings scorching heat temperatures to Southern Arizona and other places across the country, it's negatively impacting our workforce and more often creating conditions that can prove fatal...A federal OSHA standard for heat stress is necessary to protect our workers and limit their exposure to excessive heat in both indoor and outdoor environments. Climate change is no longer a theoretical threat, and lack of aggressive action to address it has made a standard to

[1] See "*House, Senate Democrats Introduce Heat Stress Legislation to Protect Farm Workers*."

protect our workers absolutely urgent."

- Representatives Raúl M. Grijalva, 2021

"Protecting workers from heat stress is essential, particularly as global temperatures continue to rise and extreme weather conditions become more common...Every worker deserves a safe work environment, and this legislation is an important step toward creating national standards and protections that will keep workers safe on the job as the risks of heat stress increase."

- Senator Sherrod Brown, 2021

"Whether it's in the kitchen or on a farm, heat-related illness is a severe and dangerous condition, and this bill would help keep workers safe regardless of their occupation. With rising temperatures, there is no time to delay action, and I'll continue working with my colleagues to prioritize the health and safety of our workers and get this done."

- Senator Cortez Masto, 2021

"The Asunción Valdivia Heat Illness and Fatality Prevention Act will protect workers against occupational exposure to excessive heat by:

- *Requiring the Occupational Safety and Health Administration (OSHA) to establish an enforceable standard to protect workers in high-heat environments with measures like paid breaks in cool spaces, access to water, limitations on time exposed to heat, and emergency response for workers with heat-related illness; and*
- *Directing employers to provide training for their employees on the risk factors that can lead to heat illness, and guidance on the proper procedures for responding to symptoms."*

A.2 The Biden Administration[2]

"Today, President Biden is launching a coordinated, interagency effort to respond to extreme heat that threatens the lives and livelihoods of Americans, especially workers, children, and seniors. While climate-related disasters like hurricanes, wildfires, and floods produce dramatic images of

[2]See "*FACT SHEET: Biden Administration Mobilizes to Protect Workers and Communities from Extreme Heat*."

devastation, extreme heat often takes place out of sight and out of the news. But heat is the nation's leading weather-related killer.."

A.3 The Environmental Protection Agency (EPA)[3]

"*Understanding the threats that climate change poses to human health can help us work together to lower risks and be prepared.*"

"*It is important that employers understand how climate change affects the health and safety of their workers. There are actions employers can take to prepare now, such as including a climate change component in existing safety and health training. Established tools and strategies for protecting workers from climate change related hazards, such as temperature extremes and pesticide use, can be used to protect workers currently experiencing the health impacts of climate change. These tools and strategies can also be used as the basis for planning for the prevention of future health impacts on vulnerable occupational groups.*"

A.4 The Department of Labor[4]

"*Throughout the nation, millions of workers face serious hazards from high temperatures both outdoors and indoors. Amid changing climate, the growing frequency and intensity of extreme heat events is increasing the dangers workers face, especially for workers of color who disproportionately work in essential jobs in tough conditions...As Secretary of Labor, my priority is to make sure we are taking appropriate action to keep workers healthy and safe on the job.*"

- U.S. Department of Labor Secretary Marty Walsh, 2021

"*While agricultural and construction workers often come to mind first when thinking about workers most exposed to heat hazards, without proper safety actions, sun protection and climate-control, intense heat can be harmful to a wide variety of workers indoors or outdoors and during any season.*"

[3] See "*Climate Change and the Health of Occupational Groups*."

[4] See "*US Department of Labor announces enhanced, expanded measures to protect workers from hazards of extreme heat, indoors and out*" and "*Department of Labor announces hazard alert, steps up enforcement as extreme heat endangers workers across the nation*."

- Acting Assistant Secretary for Occupational Safety and Health Jim Frederick, 2021

"*As the Occupational Safety and Health Administration works toward proposing a rule to protect workers from heat illness, we are taking several measures today to better protect workers in extreme heat...Employers have a duty to protect workers by reducing and eliminating hazards that expose workers to heat illness or injury.*"

- Assistant Secretary for Occupational Safety and Health Doug Parker, 2023

A.5 The National Institute for Occupational Safety and Health (NIOSH) [5]

"*Occupational exposure to heat can result in injuries, disease, death, and reduced productivity. Workers may be at risk for heat stress when exposed to hot environments. Exposure to hot environments and extreme heat can result in illnesses, including heat stroke, heat exhaustion, heat syncope, heat cramps, and heat rashes, or death. Heat also increases the risk of workplace injuries, such as those caused by sweaty palms, fogged-up safety glasses, and dizziness.*"

"*NIOSH urges employers to use and disseminate this information to workers. NIOSH also requests that professional associations and labor organizations inform their members about the hazards of occupational exposure to heat and hot environments.*"

[5] See "*Criteria for a Recommended Standard: Occupational Exposure to Heat and Hot Environments*".

B State Regulatory Developments on Heat Illness Prevention

In this section, we review recent state-level developments in heat illness prevention regulations across the United States. We describe the progress made in states that have adopted enforceable standards, as well as efforts in states where proposed legislation has stalled or remains pending. Key developments are summarized in Table B.1. These descriptions provide a broader perspective on how U.S. states are addressing occupational heat risks through diverse regulatory approaches and timelines. States are listed alphabetically, with consideration given to the approximate chronological order of adoption and the significance of each legislative effort.

B.1 States with Enacted Heat Illness Prevention Regulations

B.1.1 California

After becoming the pioneering state to introduce the HIPS in 2005 for outdoor workers, California has continued to promote awareness of heat-related risks and update its regulations. On June 20, 2024, the Occupational Safety and Health Standards Board approved *Title 8, Section 3396* of the California Code of Regulations, "Heat Illness Prevention in Indoor Places of Employment." This standard applies to most workplaces where the indoor temperature reaches 82° and establishes safety measures to prevent worker exposure to heat illness. The regulation took effect on July 23, 2024. The indoor standard shares the same underlying goal as the outdoor rule to prevent heat-related illnesses but differs in specific implementation requirements.[6]

B.1.2 Minnesota

Minnesota adopted a heat illness prevention standard as early as 1997, *Minnesota Administrative Rule 5205.0110, Indoor Ventilation and Temperature in Places of Employment*.[7] However, this standard is limited to indoor workplaces and is beyond the scope of this paper.

[6] For more details, see *California Code of Regulations Title 8, Section 3396*.
[7] See https://www.revisor.mn.gov/rules/5205.0110/.

As of November 2025, Minnesota has not yet adopted a dedicated heat illness standard for outdoor workers

B.1.3 Washington

Washington initially implemented emergency heat illness prevention standards for outdoor workers during the summers of 2006 and 2007. These temporary measures were subsequently formalized when the state adopted a permanent outdoor heat exposure rule in 2008. The Washington HIPS for outdoor workers in general industries are codified under WAC 296-62-095, while the standards for outdoor workers in the agriculture industry fall under WAC 296-307-097.[8] The standards in California and Washington are nearly identical, mandating that employers train supervisors and workers, ensure access to water and cooling resources, and devise written plans for training, risk management and symptom response. The differences lie primarily in their scope and requirements for cooling measures. California's regulations cover all outdoor work activities year-round, while Washington's are limited to outdoor work between May and September, contingent upon reaching specific temperature thresholds associated with three categories of clothing. For example, Washington's HIPS is activated at an ambient temperature of 52°F for individuals wearing non-breathable clothing and at 89°F for any other clothing choice. The threshold of 89°F was lowered to 80°F in the 2023 amendment.

B.1.4 Oregon

Oregon adopted two permanent rules in May 2022, which became effective in July 2022 – *OAR 437-002-0156* and *437-004-1131*[9] – to protect workers from heat-related illnesses. The rules apply whenever an employee performs work activities, whether in indoor or outdoor environments, where the temperature equals or exceeds 80°F. *OAR 437-004-1131* applies to agricultural workplaces and *437-002-0156* applies to all other workplaces. An exception to this rule applies when an employee's exposure to heat arises solely from

[8] See *Title 296 WAC: 296-62-095* and "*Title 296 WAC: 296-307-097*."
[9] See https://osha.oregon.gov/pages/topics/heat-stress.aspx.

the work process — such as in foundries or bakeries — rather than from ambient conditions. In such cases, employers must comply with the requirements of *OAR 437-002-0144(2)*. These rules closely resemble the California HIPS, such as access to shade and water, high heat practices, medical support, and training. Before their formal adoption, Oregon OSHA employed these rules as an emergency response to the deadly heat event of summer 2021.[10]

B.1.5 Colorado

Colorado adopted regulation *7 CCR 1103-15* in 2022, establishing heat illness prevention requirements for agricultural workers. The rule mandates access to drinking water, shade, and rest breaks when temperatures reach specified thresholds, along with employee training and emergency response procedures.[11]

B.1.6 Maryland

Maryland Heat Stress Illness Prevention Standard *COMAR 09.12.32* became effective in Sep 2024.[12] The regulation applies to both indoor and outdoor workplaces where there is employee exposure to a heat index at or above 80°F. The Maryland regulations share many similarities with existing heat illness prevention standards in California, Washington, and Oregon, particularly in their emphasis on hazard assessment, employee training, and preventive measures such as access to water, rest, cooling measures, and medical support.

B.1.7 Nevada

Nevada adopted the heat illness prevention regulation *R131-24AP* in November 2024 to protect workers from heat-related hazards in both indoor and outdoor environments.[13]

[10]See "*Adoption of Temporary Rules to Address Employee Exposure to High Ambient Temperatures, 2021*."
[11]See "*7 CCR 1103-15-3 - Heat Illness and Injury Protection*."
[12]See more details "*COMAR 09.12.32*."
[13]See more details "*Regulation R131-24AP: Heat Illness Prevention*."

Nevada OSHA subsequently issued implementation guidance, with enforcement scheduled to begin in April 2025. The rule requires employers to conduct a one-time written Job Hazard Analysis (JHA). If the JHA identifies heat illness risks, employers must incorporate specific heat illness prevention measures into their written safety program to protect employees from heat-related exposure.

B.2 States with Proposed but Unenacted or Pending Heat Standards

B.2.1 Arizona

On February 7, 2023, Representative Andres Cano introduced *HB2628* in the Arizona House of Representatives. The bill did not pass during the legislative session. It would have required the Industrial Commission of Arizona (ICA) to adopt standards to protect outdoor workers from heat-related illness. In 2025, the governor issued an executive order directing the ICA's Division of Occupational Safety and Health (ADOSH) to draft a workplace heat safety standard. In addition, the City of Phoenix and Pima County passed local heat safety ordinances in 2024 that apply to outdoor workers employed under public contracts within their respective jurisdictions.

B.2.2 Florida

Florida does not have a statewide heat exposure standard for workers. In 2023, bills *SB 706* and *HB 903*, aimed at preventing heat-related illnesses among outdoor workers, were introduced by Senator Ana Rodriguez and Representative Mike Gottlieb. However, both failed to pass during the legislative session. In 2024, the state enacted *HB.433*, which prohibits local governments from adopting their own workplace heat safety ordinances. The law includes a limited exception allowing political subdivisions to establish heat exposure requirements for their own direct employees; however, these provisions do not apply if compliance would jeopardize the subdivision's eligibility for federal funding. In 2025, the Florida House introduced bill *HB.35* to establish statewide heat protection standards for outdoor workers; however, the bill did not advance and ultimately died in committee.

B.2.3 Maine

Maine introduced *LD.1461* in 2021 to establish statewide heat illness prevention requirements for workers in both outdoor and indoor high-heat environments, including provisions for water, rest, shade, and training. However, the bill did not pass, and no subsequent legislation has been enacted, leaving the state without a formal heat illness prevention standard.

B.2.4 Massachusetts

Massachusetts currently has no statewide legally binding regulation mandating heat illness protections for workers in either indoor or outdoor environments. In 2023, the state introduced bill *S.1219*, titled "*An Act to establish a standard for prevention of heat illness in outdoor public sector workers*," but it was not enacted into law. In 2025, Massachusetts introduced two additional bills: *S.1367*, addressing outdoor public-sector workers, and *S.1357*, establishing protections for all workers in hot conditions. The outcomes of these two 2025 bills are currently pending.

B.2.5 New Jersey

New Jersey currently has no statewide heat illness prevention regulation in effect. In late 2024, the state introduced *S.3884* and its Assembly counterpart *A.5022* to establish an "*Occupational Heat-Related Illness and Injury Prevention Program*" covering both indoor and outdoor workplaces. Both bills aim to require the Department of Labor and Workforce Development to adopt standards addressing heat exposure, worker training, and preventive measures. As of 2025, both bills remain under committee review and have not yet been enacted into law.

B.2.6 New York

New York has not yet adopted a mandatory regulatory standard for heat illness prevention. Two bills on heat illness prevention, *S.1604C* and *A.03321C* were introduced in New

York in 2023 for all indoor and outdoor worksites but both failed to pass during the legislative session. Another bill *A.365* was introduced in 2025 and has not yet been enacted into law.

B.2.7 Rhode Island

Rhode Island introduced *S.2900* in 2024, which sought to establish protections for workers exposed to extreme temperatures in both indoor and outdoor environments; however, the bill failed to advance. In 2025, the state introduced *H.5305* and *S.0586*, both addressing similar heat and cold exposure protections for indoor and outdoor workers, but neither was enacted. These repeated but unsuccessful efforts reflect Rhode Island's growing legislative attention to temperature-related occupational risks despite the absence of a binding standard to date.

B.2.8 Texas

Texas continues to lack a statewide mandated heat illness prevention standard for workers. In March 2023, the Texas House introduced *HB.4673*, which would have required the Texas Workforce Commission to adopt protections covering indoor and outdoor work. The bill was referred to committee and ultimately died without passage. Meanwhile, in 2023 the state passed *HB.2127*, a preemption law that prohibits local governments from adopting more stringent heat or labor-safety regulations, thus limiting local protections.

B.2.9 Virgina

Virginia has not yet adopted a statewide heat illness prevention standard for workers. The Department of Labor and Industry initiated rulemaking in 2020 to develop a Heat Illness Prevention Standard covering indoor and outdoor worksites, but the process has not resulted in a formal regulation. In 2025, the General Assembly considered *HB.1980* and *SB.1103*, both aimed at mandating such protections, but neither bill advanced out of committee. As a result, Virginia continues to rely on general occupational safety provisions and nonbinding guidance rather than an enforceable heat-specific rule.

B.3 Other States

B.3.1 Michigan

Michigan does not have a statewide regulation on heat illness prevention. Instead, the Michigan Occupational Safety and Health Administration (MIOSHA) introduced a State Emphasis Program (SEP) on heat-related hazards in July 2022. The SEP serves as an enforcement and outreach initiative rather than a legally binding standard – it prioritizes inspections and employer guidance but does not impose mandatory heat exposure limits or prevention requirements.

Table B.1. State-Level Developments in Heat Illness Prevention Standards

This table summarizes recent state-level developments in heat illness prevention, including adopted standards and stalled or pending legislation. "Year" refers to the year of emergency implementation (if applicable) or bill introduction (if not adopted).

State	Year	HIPS Enacted	Unenacted or Pending	Bill / Regulation Citation	Covered Environment
Arizona	2023	-	Yes	HB 2628	Outdoor
Arizona	2024	Yes	-	-	City of Phoenix, outdoor workers under public contracts
Arizona	2024	Yes	-	-	Pima County, outdoor workers under public contracts
California	2005	Yes	-	Title 8, Section 3395	Outdoor
California	2024	Yes	-	Title 8, Section 3396	Indoor
Colorado	2022	-	-	7 CCR 1103-15	Indoor & Outdoor (Agriculture only)
Florida	2023	-	Yes	SB 706 / HB 903	Outdoor
Florida	2025	-	Yes	HB.35	Outdoor
Maine	2021	-	Yes	LD.1461	Indoor & Outdoor
Maryland	2024	Yes	-	COMAR 09.12.32	Indoor & Outdoor
Massachusetts	2023	-	Yes	S.1219	Outdoor (Public Sector)
Massachusetts	2025	-	Pending	S.1367	Outdoor (Public Sector)
Massachusetts	2025	-	Pending	S.1357	Indoor & Outdoor
Minnesota	1997	Yes	-	Administrative Rule 5205.0110	Indoor
Nevada	2024	Yes	-	R131-24AP	Indoor & Outdoor
New Jersey	2024	-	Pending	S.3884	Indoor & Outdoor
New Jersey	2025	-	Pending	A.5022	Indoor & Outdoor
New York	2023	-	Yes	S.1604C / A.03321C	Indoor & Outdoor
New York	2025	-	Pending	A.365	Indoor & Outdoor
Oregon	2021	Yes	-	OAR 437-002-0156 / 437-004-1131	Indoor & Outdoor
Rhode Island	2024	-	Yes	S.2900	Indoor & Outdoor
Rhode Island	2024	-	Yes	H.5305	Indoor & Outdoor
Rhode Island	2025	-	Yes	S.0586	Indoor & Outdoor
Texas	2023	Yes	-	HB.4673	Outdoor
Virginia	2025	Yes	-	HB.1980	Indoor & Outdoor
Virginia	2025	Yes	-	SB.1103	Indoor & Outdoor
Washington	2006	Yes	-	WAC 296-62-095 / 296-307-097	Outdoor

C HIPS Enforcement in California

C.1 Enforcement Statistics

Figure C.1, extracted from page 11 of the "*FY 2020 Follow-up Federal Annual Monitoring Evaluation (FAME) Report*," presents annual enforcement and outreach activities conducted by Cal/OSHA from 2005 to 2019. In the first year of enforcement, 2005, only 39 heat-related site inspections were conducted, with 2 violations cited. During 2006 and 2007, Cal/OSHA conducted 1,252 inspections, 60% of which resulted in one or more heat exposure citations. Enforcement intensity increased significantly beginning in 2008, with the number of inspections rising to 2,586 in that year and further to 3,574 in 2009. Over the full period from 2005 to 2019, Cal/OSHA conducted 45,889 inspections and cited 20,947 HIPS violations, resulting in an overall citation rate of 46%. Additionly, Cal/OSHA conducted around events from 2005 to 2019.

C.2 An Enforcement Case Study - Merced Farm Labor Contractor

In 2008, a tragic incident involving the death of 17-year-old farmworker Maria Vasquez Jiminez led to significant enforcement action against Merced Farm Labor Contractor. Jiminez collapsed from heat stroke and dehydration while working in conditions exceeding 100°F. Following this, Cal/OSHA issued six citations, three of which were serious and willful, with a total fine of $262,700. Despite an appeal, the citations were upheld.[14]

The fines against Merced Farm Labor Contractor include:

[1] $5,000 for failure to timely report serious injury;

[2] $1,350 for failure to train new employees about the requirements of the injury and illness prevention program;

[3] $1,350 for failure to include written procedures for complying with heat illness prevention requirements;

[14] See the legal record at "https://www.dir.ca.gov/oshab/Decisions/Precedential/08-3093-Maria-De-Los-Angeles-Colunga-DAR.pdf"

[4] $22,500 for failure to provide access to drinking water;

[5] $22,500 for failure to provide access to shade;

[6] $70,000 for failure to provide required heat illness training to employees;

[7] $70,000 for failure to provide required heat illness training to supervisors;

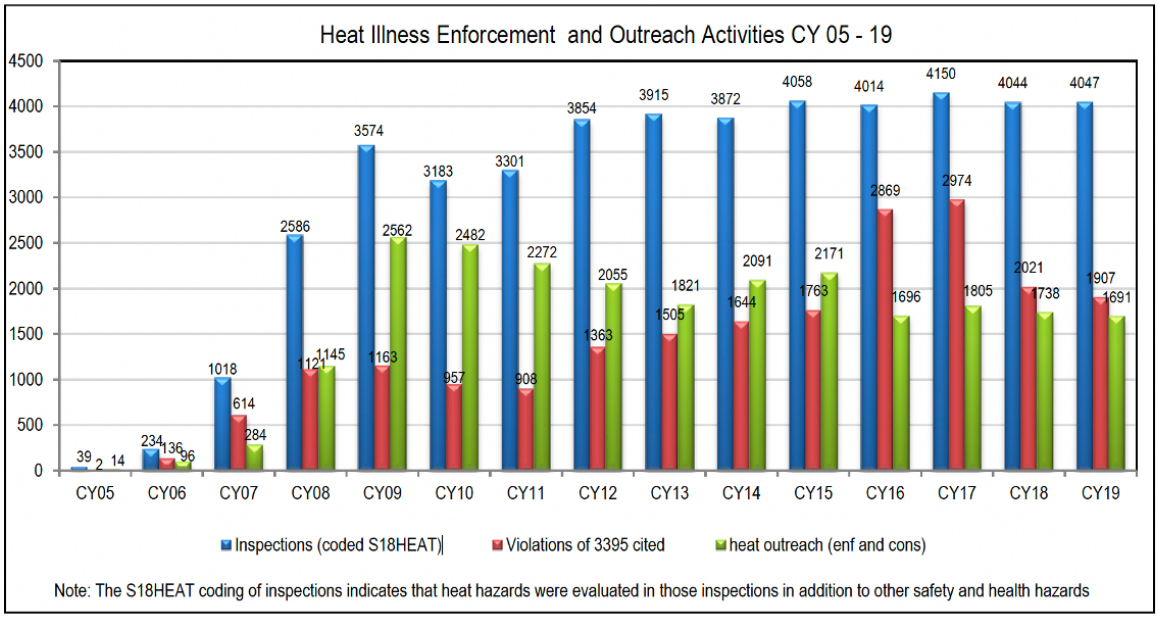
[8] $70,000 for failure to make provisions in advance for prompt medical attention.

In a further response to these violations, the Department of Industrial Relations's Division of Labor Standards Enforcement (DLSE) revoked Merced Farm Labor's license in 2008. This decision was due to non-disclosure of prior Cal/OSHA citations and non-compliance with heat illness regulations. DIR Director John C. Duncan emphasized that the enforcement reflected the company's willful violations that led to severe consequences. Specifically, Duncan stated that "*This company willfully violated the key provisions of the heat illness prevention regulations with tragic consequences...All California employers are required to provide a safe and healthful workplace and this company willfully failed to do so despite knowing the requirements contained in the heat illness regulations and continued to do so even after this terrible death.*"

A plea agreement in March 2011 resulted in Maria De Los Angeles Colunga, the former owner, receiving 40 hours of community service and three years of probation. Her brother, the safety coordinator, pleaded guilty to a felony count of violating a health or safety regulation resulting in death, receiving 480 hours of community service and five years probation. Both agreed to cease farm labor contracting activities.

Figure C.1. Heat Illness Enforcement and Outreach Activities in California

This figure presents the year-round enforcement and outreach activities conducted by Cal/OSHA from 2005 to 2019. This figure is extracted from Page 11 of the "FY 2020 Follow-up Federal Annual Monitoring Evaluation (FAME) Report."



D Robustness of the Main Results in Table 3

This section presents additional analyses to demonstrate the robustness of our main findings on the positive effects of HIPS implementation on plant-level IT intensity.

D.1 Alternative Measures of IT Capital

In the main analysis, we measure IT as the number of computers. For robustness, we also include servers, which function as high-capacity computing stations and share similar properties with computers, to capture a broader measure of IT. The results, presented in Table D.1, remain consistent, with comparable economic magnitudes.

D.2 HIPS Enforcement and Outreach Activities in California

We also incorporate yearly enforcement and outreach activities in California. Specifically, we construct three variables. *Inspections* is defined as one plus the number of yearly inspections conducted by Cal/OSHA divided by 1000, that is, *1 + No. Inspections / 1000*. *Violations* is defined as one plus the number of yearly violations identified by Cal/OSHA divided by 1000, that is, *1 + No. Violations / 1000*. *Outreach* is defined as one plus the number of yearly outreach events conducted by Cal/OSHA divided by 1000, that is, *1 + No. Outreach Events / 1000*. The constructed variables *Inspections*, *Violations*, and *Outreach* are set to zero in all years prior to the implementation of HIPS. Triple-differences analysis in Table D.2 confirms that enforcement and outreach efforts by Cal/OSHA under HIPS spur IT adoption in high-exposure plants in California, lending further support to the main results.

D.3 HIPS Implementation and Firm-level Capital-labor Ratio: Validation with Compustat

To validate the main findings on IT adoption based on CiTDB data, we conduct additional analyses to examine the impact of HIPS implementation on firm-level capital-to-labor ratios for public firms using Compustat data. To this end, we construct a firm-level measure

of exposure to the HIPS implemented in California, defined as the standardized pre-HIPS proportion of a firm's total employment located in California-based plants with heat exposure above the median. Plant-level exposure is defined as the pre-HIPS average heat exposure for a NAICS4 industry, based on its industry classification (Equation (1)).

Table D.3 presents the results.[15] The dependent variable in columns (1) through (3) is the natural logarithm of a firm's property, plant, and equipment divided by the number of employees (*Log(PPENT/Emp)*). We find that firms with high exposure to California HIPS significantly increase their capital-to-labor ratios after the implementation. This evidence is consistent with the plant-level findings that high-exposure plants under California HIPS increase IT adoption. Furthermore, the economic magnitude is comparable: HIPS implementation leads to a 1.7% increase in the capital-to-labor ratio for firms with a one-standard-deviation higher labor exposure. Columns (4) through (6) and (7) through (9) report the effects of HIPS on firm-level PPENT (*Log(PPENT)*) and employment (*Log(Emp)*), respectively. The results show positive and significant effects on PPENT but no significant effects on employment. The null results on employment could possibly be explained by reallocation effects, where firms shift production outside of California in response to the policy, consistent with patterns documented in prior studies. One caveat of the firm-level analysis is that, due to the nature of the data, we do not observe the geographic location of PPENT investment.

Table D.4 and Figure D.1 present the dynamic effects of HIPS implementation on firm-level capital-to-labor ratios. We find no significant differences in capital-to-labor ratios across firms with varying exposure to California HIPS before 2005. However, after HIPS implementation, high-exposure firms exhibit significantly higher capital-to-labor ratios. This evidence supports the parallel trends assumption underlying the difference-in-differences (DID) analysis. Additionally, consistent with Table 4 and Figure D.1, we observe a noticeable increase in the HIPS effects from 2007 to 2008, consistent with the

[15]Note that, to further explore the effects of HIPS after the 2008 crisis, we extend the sample by two additional years, covering the period from 2002 to 2011. The results remain nearly identical when restricting the sample to the main analysis period, 2002 to 2009.

enforcement patterns documented in Figure 1.

D.4 HIPS Implementation and Plant Employment: Validation with QCEW

In addition to using the CiTDB and the Compustat data, we validate our results on the effects of HIPS implementation on plant employment using QCEW data, which is compiled by the U.S. Bureau of Labor Statistics (BLS). The QCEW provides employer-reported data on employment and wages, covering over 95% of jobs in the United States. The dataset is available at the six-digit NAICS industry level for more than 3,000 U.S. counties from 1990 to 2024. The results are presented in Table D.5. The dependent variable is *Log(Emp)*, defined as the natural logarithm of the annual average of monthly employment levels for a given year at the county by NAICS4 level. The results show that HIPS implementation leads to a greater reduction in employment in high-exposure industries in California than in lower-exposure industries, relative to the corresponding difference in non-HIPS states. The economic magnitudes are also similar: HIPS implementation leads to a 0.8% decrease in employment for treated industries with a one-standard-deviation higher labor exposure.

Figure D.1. Dynamic Differences in Firm-level Capital-to-labor Ratio Around the HIPS Implementation

This figure presents dynamic differences in firm-level capital-to-labor ratios around the implementation of HIPS in California. Capital-labor ratio is measured as the natural logarithm of a firm's property, plant, and equipment divided by the number of employees (*Log(PPENT/Emp)*). The coefficients on the y-axis represent the coefficient estimate on the interaction terms between *Firm Exposure* and year dummies from 2002 to 2011. *Firm Exposure* is the standardized pre-HIPS proportion of a firm's total employment in California-based plants with heat exposure above the median level. The plant-level exposure is the pre-HIPS average heat exposure for a NAICS4 industry, based on its industry classification (Equation (1)). The estimation is based on column (2) in Table D.4.

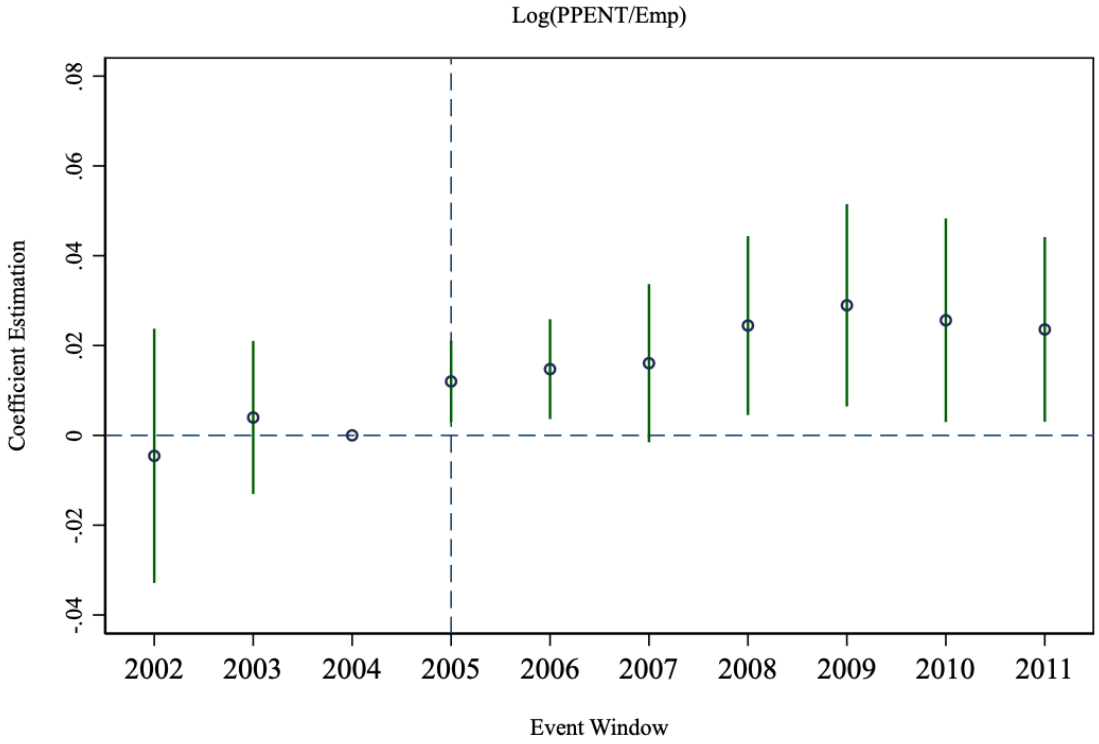


Table D.1. HIPS Implementation and IT Intensity: Alternative Measures of IT Capital

This table presents the effects of HIPS implementation on plant-level IT intensity, using an alternative measure of IT. The dependent variables are *Log(IT/Emp)* in columns (1) - (4) and *Log(IT/Sales)* in columns (5) - (8). *Log(IT/Emp)* is the natural logarithm of the number of computers (desktop and laptop PCs) and servers per employee. *Log(IT/Sales)* is the natural logarithm of the number of computers and servers per million dollars of sales. *Exposure* is the standardized the pre-HIPS average exposure to heat of a NAICS4 industry, defined in Equation (1). *CA* is an indicator variable set to one for plants located in California, and zero otherwise. *Post* is an indicator variable set to one for years 2005 and after, and zero otherwise. *Log(Laborforce)* is the natural logarithm of a county's total laborforce at t-1. *Log(Income)* is the natural logarithm of a county's total income at t-1. *Unemployment Rate* is a county's unemployment rate at t-1. *Temperature* is a county's average temperature from May to September at t-1. *Precipitation* is a county's average precipitation from May to September at t-1. See "*Appendix A: Variable Definitions*" for more detailed definitions of variables. The sample period is from 2002 to 2009. Numbers in parentheses are standard errors. Standard errors are double clustered at the state and the plant levels. ***, **, and * indicate p-values of 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Log(IT/Emp)				Log(IT/Sales)			
CA x Post	0.013**	0.014**			0.016***	0.017***		
	(0.006)	(0.006)			(0.006)	(0.006)		
CA x Exposure x Post		0.018***	0.018***	0.017***		0.018***	0.018***	0.018***
		(0.004)	(0.003)	(0.003)		(0.003)	(0.003)	(0.003)
Exposure x Post		0.038***	0.038***	0.039***		0.040***	0.040***	0.040***
		(0.004)	(0.004)	(0.004)		(0.004)	(0.004)	(0.004)
Log(Laborforce)				-0.303***				-0.327***
				(0.063)				(0.065)
Log(Income)				0.073				0.084
				(0.069)				(0.076)
Unemployment Rate				0.017***				0.017***
				(0.004)				(0.004)
Temperature				-0.010*				-0.011**
				(0.005)				(0.005)
Precipitation				-0.002				-0.003
				(0.002)				(0.002)
Observations	139,000	139,000	139,000	138,077	139,000	139,000	139,000	138,077
Plant FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
NAICS2 Industry x Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State x Year FE	No	No	Yes	Yes	No	No	Yes	Yes
Adjusted R^2	0.635	0.636	0.638	0.637	0.828	0.829	0.829	0.830

Table D.2. HIPS Implementation and IT Intensity: Enforcement and Outreach Activities in California

This table presents the effects of HIPS implementation on plant-level IT intensity, using annual enforcement and outreach activities in California. The dependent variable is *Log(IT/Emp)*, the natural logarithm of the number of computers (desktop and laptop PCs) and servers per employee. *Exposure* is the standardized the pre-HIPS average exposure to heat of a NAICS4 industry, defined in Equation (1). *CA* is an indicator variable set to one for plants located in California, and zero otherwise. *Inspections* is defined as one plus the number of yearly inspections conducted by Cal/OSHA divided by 1000, that is, *1 + No. Inspections/1000*. *Violations* is defined as one plus the number of yearly violations identified by Cal/OSHA divided by 1000, that is, *1 + No. Violations/1000*. *Outreach* is defined as one plus the number of yearly outreach events conducted by Cal/OSHA divided by 1000, that is, *1 + No. Outreach Events/1000*. The constructed variables *Inspections*, *Violations*, and *Outreach* are set to zero in all years prior to the implementation of HIPS. Controls include other interaction terms, *Log(Laborforce)*, *Log(Income)*, *Unemployment Rate*, *Temperature*, and *Precipitation*. *Log(Laborforce)* is the natural logarithm of a county's total laborforce at t-1. *Log(Income)* is the natural logarithm of a county's total income at t-1. *Unemployment Rate* is a county's unemployment rate at t-1. *Temperature* is a county's average temperature from May to September at t-1. *Precipitation* is a county's average precipitation from May to September at t-1. See "*Appendix A: Variable Definitions*" for more detailed definitions of variables. The sample period is from 2002 to 2009. Numbers in parentheses are standard errors. Standard errors are double clustered at the state and the plant levels. ***, **, and * indicate p-values of 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
	Log(IT/Emp)					
CA x Exposure x Inspections	0.008***	0.008***				
	(0.002)	(0.002)				
CA x Exposure x Violations			0.021***	0.022***		
			(0.004)	(0.005)		
CA x Exposure x Outreach					0.011***	0.011***
					(0.002)	(0.002)
Observations	138,077	138,077	138,077	138,077	138,077	138,077
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Plant FE	Yes	Yes	Yes	Yes	Yes	Yes
NAICS2 Industry x Year FE	Yes	Yes	Yes	Yes	Yes	Yes
State x Year FE	No	Yes	No	Yes	No	Yes
Adjusted R^2	0.634	0.636	0.634	0.636	0.634	0.636

Table D.3. HIPS Implementation and Firm-level Capital-labor Ratio

This table presents the effects of HIPS implementation on firm-level capital-to-labor ratios. The dependent variables are *Log(PPENT/Emp)* in columns (1) – (3), *Log(PPENT)* in columns (4) – (6), and *Log(Emp)* in columns (7) – (9). *Log(PPENT/Emp)* is the natural logarithm of a firm's property, plant, and equipment divided by the number of employees. *Log(PPENT)* is the natural logarithm of a firm's property, plant, and equipment. *Log(Emp)* is the natural logarithm of a firm's number of employees. *Firm Exposure* is the standardized pre-HIPS proportion of a firm's total employment in California-based plants with heat exposure above the median level. The plant-level exposure is the pre-HIPS average heat exposure for a NAICS4 industry, based on its industry classification (Equation (1)). *Post* is an indicator variable set to one for years 2005 and after, and zero otherwise. Controls include the logarithm of total assets (*Size*), book leverage (*Book Leverage*), cash holdings (*Cash*), cash flow (*Cashflow*), and a dummy variable indicating whether a firm pays dividends (*Dividend Payer*). All control variables are lagged by one year. The sample period is from 2002 to 2011. Numbers in parentheses are standard errors. Standard errors are double clustered at the state and the firm levels. ***, **, and * indicate p-values of 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Log(PPENT/Emp)			Log(PPENT)			Log(Emp)		
Firm Exposure x Post	0.028***	0.020***	0.017**	0.029***	0.029***	0.021**	-0.001	0.009	0.004
	(0.009)	(0.007)	(0.008)	(0.009)	(0.010)	(0.009)	(0.015)	(0.007)	(0.007)
Observations	19,668	19,646	19,104	19,668	19,646	19,104	19,822	19,800	19,134
Controls	No	No	Yes	No	No	Yes	No	No	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No
NAICS2 X Year FE	No	No	Yes	No	No	Yes	No	No	Yes
State x Year FE	No	No	Yes	No	No	Yes	No	No	Yes
Adjusted R^2	0.935	0.939	0.943	0.964	0.967	0.981	0.966	0.969	0.981

Table D.4. HIPS Implementation and Firm-level Capital-labor Ratio: Dynamic Effects

This table presents the dynamic effects of HIPS implementation on firm-level capital-to-labor ratios. The dependent variable is the natural logarithm of a firm's property, plant, and equipment divided by the number of employees (*Log(PPENT/Emp)*). *Firm Exposure* is the standardized pre-HIPS proportion of a firm's total employment in California-based plants with heat exposure above the median level. The plant-level exposure is the pre-HIPS average heat exposure for a NAICS4 industry, based on its industry classification (Equation (1)). *Year 2002*, *Year 2003*, *Year 2005*, *Year 2006*, *Year 2007*, *Year 2008*, *Year 2009*, *Year 2010*, and *Year 2011* denote dummy variables for the corresponding years. *Year 2004* serves as the benchmark year and is therefore omitted from the regression. Controls include the logarithm of total assets (*Size*), book leverage (*Book Leverage*), cash holdings (*Cash*), cash flow (*Cashflow*), and a dummy variable indicating whether a firm pays dividends (*Dividend Payer*). All control variables are lagged by one year. The sample period is from 2002 to 2011. Numbers in parentheses are standard errors. Standard errors are double clustered at the state and the firm levels. ***, **, and * indicate p-values of 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)
	Log(PPENT/EMP)		
Firm Exposure x Year 2002	-0.003	-0.005	-0.006
	(0.014)	(0.014)	(0.017)
Firm Exposure x Year 2003	0.005	0.004	0.003
	(0.008)	(0.008)	(0.008)
Firm Exposure x Year 2005	0.014***	0.012**	0.014***
	(0.003)	(0.005)	(0.005)
Firm Exposure x Year 2006	0.024***	0.015**	0.012**
	(0.004)	(0.006)	(0.005)
Firm Exposure x Year 2007	0.029***	0.016*	0.012
	(0.006)	(0.009)	(0.008)
Firm Exposure x Year 2008	0.032***	0.024**	0.017*
	(0.007)	(0.010)	(0.010)
Firm Exposure x Year 2009	0.035***	0.029**	0.024**
	(0.008)	(0.011)	(0.011)
Firm Exposure x Year 2010	0.037***	0.026**	0.021*
	(0.009)	(0.011)	(0.011)
Firm Exposure x Year 2011	0.038***	0.024**	0.018*
	(0.014)	(0.010)	(0.010)
Observations	19,668	19,646	19,104
Controls	No	No	Yes
Firm FE	Yes	Yes	Yes
Year FE	Yes	Yes	No
NAICS2 X Year FE	No	No	Yes
State x Year FE	No	No	Yes
Adjusted R^2	0.935	0.939	0.943

Table D.5. HIPS Implementation and Plant Employment: Validation with QCEW

This table presents the effects of HIPS implementation on plant-level employment, using QCEW data at the county by NAICS4 level. The dependent variable is *Log(Emp)*, defined as the natural logarithm of annual average of monthly employment levels for a given year. *Exposure* is the standardized the pre-HIPS average exposure to heat of a NAICS4 industry, defined in Equation (1). *CA* is an indicator variable set to one for plants located in California, and zero otherwise. *Post* is an indicator variable set to one for years 2005 and after, and zero otherwise. Controls in columns (1) includes other interaction terms. Controls in columns (2) – (5) include other interaction terms, *Log(Laborforce)*, *Log(Income)*, *Unemployment Rate*, *Temperature*, and *Precipitation*. *Log(Laborforce)* is the natural logarithm of a county's total laborforce at t-1. *Log(Income)* is the natural logarithm of a county's total income at t-1. *Unemployment Rate* is a county's unemployment rate at t-1. *Temperature* is a county's average temperature from May to September at t-1. *Precipitation* is a county's average precipitation from May to September at t-1. See "*Appendix A: Variable Definitions*" for more detailed definitions of variables. The sample period is from 2002 to 2009. Numbers in parentheses are standard errors. Standard errors are double clustered at the state and the NAICS4 industry levels. ***, **, and * indicate p-values of 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)	(5)
	Log(Emp)				
CA x Exposure x Post	-0.008***	-0.008**	-0.008**	-0.009**	-0.007**
	(0.003)	(0.004)	(0.003)	(0.004)	(0.003)
Observations	641,527	614,693	614,693	614,717	612,831
Controls	Yes	Yes	Yes	Yes	Yes
NAICS2 Industry x Year FE	Yes	Yes	Yes	No	Yes
NAICS4 FE	Yes	Yes	Yes	No	Yes
NAICS4 Industry x Year FE	No	No	No	Yes	No
State x Year FE	No	No	Yes	Yes	No
County FE	Yes	Yes	Yes	Yes	No
County x Year FE	No	No	No	No	Yes
Adjusted R^2	0.646	0.658	0.658	0.631	0.651

E Discussions

This section provides additional analyses that support the discussion in Section 6 and complement the main findings with further empirical evidence.

E.1 Number of High and Low Exposure Plants

Table D.1 examines the impact of HIPS implementation on the number of high- and low-exposure plants in California and other states. The dependent variable is *Log(Plants)*, defined as the natural logarithm of the annual average of quarterly plant counts for a given year at the county by NAICS4 level, sourced from the QCEW. We find no significant change in the number of high- versus low-exposure plants in California following HIPS implementation, when compared to other states. This suggests that firms did not respond by relocating operations or withdrawing from high-exposure industries.

Table D.1. HIPS Implementation and Number of Plants

This table presents the effects of HIPS implementation on the number of high and low exposure plants in California and other states, using QCEW data at the county by NAICS4 level. The dependent variable is *Log(Plants)*, defined as the natural logarithm of the annual average of quarterly plant counts for a given year. *Exposure* is the standardized the pre-HIPS average exposure to heat of a NAICS4 industry, defined in Equation (1). *CA* is an indicator variable set to one for plants located in California, and zero otherwise. *Post* is an indicator variable set to one for years 2005 and after, and zero otherwise. Controls in columns (1) includes other interaction terms. Controls in columns (2) – (5) include other interaction terms, *Log(Laborforce)*, *Log(Income)*, *Unemployment Rate*, *Temperature*, and *Precipitation*. *Log(Laborforce)* is the natural logarithm of a county's total laborforce at t-1. *Log(Income)* is the natural logarithm of a county's total income at t-1. *Unemployment Rate* is a county's unemployment rate at t-1. *Temperature* is a county's average temperature from May to September at t-1. *Precipitation* is a county's average precipitation from May to September at t-1. See "*Appendix A: Variable Definitions*" for more detailed definitions of variables. The sample period is from 2002 to 2009. Numbers in parentheses are standard errors. Standard errors are double clustered at the state and the NAICS4 industry levels. ***, **, and * indicate p-values of 1%, 5%, and 10%, respectively.

	(1)	(2)	(3)	(4)	(5)
	Log(Plants)				
CA x Exposure x Post	-0.000	-0.002	-0.002	-0.001	-0.002
	(0.004)	(0.004)	(0.004)	(0.003)	(0.004)
Observations	641,527	614,693	614,693	614,717	612,831
Controls	Yes	Yes	Yes	Yes	Yes
NAICS2 Industry x Year FE	Yes	Yes	Yes	No	Yes
NAICS4 FE	Yes	Yes	Yes	No	Yes
NAICS4 Industry x Year FE	No	No	No	Yes	No
State x Year FE	No	No	Yes	Yes	No
County FE	Yes	Yes	Yes	Yes	No
County x Year FE	No	No	No	No	Yes
Adjusted R^2	0.791	0.807	0.807	0.787	0.803