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Economic Effects of the Virginia Occupational Safety and Health (VOSH) Compliance Programs

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EXECUTIVE SUMMARY

This report evaluates the economic effects of the Virginia Department of Labor and Industry's (DOLI) Virginia Occupational Safety and Health (VOSH) compliance programs. Virginia is one of 22 states authorized by the federal Occupational Safety and Health Administration (OSHA) to enforce its own Occupational Safety and Health (OSH) regulations for private enterprises and state and local government organizations. The VOSH program, initially approved in 1976 and fully approved in 1988, seeks to improve workplace safety and health through inspections and compliance activities.

Key Findings

Program Structure and Activities

The VOSH program is designed to support safe and healthy working conditions for Virginia workers through a comprehensive approach that includes enforcement, education, and cooperative relationships between employers and employees. VOSH conducts both programmed and unprogrammed inspections, focusing on high-hazard workplaces and responding to imminent dangers, fatalities, injuries, illnesses, and worker complaints. It also supports cooperative initiatives and various voluntary protection programs to promote and recognize exceptional workplace safety and health practices. These activities have the ultimate goal of reducing workplace injuries, illnesses, and fatalities, thereby enhancing the overall economic and social well-being of the state.

Workplace Safety and Health Trends

VOSH inspections declined from 3,777 in 2008 to 2,009 in 2022 due, in part, to slow growth in financial resources and staffing levels. Despite the decline in inspections, Virginia's workplace injury and illness rates have generally decreased over the past two decades, with the state maintaining lower rates compared to national averages.

Long-term Effects of Workplace Injuries and Illnesses

Workplace injuries and illnesses have significant long-term economic impacts on workers, including reduced earnings, lower labor force participation, and increased mortality rates. Studies of workplace injuries indicate that workers suffer persistent wage losses over the first decade and reduced labor force participation, especially among older workers. Injured workers often face decreased wealth accumulation and lower consumption levels due to financial strain. Additionally, these injuries and illnesses can lead to higher mortality rates and a diminished quality of life, affecting both physical and mental health. The VOSH inspections are important in mitigating workplace hazards and adverse effects of injuries and illnesses, enhancing worker well-being, and promoting economic growth.

Economic Impact Analysis

The study uses the Virginia REMI PI+ economic impact model to assess the effects of VOSH inspections on reducing workforce injuries and illnesses. VOSH inspections in 2022 helped reduce job losses by approximately 29 jobs in the first year. The cumulative impacts from the 2022 inspections over a 20-year period are as follows: $28,967,538 in output, $16,707,020 in GDP, $16,348,886 in personal income, and $931,521 in state tax revenue.

Cost-Effectiveness Analysis

A Cost-Effectiveness Analysis (CEA) of VOSH inspections estimates that it costs $20,965 per additional Quality Adjusted Life Year (QALY), making the inspections cost-effective compared to many other medical interventions. The analysis shows that VOSH inspections are cost-effective at a willingness to pay threshold of $50,000 per QALY.

Conclusion

The VOSH compliance programs provide substantial economic benefits to the state of Virginia by reducing workplace injuries and illnesses, improving worker productivity, and generating positive fiscal impacts. The cost-effectiveness of VOSH inspections further supports the value of continued investment in workplace safety and health initiatives.

INTRODUCTION

This purpose of this study is to evaluate the economic effects of the Virginia Department of Labor and Industry's (DOLI) Virginia Occupational Safety and Health (VOSH) compliance programs.[1] Virginia is one of 22 states authorized by the federal Occupational Safety and Health Administration (OSHA) to provide its own Occupational Safety and Health (OSH) enforcement of private enterprises and state and local government organizations. Another 7 states provide OSH public-sector-only compliance programs. The VOSH program received initial federal approval in 1976 and final approval in 1988.

The study uses two different economic evaluation frameworks to assess the economic effects of VOSH: economic impact analysis and social cost benefit analysis. The purpose of economic impact analysis is to quantify the changes in regional economic activity, such as employment output, and income that results from a policy, project, or program. In contrast, social cost-benefit analysis is a broader approach that assesses the overall societal desirability of an intervention by tabulating the market and non-market costs and benefits that accrue to society as a whole. Cost-Effectiveness Analysis (CEA) is a tool within the cost-benefit evaluation framework that is used when it is challenging to assign monetary values to certain benefits. CEA provides a way to compare the relative efficiency of different interventions by focusing on the costs required to achieve a specific measurement outcome.

The economic impact analysis uses a Virginia REMI PI+ economic impact model to examine the effects of VOSH workplace safety and health inspections. The inspections decrease workforce injuries and illnesses, which reduces long-term worker earnings and productivity losses, mortality, and private industry and state government workforce costs, and improves worker quality of life. These intermediate inspection effects are entered into the REMI PI+ model to assess the statewide economic impacts of the program. Additionally, the fiscal implications for state government resulting from these economic impacts are assessed along with the return on investment (ROI) in state government revenue. The analysis looks at the effect of VOSH compliance activities on injuries and illnesses for the 2022 cohort of workers, and its long-term economic impact through a 20-year period, 2022-2041.

The cost-effectiveness analysis of VOSH inspection activities compares the cost-effectiveness of inspection activities by assessing the cost of reducing occupational illness and injury Quality Adjusted Life Years (QALY). The analysis includes the following data: expected effectiveness of VOSH inspection activities in reducing workplace injuries and illnesses, the average QALY losses of various injuries and illnesses, the societal benefit of avoiding reduced QALY, and the cost of providing VOSH inspections.

[1] Jay Withrow and Zahra Qarni of the Department of Labor and Industry provided helpful comments on earlier version of this study. Amy Muldoon of the Weldon Cooper Center for Public service assisted with document editing, design, and formatting. Any errors or omissions are the responsibility of the authors.

The results of these analyses indicate that the VOSH inspection activities provide positive state economic impacts and are cost-effective compared to many other medical interventions. According to the economic impact analysis, VOSH inspections in 2022 helped reduce the number of jobs lost by approximately 29 jobs in 2022, falling to nearly 12 jobs in the next year, with incremental decline in each succeeding year until stabilizing near 2.5 jobs in 2032. The cumulative impacts for 2022 are as follows: $28,967,538 in output, $16,707,020 in GDP, $16,348,886 in personal income, and $931,521 in state tax revenue over a 20-year period. For comparison purposes, the entire fiscal year 2022 budget for VOSH programs, according to the 23g Federal Grant Application, was $10,271.600, with marginal compliance-inspection-related costs being even less, estimated at $6,686,938. These results represent the 2022 compliance effects alone, which are sustained over time for the 2022 cohort of workers affected.

In Cost-Effectiveness Analysis, the primary measure used to evaluate an intervention is the incremental cost-effectiveness ratio (ICER). The ICER estimates how much it will cost to achieve one additional Quality Adjusted Life Year (QALY) for employees at a worksite when there is a VOSH inspection compared to when there is no inspection. According to the analysis undertaken here, the estimated ICER of inspection is $20,965 per additional QALY. This means that if the Commonwealth of Virginia has a willingness to pay (WTP) at least $20,965 per QALY, then the inspection is cost-effective. Although the WTP threshold when an intervention is "worth it" is subjective, health economics often uses an ICER value of $50,000 per QALY. At a WTP of $50,000, a VOSH inspection is cost-effective at $20,965 per QALY. Further analysis indicates that this finding of inspection cost-effectiveness is relatively insensitive to assumptions within certain ranges of several key parameters used in the baseline analysis, including the cost of inspection, the probability of injury, the cost of a fatality, and the effectiveness of OSH inspections in reducing workplace injuries and illnesses.

The study is divided into four sections.

The study begins with an in-depth examination of the mission, functions, and organizational structure of DOLI, emphasizing the role of VOSH in efforts to improve workplace safety and health. A logic model is constructed to describe the inputs, activities, outputs, and outcomes of VOSH programs, providing a holistic view of their functioning and their ultimate role in providing economic benefits in the form of lower medical costs, fewer compensation claims, and reduced lost work time. Next, it examines statistics on the characteristics and trends of VOSH inspection activities and Virginia workplace injuries, illnesses, and fatalities in comparison to the United States benchmark.

The second section provides a literature review that examines the influences on workplace health and safety, determinants of injury and illness trends, the impact of regulatory programs on worker safety and health, and the short- and long- term effects of workplace injuries and illnesses on worker physical and economic wellbeing, including earnings potential, productivity, labor force participation, wealth, and mortality. Drawing upon economic theories and empirical evidence, the review describes the costs associated with workplace injuries and illnesses and assesses methods for valuing these costs.

The third section estimates the statewide economic impacts of VOSH inspection activities. It describes the REMI PI+ dynamic, multi-sector regional economic simulation model used in the analysis and manner of constructing model inputs. Economic and demographic outcome variables examined include gross domestic product (GDP), output, personal income, employment, population, labor force, and state tax revenue. In addition, the economic impacts are assessed in terms of their underlying source, including changes in worker earnings, productivity, mortality, firm production costs, and quality of life.

The fourth section evaluates the cost-effectiveness of VOSH inspection efforts in reducing workplace hazards using Cost-Effectiveness Analysis (CEA). CEA computes the costs and health outcomes of worker safety and health inspections by VOSH. It compares inspection to no inspection by estimating how much it costs to achieve an additional quality adjusted year of life (QALY). In addition to a baseline analysis using assumptions informed by the scholarly literature, VOSH program costs, injury and illness data, and various sensitivity analyses are provided.

SECTION 1

VIRGINIA WORKPLACE SAFETY AND HEALTH

This section provides a review of workplace safety and health conditions in Virginia. It begins by providing a description of the role of the Virginia Department of Labor and Industry (DOLI) with a specific focus on its Virginia Occupational Safety and Health (VOSH) program, including its role in ensuring workplace safety and health in Virginia. It also presents a logic model depicting the key components and interconnections of VOSH programs, highlighting inputs such as funding, human resources, regulatory frameworks, and partnerships; activities, such as compliance inspections, training, technical assistance, and data analysis; and outcomes like increased awareness, enhanced compliance, and improved safety and health practices, which result in healthier workforces, enhanced productivity, and other economic benefits. It then examines VOSH's safety and health compliance activities, including the number and types of inspections conducted, violations identified, and penalties imposed. It concludes with an examination of Virginia workplace injury, illness, and fatality incidence rate patterns with reference to U.S. and other benchmarks when relevant, including patterns over time, worker demographics (gender and age), and employer characteristics (industry).

VOSH Role and Functions

Located within the Secretariat of Labor, DOLI promotes safe and healthy workplaces by fostering favorable working conditions, protecting children from hazardous employment conditions, and ensuring the safe operation of boilers and pressure vessels. To improve and protect Virginia's workplaces through education, training and compliance, thereby reducing fatalities, injuries and illnesses is the mission of the VOSH program, the largest division within the department. The VOSH program was created by § 40.1-1 of the Code of Virginia. It was established in 1972 as a "state plan" under Section 18 of the federal Occupational Safety and Health Act of 1970 (P.L. 91-596), receiving initial federal approval in 1976, certification in 1984, and final approval in 1988.

VOSH enforces safety and health laws, standards, and regulations for private sector and state and local government workplaces within the Commonwealth of Virginia. Federal workplaces and workers, private sector maritime workplaces, and selected other industries fall under federal OSHA or other federal agency jurisdiction (e.g., the Federal Railroad Administration [FRA] has safety and health jurisdiction over workplace activities associated with "rolling stock"; Mine Safety and Health is covered by the federal Mine Safety and Health Administration [MSHA] and the Virginia Department of Mines, Minerals and Energy [DMME]). VOSH workplace standards and regulations are generally the same as OSHA's, but some are unique to Virginia to address hazards where the federal standard does not exist or is less effective than VOSH's unique standard. OSHA monitors the performance of state programs such as VOSH on an annual basis and provides up to 50% of its operating costs for most activities.

VOSH aims to 1) improve knowledge of workplace safety and health and 2) ensure compliance with safety and health regulations. It takes both regulatory and non-regulatory approaches to achieve these goals and is organized into two units for these purposes: compliance and cooperative programs. The safety and health compliance programs conduct scheduled unannounced inspections of high hazard workplaces to ensure compliance with safety and health standards (programmed inspections) and respond to imminent danger situations, reports of workplace fatalities, injuries and illnesses, referrals from other governmental agencies, and worker complaints about workplace hazards (unprogrammed inspections). When violations are found, the department takes appropriate enforcement actions, including issuing citations, orders of abatement, and penalties.

Cooperative programs are designed to promote and recognize enhanced workplace safety and health practices. These programs promote a more collaborative approach to occupational safety and health by encouraging employers to go beyond basic compliance with standards and regulations to foster safe and healthy work environments. The Cooperative Programs Division provides free outreach, consultation services, and training for small businesses through VOSH Consultation Services. It also offers six voluntary programs to promote and recognize exceptional workplace safety and health efforts:

- Virginia Safety and Health Achievement Recognition Program (SHARP) (small businesses through VOSH Consultation and Training), AND

The following Virginia Voluntary Protection Programs available to businesses of all sizes:

- Virginia STAR: The highest level of recognition of safety and health excellence
- Virginia BEST: Building Excellence in Safety, Health, and Training (construction)
- Virginia CHALLENGE Program: A three-stage process to qualify to apply for Virginia STAR recognition)
- Virginia Department of Corrections (VADOC) CHALLENGE (state correctional facilities)
- Virginia BUILT: Building Safety and Health Excellence in Construction through Mentorship and Training (construction mentorship program)

Logic Model of DOLI OSH Programs

The VOSH program supports safe and healthy working conditions for Virginia workers by enforcing standards, providing education, and fostering cooperative relationships between employers and employees. A logic model for VOSH illustrates how the program's inputs, activities, outputs, and outcomes interconnect to achieve its ultimate goal of reducing workplace injuries, illnesses, and fatalities, thereby enhancing the overall economic and social well-being of the state. **Figure 1.1** summarizes the VOSH program logic model, illustrating the flow from inputs to final outcomes.

Inputs and Activities

The VOSH program relies on several inputs for its operations. These include funding from state and federal sources; human resources, such as inspectors and trainers; a statutory and regulatory framework; and partnerships with other agencies, industry groups, and labor organizations. These inputs support the program's activities, which include compliance inspections, training and education initiatives, recognition programs, technical assistance, data collection and analysis, and policy development. Compliance inspections—sometimes with issued citations, orders of abatement and penalties—ensure that workplaces adhere to established safety and health standards, while training, education, and recognition programs equip both employers and employees with the knowledge needed to maintain safe and health work environments. Technical assistance offers direct support and guidance on implementing safety and health protocols, and data collection efforts provide information about workplace hazards and trends.

Outputs and Short-term Outcomes

The activities of the VOSH program produce measurable outputs that show its immediate effects. These outputs include the number of compliance inspections conducted, the numbers of hazards identified and abated, the frequency and magnitude of VOSH Cooperative Programs' outreach, education and training sessions, the volume of employer technical assistance requests handled, and the policy changes implemented based on new safety and health insights. These outputs lead to several short-term outcomes. Increased awareness among employers and workers about occupational safety and health standards is a primary short-term outcome, contributing to safer and healthier workplace environments. Enhanced compliance with safety and health regulations and the adoption of improved safety and health practices are also expected, reducing immediate risks in Virginia workplaces. Furthermore, the program builds capacity within organizations, enabling them to independently assess and manage safety and health risks effectively.

Intermediate and Final Outcomes

Short-term outcomes support more significant intermediate and final outcomes. Intermediate outcomes include a sustained increase in compliance rates, a reduction in workplace hazards and exposures, and stronger organizational safety and health cultures. These outcomes contribute to the long-term outcomes of the program. In the final analysis, the VOSH program seeks to achieve several key impacts: a reduction in workplace fatalities, injuries and illnesses; a healthier workforce with improved overall well-being; enhanced workplace productivity and efficiency; and economic benefits resulting from lower medical costs, fewer workers' compensation claims, and reduced lost work time.

FIGURE 1.1 VOSH Logic Model

Inputs	Activities	Outputs	Short-term outcomes	Intermediate Outcomes	Final Outcomes
Funding	Compliance inspections	Number of inspections conducted	Increased awareness		Reduction in workplace injuries, illnesses and fatalities
Human resources	Training and education Recognition programs	Number of hazards identified and corrected Frequency and reach of training sessions	Enhanced compliance with safety and health regulations	Sustained reduction in workplace hazards and exposure	Healthy workforce with improved well-being
Regulatory framework	Technical assistance	Volume of technical assistance requests handled	Improved safety and health practices	Stronger safety and health cultures within organizations	Enhanced productivity and efficiency
Partnerships	Data collection and analysis	Policy changes implemented	Organizational capacity building		Economic benefits (lower medical costs, fewer compensation claims, reduced lost work time)
	Policy development				

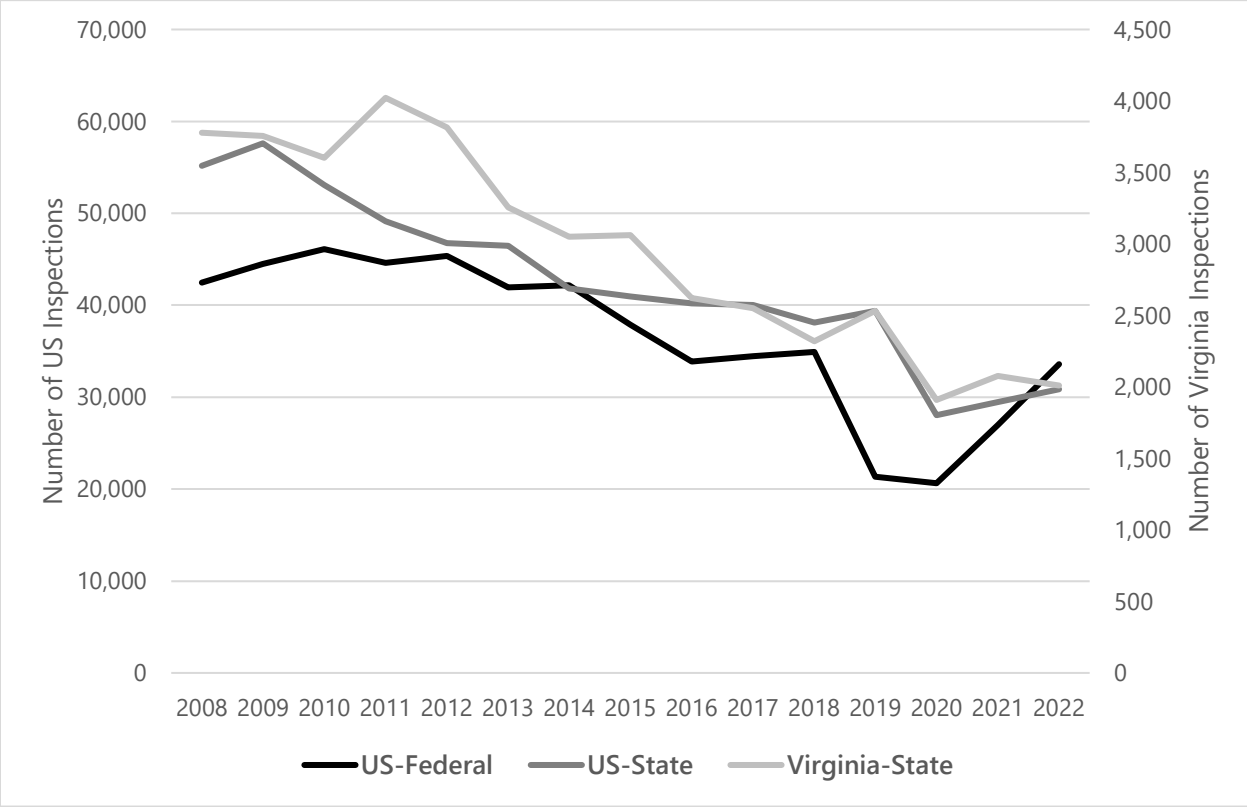
Acknowledgement: ChatGPT 4.0 was used as a resource in developing the VOSH Logic Model described here.

Workplace Safety and Health Compliance Activities

VOSH inspections declined from 3,777 in 2008 to 2,009 in 2022, a decline of 53% according to USDOL OSHA data. This pattern is similar in relative magnitude to that of other state OSH offices which declined 41% over the same period (see **Figure 1.2**).[1] However, federal (OSHA) inspections declined by only 12%. One possible explanation for the disparities in federal and state enforcement may be financial resources. According to the Occupational Safety and State Plan Association (2021), federal OSHA funding, over the period 2005 to 2021, increased by over 27.6% while state plan

federal funding increased less than 18.7%. Furthermore, DOLI has indicated that VOSH staffing resources, in relation to the number of Virginia employers and employees, have not changed since the program was established (based on business and employment level data from 1984—109,238 employers and 2,098,046 employees [Virginia Department of Labor and Industry 2023]). These numbers have more than doubled to 4.6 million workers in 310,666 establishments for Virginia in 2023. Another possible explanation for the Virginia disparity is that VOSH has not been at or near full staffing in several years. When it was at full staffing in the first decade, it undertook nearly 3,000 inspections. The division is currently understaffed by 14 positions. If these positions produced the number of inspections that existing staff did, a projected additional 567 inspections could be undertaken.

FIGURE 1.2 Occupational Safety and Health Inspections, Federal and State, 2008-2022



Source: U.S. Department of Labor, OSHA Inspection Explorer: https://enforcedata.dol.gov/views/oshaLab.php

VOSH inspections are classified in various ways, including by category and inspection type, and categorized as being related to either worker safety or health. Safety inspections are concerned primarily with identifying and mitigating physical hazards, such as machine guarding, electrical safety, fall protection, fire safety, and material handling, as well as enhancing procedural safety, such as using personal protective equipment (PPE) and observing emergency procedures. Health inspections focus on identifying and mitigating long-term risks associated with exposure to hazardous substances and environments, such as chemical hazards (e.g., toxic substances, poor ventilation), biological hazards (e.g., infection agents, unsanitary conditions), physical health hazards (e.g., excessive noise, radiation, temperatures and ergonomic stresses such as heavy lifting and

repetitive strain). In 2022, 1,437 (72%) of the inspections were related to safety while 572 (28%) were related to health. In comparison, for all state plan inspections, 75% were safety-related and 25% health-related for the same year.

Inspections of work sites are also classified by type—programmed versus unprogrammed. Programmed inspections are planned and scheduled based on specific criteria. These criteria are designed to target industries and workplaces that have higher rates of injuries and illnesses or are involved in hazardous activities. Virginia gets its programmed inspection lists mainly from two sources: 1) a state plan emphasis program (similar to OSHA's national emphasis programs or NEPs) that targets establishments in an industry with a particular hazard or high injury/illness and fatality rates and 2) Industry Priority Lists, or randomized establishments, generated every year by OSHA. Unprogrammed inspections are not scheduled and are conducted in response to specific incidents or information, which include the following: 1) reports of an imminent danger, fatality/catastrophe incident, employee complaints about unsafe or unhealthful worksites; 2) referrals from other government agencies, organizations, or individuals; and 3) follow-up inspections for previously cited violations. Programmed inspections account for over half (54%) of inspections while 44% are unprogrammed and 2% are not identified by type. In comparison, other state plans report that 58% of their inspections are unprogrammed, 38% programmed, and 3% are not identified.

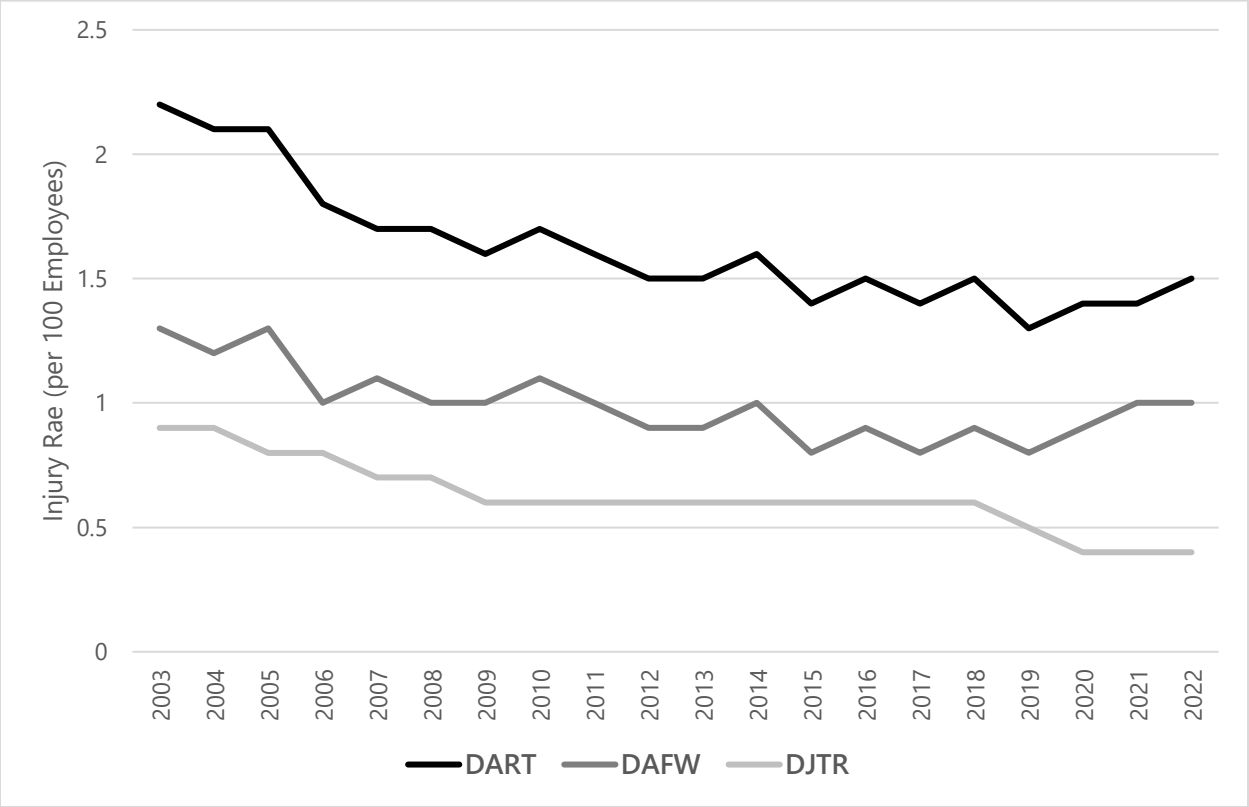
In 2022, VOSH issued 4,121 violations. Most of these violations (2,982 or 72%) were classified as serious, willful (11 or 0.2%), or repeat (84 or 2%). 1,044 violations (25%) were classified as other-than-serious (OTS). Proposed initial penalties for issued citations for violations in 2022 amounted to $7,397,121.

Virginia Workplace Injury and Illness, and Fatality Incidence

Historical and cross-sectional data on workplace injuries, illnesses, and fatalities from the Bureau of Labor Statistics (BLS) Census of Fatal Occupational Injuries (CFOI) and Survey of Occupational Injuries and Illnesses (SOII) data is useful in illustrating the characteristics and changes (both absolute and relative to U.S. and state benchmarks) in workforce safety and health outcomes in Virginia.

Figure 1.3 indicates that Virginia injury and illness cases involving days away from work, job transfer, or restriction (DART); cases involving days away from work (DAFW); and cases involving days of job transfer or restriction (DJTR) injury and illness rates per 100 employees have declined over the last two decades. The only source of change in approximately the last decade, however, is DTJR. Over the period 2011 to 2022, DAFW was unchanged, while less serious DJTR injuries and illnesses decreased 33%.

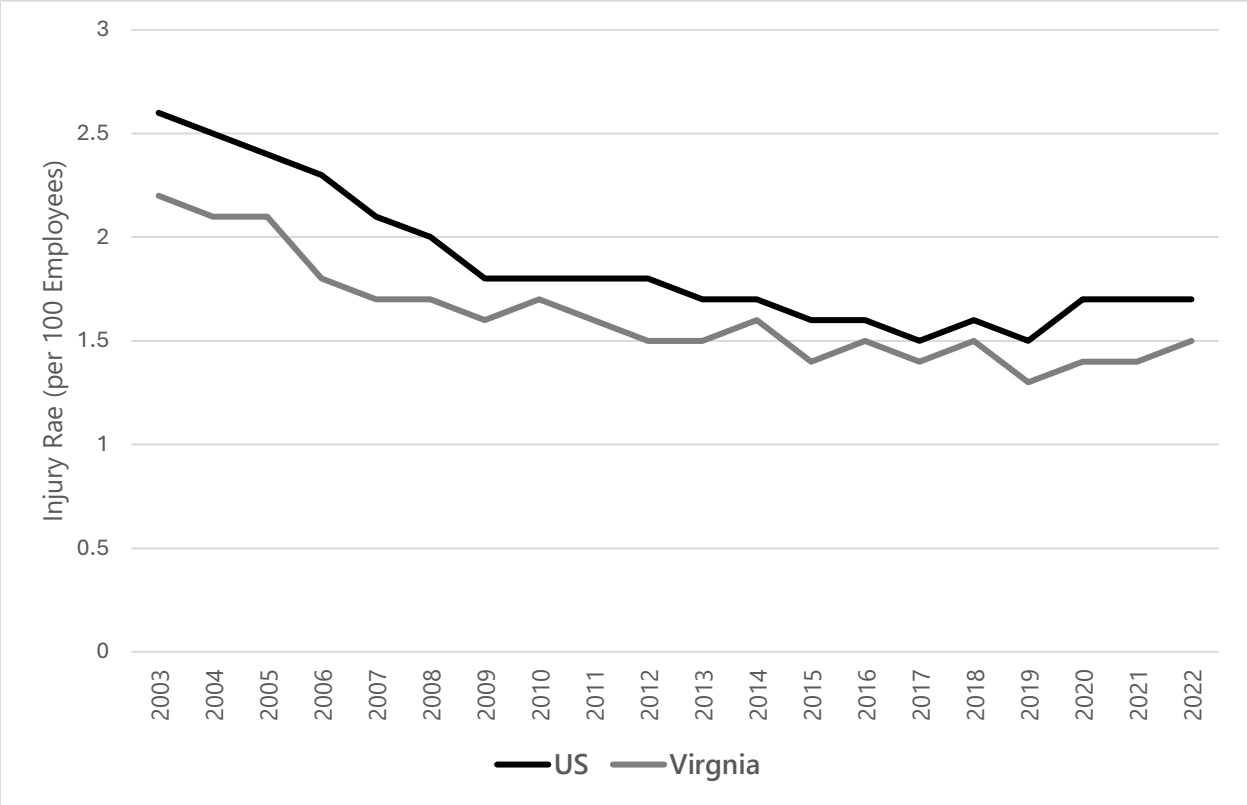
FIGURE 1.3 Injury and Illness Rate per 100 Employees in Virginia, 2003-2022



Source: Bureau of Labor Statistics, Survey of Occupational Injuries and Illnesses

The long-term decline in DART incidence rates and stabilization beginning in the last 8 years is also observed at the national level (see **Figure 1.4**). However, the national rate has declined at a slower rate of 5.6% compared to 6.3% in Virginia over the 2011-2022 period. These secular changes are driven by economic, demographic, technological, regulatory, and other factors that are explored in more detail in the next section. Virginia's rate is also below the national rate over the entire 20-year period. Virginia currently has significantly lower injury and illness rates compared to the U.S. across various demographic and employer characteristics (see **Table 1.1**).

FIGURE 1.4 DART Injury and Illness Rate, US and Virginia, 2003-2022



Source: Bureau of Labor Statistics, Survey of Occupational Injuries and Illnesses

TABLE 1.1 Incidence Rates (per 10,000 Workers) of Nonfatal Workplace Injuries and Illnesses involving Days Away from Work by Selected Worker Characteristics and Industry, U.S. and Virginia, 2022

	U.S.	Virginia
Gender*		
Male	1.8	1.5
Female	1.8	1.4
Age*		
16 to 19	2.5	1.9
20 to 24	2.3	2.1
25 to 34	1.8	1.3
35 to 44	1.7	1.2
45 to 54	1.8	1.3
55 to 64	1.9	1.4
65 and over	1.4	1.4

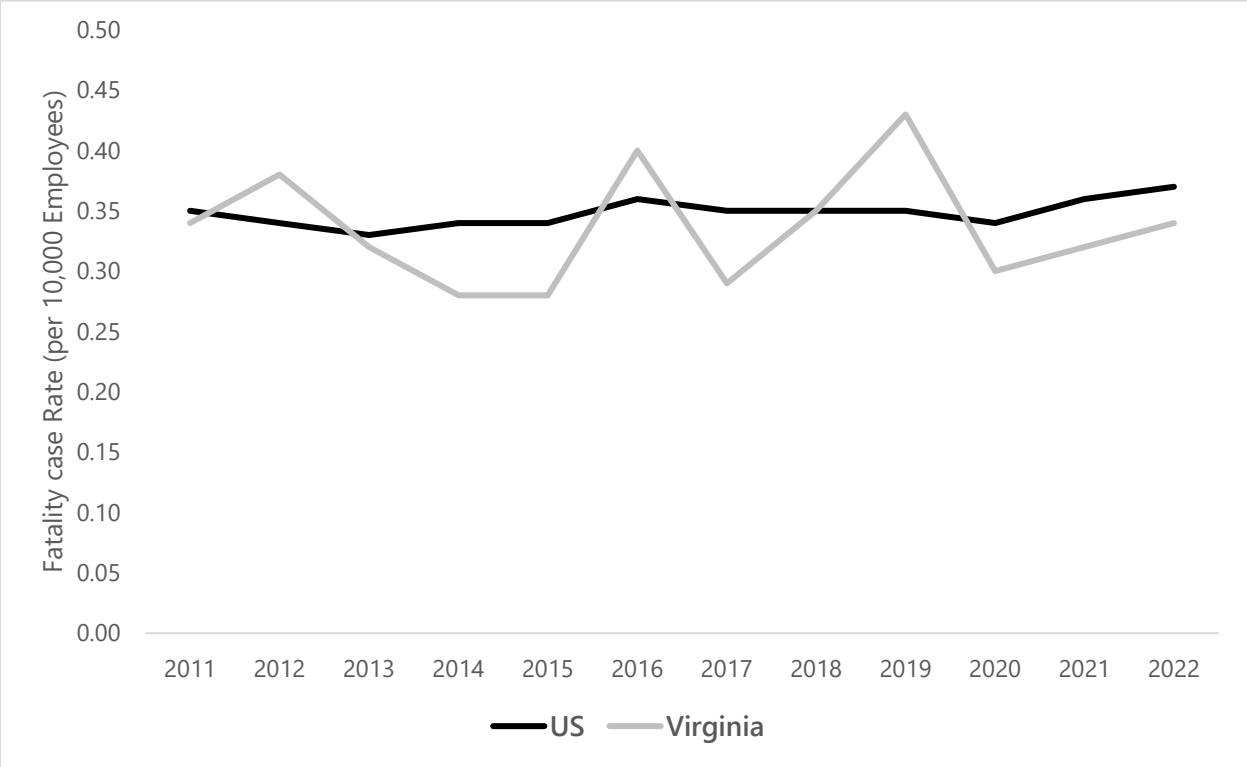
	U.S.	Virginia
Industry		
All industries including private, state and local government[5]	1.8	1.5
Agriculture, forestry, fishing and hunting[5]	2.7	1.4
Mining, quarrying, and oil and gas extraction[6]	1.0	1.0
Utilities	1.1	0.5
Construction	1.5	1.4
Manufacturing	2.0	2.2
Wholesale trade	1.8	1.7
Retail trade	2.5	2.1
Transportation and warehousing	3.8	3.2
Information	0.5	1.1
Finance and insurance	0.1	-
Real estate and rental and leasing	1.4	0.4
Professional, scientific, and technical services	0.4	0.3
Management of companies and enterprises	0.4	1.0
Administrative and support and waste management and remediation services	1.2	0.6
Educational services	1.0	-
Health care and social assistance	2.7	2.5
Arts, entertainment, and recreation	2.4	2.8
Accommodation and food services	1.3	1.2
Other services (except public administration)	1.0	1.0
State government	2.5	0.8
Local government	2.7	1.9

*Source: * 2021-2022 biennial nonfatal case and demographic rates*

*** 2022 nonfatal occupational injuries and illnesses data by industry*

Fatality rates have not declined as much as DART incidence rates in recent years. In fact, during the last 11 years, the national workplace fatality rate increased slightly from 0.35 in 2011 to 0.37 in 2022, while the Virginia rate was unchanged over the same period. However, Virginia fatality rates have generally been lower than the national rates (see **Figure 1.5**).

FIGURE 1.5 Occupational Fatality Cases per 10,000 Employees, Virginia and U.S., 2011-2022



Source: Bureau of Labor Statistics, Census of Fatal Occupational Injuries

Several explanations could be given for why Virginia has lower injury, illness, and fatality rates compared to the U.S. First of all, Virginia's economy has a higher proportion of industries that are less hazardous compared to the national average. For example, Virginia has a higher proportion of industries in service rather than manufacturing or construction. Another possible factor is workforce characteristics. Demographic factors such as age, education level, and socioeconomic status of the workforce could influence injury, illness, and fatality rates. For example, older and more educated workers might be more cautious and compliant with safety and health regulations. Other factors such as state regulations and enforcement or private industry safety and health programs could potentially also play a role in lowering rates. These and other factors will be examined more closely in the next section.

Similar factors may also explain the apparent slowdown in the reduction of fatality rate and DAFW incidence rate declines. Changes in the types of industries and the nature of work can impact injury, illness, and fatality rates differently. For example, a shift from manufacturing to service-oriented jobs might reduce the overall number of injuries and illnesses but might not significantly affect the rate of severe injuries, illnesses, or fatalities in high-risk industries. Alternatively, a slowdown in the rate of shift from industries with relatively high rates of severe injuries and illnesses to those with relatively low rates of severe injuries and illnesses could be occurring. In addition, improved safety and health practices, regulations, and technological advancements might not be as effective in preventing more severe injuries (DAFW injuries) or fatalities, which often result from more complex or unpredictable circumstances.

SECTION 2

WORKPLACE INJURY AND ILLNESS DETERMINANTS, COSTS AND CONSEQUENCES

This section provides a review of the scholarly literature on the determinants and economic ramifications of changes in workplace safety and health. This background is provided in order to lay the groundwork for the modelling decisions, assumptions, and method of constructing data needed in order to undertake economic impact modelling and cost- effectiveness analysis.

The first sub-section describes major influences on workplace safety and health, including market forces, OSH regulations, and benefits like workers' compensation. It explains that several common "market failures," such as information imperfections, labor immobility, and externalities, help explain why workplace safety and health regulation is warranted. The second sub-section examines the theoretical and empirical literature regarding the impact of OSHA and state plan OSH programs on occupational injuries and illnesses and their severity, workplace conditions, and worker well-being. The third sub-section looks at the various costs of workplace injuries and illnesses, including whether they are direct or indirect, firm, worker, or societal, and describes various methods for estimating these costs. The final sub-section examines the effect of workplace injuries and illnesses on worker long-term outcomes such as earnings, wealth, mortality, labor force participation, and uptake of government disability benefits, such as Social Security Disability Insurance (SSDI).

Influences on Workplace Health and Safety

Workplace safety and health are associated with numerous firm, industry, workforce, business cycle, technological, and public policy variables (Smitha et al. 2001; Viscusi, Vernon, and Harrington 2000). Specifying appropriate benchmarks can be difficult due to regional and temporal differences in economic and demographic conditions. Identifying these factors can also help aid understanding of the additional contribution that OSH regulators and inspections make in mitigating workplace injuries and illnesses.

Firm characteristics are key factors. Firm industry characteristics influence the degree of risk that workers experience. For example, firms in the manufacturing, construction, and transportation industries where workers frequently use heavy equipment and handle volatile supplies usually have higher rates of injuries and illnesses than those in service industries, such as real estate and insurance, that involve largely office work. In contrast to firms with varied work sites, firms that work in fixed locations often have lower injury and illness rates because the working environment is more easily controlled and less exposed to unpredictable conditions. Larger firms generally also have lower injury and illness rates than smaller firms, mainly because they are more likely to have the resources and economies of scale for providing safety and health programs and equipment. Lastly, organizational factors such as management style, concern for workers, and company safety and health culture may influence workplace injury rates (Pouliakas and Theodossiou 2010).

Workforce characteristics are also important. Unionized workforces generally experience lower injury and illness rates because unions advocate for health and safety conditions and are more likely to work to identify workplace hazards. More educated workforces have lower injury and illness rates because such workers may be more knowledgeable about safety and health practices. Age is also a factor: younger, less experienced workers and older workers are more susceptible to accidents.

Workplace injury and illness rates also change over time due, in large part, to economic conditions as reflected in unemployment rates. Injury and illness rates tend to increase during economic downturns and into economic upturns. During downturns, firms may cut costs that affect workplace safety and health conditions, while during upturns the recall of laid off and new inexperienced workers and a greater prevalence of overtime work may result in more injuries and illnesses. Over time, worker injury and illness rates have tended to gradually decline, in part, due to technological advances in worker safety and health and to greater investments in automation which can reduce human error and exposure to hazardous conditions. Another factor in declining rates is economic development. Workers, as a result of higher incomes and growing wages, demand greater safety and health enhancements; and employers, due to increases in employer costs to cover injury and illness, encourage workers to pay more attention to safety and health, and invest more in equipment to substitute for workers.

Lastly, public policy may influence workplace safety and health. Workers' compensation benefits and length of leave are linked with injury and illness rate reporting, although the relationship is obscured by offsetting influences. On the one hand, higher and more easily accessed workers' compensation benefits can increase reported injury and illness rates because workers are more likely to report their injuries and illnesses. On the other hand, experience ratings may cause firms to underreport or "engage in more aggressive claims management" (Ruser and Butler 2009) to minimize their costs. At the same time, they also have a greater incentive to invest in workplace safety and health, resulting in decreased injury and illness rates.

The theory of compensating wage differentials suggests that, in a free market absent market failures, there is little role for government regulation of workplace safety and health (Levine et al 2012). The theory assumes that workers freely arrange themselves into jobs with different risk levels based on their risk preferences and that firms with higher safety and health costs will pay higher wages to avoid the costlier alternative of investing in workplace safety and health (Ruser and Butler 2009). Thus, workers in higher risk industries and occupations will receive higher wages that reflect the economic value of the additional risk.

Compensating wage differential theory requires several assumptions that are not reflective of actual conditions, namely that workers are perfectly aware of the risks that they face in different jobs, that labor markets are perfectly competitive, that workers are perfectly mobile, and that outside parties are not affected by workplace injuries and illnesses (i.e., there are no externalities) (Viscusi, Vernon, and Harrington 2000). The first assumption is often questionable. The field of behavioral economics suggests that workers underestimate workplace hazards because of optimism biases, overconfidence, desensitization to hazards, and prioritizing short-term rewards over long-term

consequences. Moreover, this worker myopia in assessing risks is likely to be even more pronounced for health hazards than for safety ones since they are less well understood, and illnesses often manifest themselves only after long periods of time.

Perfect labor mobility is unlikely to be realized in many situations, such as when workers have accumulated significant firm-specific human capital (i.e., specific skills, seniority, or pension benefits) that cannot be fully utilized elsewhere or during recessionary periods when alternative job opportunities may be restricted.[2] Lastly, costs of worker injuries and illnesses often fall on individuals other than the worker and firm, such as on families of the injured or ill worker or on the general taxpaying public who fund public assistance which may be necessary to pay costs not covered by workers' compensation. All of the above market failures speak to economic efficiency, but workplace safety and health regulations are implemented also for reasons of worker equity (Pouliakas and Thoedossiou 2010). Workplace injuries and illnesses tend to be skewed toward lower skilled, lower wage workers, contributing to even more unfair social and economic opportunities.

Effect of OSH Regulation Programs on Workplace Compliance, Injuries and Illnesses

Workplace regulations can be expected to improve firm safety and health and, along with inspections, can increase compliance of inspected firms. Compliance occurs for at least two reasons (Ruser and Butler 2009). First, higher firm injury and illness rates can increase the likelihood that firms will be inspected, that violations will be identified, and citations and penalties issued. Second, fines for workplace safety and health violations lower firm profits, which increases the likelihood of compliance.

Early analysis of regulatory compliance suggested that OSHA inspections were undertaken too infrequently, and fines were too low to encourage a large firm response. However, firms also experience additional costs from violations, including reputational costs, legal and litigation costs, and higher workers' compensation premiums that may encourage more firm compliance. Much empirical evidence points to the conclusion that inspections tend to increase firm compliance. For example, Weil (1996) found that firms are very responsive to inspections in the woodworking industry, in part, due to the extraordinary risk aversion of managers and because inspections help spread knowledge about safety and health practices. Bartel and Thomas (1995) found that a doubling of the inspection rate would increase compliance by 25.8%. A systematic review of international studies (that included many U.S. studies) by Andersen et al. (2019) found that workplace injuries and illnesses improve compliance by an average of 35%.

Studies also distinguish between specific and general deterrence effects of inspections. Specific deterrence refers to the direct firm compliance effects described above. General deterrence occurs when other uninspected firms react to the regulatory environment by adjusting their workplace compliance as well. Early studies suggested the possible existence of general deterrence effects, but they were difficult to separate from other regulatory effects and measurement problems (Scholz and Gray 1990; Ruser and Smith 1988). Recent studies by Johnson (2020) and Johnson, Levine, and Toffel (2017) suggest that general deterrence effects occur through two different channels, diffusion in the

neighborhood of an inspected plant and through the various plant establishments of the inspected firm. The first occurs due to localized knowledge flows while the latter occurs because firms might establish company-wide standard procedures for all of their branches as a result of the inspection.

Examining an OSH policy of publicizing workplace safety and health violations beginning in 2009, Johnson (2020) found that other nearby establishments had improved compliance and experienced fewer injuries and illnesses, though the effect was not observed in right-to-work states, suggesting that union bargaining power may have been important to improving workplace safety and health in those facilities. Johnson, Levine, and Toffel (2017) found that OSHA's SST (Site-Specific Targeting) inspections of establishments led to decreases in injury and illness rates (2.2% decrease in DAFW injury rate) over the subsequent four years with the effects being stronger for company establishments that are closer to inspected company branches. However, they did not find general spatial deterrence effects for unrelated establishments. Another study by Lee and Taylor (2019), however, did not find the same firm-level deterrence effects on injuries and illnesses.

Due to the OSH Act legal framework for the establishment of state plan programs, OSH programs must be "at least as effective as" the federal OSHA program (29 USC 667(c)). A couple of studies suggest that federal OSHA and state plan programs differ in regulatory enforcement and effectiveness. Jung and Makowsky (2014) find that state programs are less likely to find violations when economic conditions deteriorate, suggesting that state programs are more likely to attempt to minimize the negative economic fallout of penalties. Bradbury (2006) finds that state-administered programs are associated with lower workforce fatality rates. Possible reasons for this finding are that states provide more optimal and effective regulatory programs due to interstate competition, are more likely to adapt to state business safety and health needs, and provide more innovative programs.

There is a long history of research on the effects of workplace safety and health regulations on injury and illness rates that date back to the establishment of OSHA (see **Table A.1**). Many of the earlier studies found little or limited effects of OSH regulations, which led some researchers to conclude that the effects were quite modest (Viscusi, Vernon and Harrington 2000). For example, Smith (1979) found that the lost-workday injury and illness rate at inspected manufacturing plants decreased by 16% in 1973 but had no statistically significant effect in 1974. A replication of that study design by McCaffrey (1983) found no effects for the 1976-78 period. The next wave of studies tended to find more substantial effects, though later ones indicated that the effects could be waning. Scholtz and Gray (1990), in a study of 6,842 large manufacturing plants over the 1979-85 period, estimates that a 10% increase in inspection would reduce injuries by 1%. For the same time period, Gray and Scholz (1993) found that inspections with penalties were associated with a 22% decrease in injuries and illnesses three years after the inspections, though the effects atrophied over time. Because only one in three inspections resulted in a penalty, this suggested that injuries and illnesses were reduced by about 7%. Gray and Mendeloff (2005) estimated that the effect of OSHA inspection penalties decreased from 19% in 1979-1985 to 11% in 1987-1991 and was an insignificant 1% in 1992-98.

More studies conducted in approximately the last decade that rely on improved establishment level data and often utilize contemporary econometric causal identification methods are more likely to

find significant effects of regulatory enforcement on reducing injuries and illnesses. In a study of 409 randomly inspected California establishments, Levine, Toffel, and Johnson (2012) found that inspected workplaces experienced a 9.4% reduction in injury and illness rates and 26% decline in related costs. Haviland et al (2010), using administrative data linked with confidential Survey of Occupational Injury and Illness (SOII) data in Pennsylvania, found that inspections with penalties reduced injuries and illnesses related to OSHA standards by 8.2% over two years and 14.4% for ones closely related to those standards. An updated study (Haviland et al. 2012) found that inspections with penalties reduced injuries and illnesses by 19-24% two years after the inspection, though the effects were restricted to establishments with 21-250 employees.

In a study utilizing 10 years of enforcement data combined with workers' compensation injury records for Washington State, Foley et al. (2012) found that inspections reduced lost-time claims by 4%. A study of workplace fatalities by Lee and Taylor (2019), using data on randomized OSHA first-time inspections during 1987-1997, found that these inspections reduced fatal injuries by approximately 45%. In a study of OSHA Site-Specific Targeting (SST) inspections over the 1996-2011 period, Li and Singleton (2019) found that inspections reduced DART injuries and illnesses by 20% in the year after inspection. Johnson, Levine and Toffel (2023), in comparing establishments that received randomly assigned inspections to other eligible establishments that did not, found that inspections reduced "serious injuries" by 9%.

Systematic literature reviews of the international OSH regulatory literature tend to support these recent findings—that regulatory inspections effectively reduce injury and illness rates. Dyreborg et al (2022) found that there is limited evidence of a small effect of inspections on rates at short-term and strong evidence for long-term effects. Andersen et al. found "moderately strong evidence" that inspections improve compliance with health and safety regulations and reduce injuries and illnesses. Reviews by Tompa et al. (2016; 2007) found limited evidence that specific and general inspection had an effect on injury and illness but found more substantial evidence that citations and penalties had an effect. A review of 23 studies (17 from the U.S.) by Mischke et al (2013) found that inspections generally improve compliance rates, with some supporting evidence that injuries and illnesses decrease 3 or more years after inspection, but less conclusive evidence that injuries and illnesses decreased within 1-3 years of inspection.

Costs of Workplace Injuries and Illnesses

Worker injuries and illnesses impose specific types of costs on firms, workers, and society at large (see **Table 2.1**) (Boden et al. 2001; Weil 2001). These costs can be divided into direct (those expenses immediately realized as a result of the injury or illness) and indirect (those occurring later as a consequence of the worker injury or illness that result in increased costs to the employer, worker, family, or society). Direct worker costs include firm costs, such as medical and indemnity payments for injured or ill workers, payment of liability damages, litigation expenses, and replacement of property losses. Indirect costs stem from productivity and reputational damage. For example, lost-time injuries and illnesses may require temporary replacement workers or other firm workers to provide overtime coverage. New workers may need additional training. Firm productivity may suffer

if project schedules are delayed or if workers are idle or forced to work below capacity because of the absence of complementary skills provided by injured or ill workers. Furthermore, injured or ill workers that return to work may experience reduced productivity for a period after returning to work. Firms may need to expend administrative resources to process paperwork dealing with the situation, investigate the cause of the injury, and take corrective actions. Bad publicity from workplace injuries and illnesses may have wider impacts on firm reputation resulting in loss of customers, suppliers, and investors, and greater difficulty recruiting workers. Workers themselves may bear some additional costs of workplace injury and illness, including medical and rehabilitation expenses not covered by workers' compensation and the loss of earnings from a long-term reduction in work activity (Weil 2001).

In addition, workers may experience less tangible costs such as those associated with a reduced quality of life (e.g., stress, sleep loss, mental health problems), pain and suffering, and/or the inability of the injured or ill worker to participate in nonwork household activities, such as cooking, cleaning, childcare, etc. (Dembe 2001). Weil (2001) reports that one study found that 40% of injured or ill workers decreased the amount of time spent on household work for one or more days and 11% performed no housework at all. Finally, worker injuries and illnesses may also impose costs on the wider society through the additional government transfer payments needed by those workers to make ends meet (e.g., Social Security Disability Insurance) and such workers may be less likely to volunteer.

Although industrial accident direct worker costs are the most tangible and easily measured costs of worker injuries and illnesses, other costs can also be substantial. A review of studies and data by Manuele (2011) suggests that indirect costs are, on average, usually about the same order of magnitude as direct costs (counting only workers' compensation, medical, and indemnity payments). These indirect costs account only for business costs and not worker, family, or societal costs. Moreover, the ratio of indirect to direct costs for workplace injuries and illnesses can vary significantly based on industry, type and severity of injury, and specific workplace conditions. The OSHA Safety Pays Program has developed a dashboard showing a sliding scale ratio of direct costs ranging from a high of 4.1 (direct costs $0-$2,999) to a low of 1.1 (direct costs of $10,000) to estimate indirect costs of workplace injuries and illnesses.[3]

TABLE 2.1 Costs of Workplace Injuries and Illnesses

Direct Firm Costs	Indirect Firm Costs	Injured/Ill Worker Costs	Other Costs
Workers' compensation payments (Indemnity and Medical)	Worker replacement and/or overtime costs	Loss of income (including changes in future work activity)	Cost of other government benefits used by injured or ill workers
Civil liability damages	Additional training costs	Medical expenses not covered by workers' compensation payments	
Litigation expenses	Decreased productivity of worker after return to work	Costs of pain and suffering	
Property losses	Increased insurance premiums	Family costs	
	Delays in project schedules or lost time complementary workers		
	Administrative time for addressing injury/illness		
	Damage to firm's reputation (loss of customers, suppliers, investors)		

Methods for valuing indirect costs vary in approach, and the values that they estimate can significantly differ also, reflecting the fact that indirect costs are more complex and can differ substantially from one incident to another; can sometimes involve hidden or intangible factors, such as firm reputation loss or damage to employee morale; are sometimes realized only after substantial time lags; and can vary by industry and context such as the level of occupational interaction with other workers.

For example, in valuing losses from worker injuries and illnesses and absence from the job, the direct workers' compensation costs (i.e., disability payments, medical expenses, and death benefits) are directly measurable. Indirect firm costs such as worker replacement costs (also known as "friction costs") can also be significant and include recruitment and training costs and any productivity losses due to incorporating a new worker.

Another way of estimating indirect costs is to value the lost productivity of the worker using the "human capital approach." This method estimates such costs by expressing them in terms of the

present value of the worker's likely earnings lost. "Willingness to pay" (WTP) is another frequently used method used to quantify the value that people place on reducing injury and illness risk (and reciprocal cost of experiencing the incident). This is typically estimated by hedonic wage models and contingent valuation surveys. Hedonic wage models (also known as "revealed preference" or "compensating wage differentials") examine wage differentials for jobs with varying levels of risk to infer the implicit value of reducing risks. Contingent valuation surveys (also known as "stated preferences") solicit information from individuals on how willing they would be to pay in order to reduce injury or illness risk (or correspondingly, how much they would be willing to accept increased risk).

A final approach, used primarily in health economics to estimate the value of health outcomes, is QALY (Quality-Adjusted Life Year) analysis. In this method, various injury and illness types are related to reduced quality of life years. One QALY is equivalent to a year of perfect health; lower values reflect reduced Quality of Life, attributable to the injury or illness. Total QALY reductions are then multiplied by the economic value of one year of life in perfect health. This can be estimated by human capital or WTP approaches but is typically used in Cost-Effectiveness Analysis (CEA) by utilizing cost-effectiveness thresholds. These represent the maximum amount that health authorities or organizations are willing to pay per QALY improvement. For example, in the U.S., commonly accepted values for a QALY range from $50,000 to $150,000 (Neumann et al. 2014).

Criticisms can be offered for each of these methods on their ability to fully capture costs. The methods vary in terms of scope, subjectivity, simplicity, treatment of equity concerns, and other features. For example, WTP can capture a wide range of factors such as quality of life, pain, suffering, and individual risk aversion, while the human capital approach measures primarily economic productivity, and CEA measures the health state itself. The methods also vary in terms of ease of application. The human capital approach is based on easily obtainable economic data such as wages, while WTP may require more extensive data and analytical resources. All three methods may undervalue the costs imposed on low-income and non-working populations. Finally, even the same methods can be very sensitive to the details of the data and methodology. For example, in a review of WTP studies, Viscusi and Aldy (2003) found that various studies of the value of statistical injury or illness provided estimates in the range of $20,000-$70,000 per injury or illness, and U.S. regulatory agencies produced estimates of the value of a statistical life (over the 1985-2000 period) that varied from a low of $1 million by the Federal Aviation Administration (FAA) to $6.3 million by the Environmental Protection Agency (EPA).

Estimates also typically vary by methodology. WTP approaches usually provide much higher estimates of injury/illness costs than the human capital approach (Weil 2001; Jo 2014). For example, the National Safety Council (NSC) uses multiple data sources to calculate injury and illness costs but relies heavily on a human capital approach (Weil 2001). It currently estimates the cost of a fatality from injury or illness to be $1.39 million. In contrast, in its most recent analysis of the proposed Heat Standard, OSHA uses a WTP Value of Statistical Life estimated cost of fatality of $13.77 million in 2023 by adjusting for inflation, a 2022 estimate made by the Department of Transportation (OSHA 2024). Although there is no standard accepted cost of a fatality from the QALY literature, one could estimate it based on the commonly accepted value of QALY in the U.S. which ranges from $50,000 to

$150,000. This QALY value, in combination with the average age of a fatally injured worker of approximately 46 tears and average life expectancy of 76 years, produces a range of $1.5 million (30×$50,000) to $4.5 million (30×$150,000), suggesting that the method provides an intermediate value. The choice of these values can imply vastly different evaluations of the benefits stemming from OSH regulatory efforts.

Effects of Workplace Injuries and Illnesses on Workers Economic Outcomes

Several studies have examined the long-term ramifications of workplace injuries and illnesses on worker earnings, labor force participation, wealth, mortality, and other outcomes (see **Table A.2**).[4] These studies generally examine the effect of work-loss injuries and illnesses using longitudinal data sets including ones constructed from joining administrative data sources, such as workers' compensation records, state unemployment insurance records, federal social security earnings files, and confidential BLS injury microdata (used in aggregate reporting such as SOII) or longitudinal microdata sets, such as the National Longitudinal Survey of Youth (NLSY) or Health Retirement Study (HHS). Work-loss injuries are the main focus because these more severe injuries and illnesses are expected to have more durable deleterious effects and workers' compensation data only covers injuries that required medical and/or indemnity payments. The studies often utilize causal econometric techniques, such as difference-in-difference and event-study designs (the latter permitting analysis of patterns of outcome variables before and after injury or illness to validate inferences made about post-injury or illness disparities). The post-injury or illness time period of these studies varies from 5 to 20 years.

These studies find persistent negative worker earnings effects on the order of 10-25% over the first decade. Moreover, workers' compensation and other income support only reimburses for a relatively small portion of lost earnings (Seabury et al. 2014). This negative effect is sometimes slightly mitigated over time, but workers never recover their full wage-earning capabilities (Boden and Galizzi 1999). Possible explanations for these long-term losses include (a) loss in worker seniority, (b) change from a union job to a nonunion job, (c) stigma attached to people who have been injured or gotten ill at work, and (d) loss of labor market experience while away from work, and workers with longer-term disabilities having weaker labor market attachments (Boden and Galizzi 1999). Many of the studies based on workers' compensation data can only compare indemnity (8+ DAFW) to medical-only cases (less than 7 DAFW) and are unable to compare injured/ill to non-injured/ill individuals with similar characteristics. As such, these results may impart a slight positive bias, meaning that a more accurate with and without injury/illness comparison would likely show even more deleterious wage effects. Studies based on longitudinal survey data that rely on individual self-reported circumstances and conditions also show persistent negative wage effects.

The relative amount of wage loss estimates varies slightly within a fairly narrow range. An early study by Boden and Galizzi (1999) for Wisconsin finds that workers' compensation replaces only 65% of 10-year projected after-tax earnings losses for men and 50% for women. Another early study by Reville (1999) indicated that Permanent Partial Disability (PPD) injured or ill workers in California saw earning losses of 25% after five years. In a similar analysis for New Mexico, Seabury et al. (2014) found that

workers with lost-time injuries or illnesses experienced a 15% earnings decrease compared to less severely injured or ill workers after 10 years. In a U.S. study using NLSY79 data, Woock (2009) found that average post-injury or illness losses grew over time, amounting to 8% of the worker average annual earnings in the sixth year; losses were even greater for more severe injuries and illnesses. For those with a work-limiting disability, the magnitude of earnings loss is 16%. Another more recent study using a longer panel of this data (Dong et al. 2016) found that annual earnings growth lagged $3,715 (in 2000 dollars) for workers with work-loss injuries or illnesses and $1,152 for injured or ill workers with no work lost. These dollar values represent an estimated 4-15% of worker wages. Dworsky and Powell (2022) estimate earnings losses of 19.6% in the first five years, 13.6% in the second five years, and 10.9% in the third five years. Collectively, these studies suggest an average earnings gap of approximately 16.7% during the first 10 years and 10.9% into the next decade.

Two studies examine the labor force participation and permanent SSDI uptake rates of older injured or ill workers. Using California administrative data, Dworsky and Powell (2022) found that older lost-time injured or ill workers aged 55 and older are more likely to drop out of the labor force at age 55, a year when SSDI benefits are more easily obtained by applicants. In a U.S. Study, Bronchetti and McInerny (2023) utilized self-reported responses from the Health and Retirement Study (HRS) data to examine the earnings and workforce participation of workers aged 55 and older. They found that workers with chronic occupational injuries or illnesses earn $8,400 less 6 years after, are more likely to retire around the OASI claiming period and are more likely to participate in SSDI. These findings suggest that workplace injuries and illnesses lead to workforce exits of older injured and ill workers and provide evidence of the existence of wider societal costs of workplace injuries and illnesses due to the early uptake of government transfer payments.

The percentage impact on other variables such as wealth, consumption, and mortality found in other studies are of similar degrees of magnitude. Lost worker earnings may also have longer term consequences for worker accumulation of wealth and consumption. In a U.S. study, Galizzi and Zagorsky (2008) found that injured or ill workers had a wealth reduction of 20% compared to those not injured, with greater reductions for workers reporting wage losses or time off work due to workplace accidents. Injured and ill workers also reported decreasing their consumption levels over time. Boden et al. (2016) examined the long-term effects of nonfatal workplace injuries and illnesses on worker mortality in New Mexico, identifying injured and ill workers from workers' compensation system records for 1994-2000 and deaths from Social Security Administration data on individual earnings and mortality through 2014. Using multivariate Cox survival models, they found that the estimated hazard ratio for lost-time injuries and illnesses is 1.24 for women and 1.21 for men, implying that mortality rates on average are 21% and 24% higher than respective mortality rates of workers with medical leave only. These results suggest that workers with lost-time workplace injuries and illnesses have substantially higher mortality rates than other lesser injured or ill workers.

SECTION 3

ECONOMIC IMPACT OF VOSH INSPECTIONS

This section examines the economics of VOSH workplace inspections using a Virginia REMI PI+ model. It utilizes estimates based on scholarly literature findings of the effects of inspection activities on injured worker earnings and productivity, worker mortality, firm production costs, and other factors. It is divided into two subsections. The first subsection describes the REMI PI+ model, the economic and demographic variables affected by VOSH inspection activities, and how these variables are accounted for as inputs into the model for use in the economic impact analysis. The second subsection presents and describes the model results.

Economic Impact Modelling of VOSH Inspections

Weldon Cooper Center researchers conducted an economic impact analysis of VOSH inspections using REMI PI+ (Regional Economic Models Inc. Policy Insight Plus) software. REMI PI+ is a dynamic, multi-sector regional economic simulation model used for economic forecasting and measuring the economic impact of public policy changes on state and regional economies (Treyz 1993). The model combines different contemporary regional economic modeling approaches, such as input-output analysis, econometric forecasting, computable general equilibrium, and New Economic Geography, to characterize the mechanics and path of a regional economy. The model has been extensively peer-reviewed and is widely used by federal, state and local agencies, private firms, and non-profit organizations to model economic and tax revenue impacts of federal, state, and regional public policies.[5] The model used for this analysis was customized for the state of Virginia. Details regarding the model are provided in **Appendix B**.

The analysis looks at the effect of VOSH compliance activities on injuries and illnesses for the 2022 cohort of workers, and its long-term economic impact through a 20-year period, 2022-2041. Seven VOSH inspection economic impact components were modelled, which are summarized in **Table 3.1**. They include: (a) changes in injured or ill worker amenities/worker quality of life, (b) injured or ill employee compensation, (c) firm output, (d) worker fatalities, (e) firm production costs, (f) injury and illness related medical costs, and (g) state government spending. Each of these components is briefly described with estimation and modelling details in **Appendix C**. Input data are comprised based on a modelling horizon of 20 years. Some changes in input variables occur only during the year of injury or illness while others are sustained for the entire two decades.

As described in section 2, worker lost-time injuries and illnesses result in relatively large and sustained wage losses that have been observed 14 years (at least) after injury. These losses are conservatively estimated here at 15% during the first decade post-injury or illness and 10% for the second decade. It is further assumed that these losses are also reflected in a proportionate loss in benefits, since workers with reduced earnings capacity will also realize a reduction in some benefits (e.g., defined contribution retirement benefits, elective dental and health plans). Thus, it is assumed that employee compensation is reduced by these percentages as well (***Employee Compensation***).

Worker health is a form of human capital, such as education and workforce skills, that is reflected in worker productivity. Therefore, a symmetrical effect on labor productivity/firm output is modelled by scaling employee compensation to output and reducing firm output (***Output***).

The next major category of worker injury and illness effect is firm production costs (***Production Costs***). These costs result from an increase in workers' compensation insurance (medical and indemnity) costs and the need to temporarily replace workers with lost-time injuries and illnesses. For self-insured firms, workers' compensation is an immediate cost while firms participating in workers' compensation insurance programs will face delayed cost increases from a gradual adjustment in their experience ratings. However, all of these delayed cost adjustments costs and costs to small businesses that are not experience rated are assumed to be passed on to all firms immediately to maintain program trust fund balances. For the purposes of the economic impact analysis, these costs are assumed to be realized in the year of the injury or illness. They are estimated for lost time injury/illness workers (DAFW 8+) for both medical and indemnity costs. In addition, workers with any days without work are assumed to be replaced by replacement workers or existing workers who work overtime. These costs are estimated based on converting lost days of injured or ill workers to employee FTEs and imputing the costs on lost time based on average earnings per worker.

Other components of injured or ill worker economic impact are smaller in absolute magnitude. They include worker/workplace amenities, mortality, state and local government spending, and medical spending. Because a less safe and healthy workplace environment contributes to injuries and illnesses that reduce the quality of life for affected workers and their families, these estimated monetized costs are also incorporated into the model as a reduction in amenities (***Amenities***). The immediate effect of reductions in amenities is to reduce economic migration into the state and reduce the size of the available workforce.

State and local government are also affected. Because state and local governments are not sensitive to production costs within the REMI model, increases in workers' compensation costs and injured worker temporary replacement costs are introduced as having an offsetting effect on other state government expenditures (***State Government Expenditures***). This modelling choice is made to ensure that the change has a neutral impact on the state government budget. Because workers' compensation is not taxable, a small portion (estimated at 3% of workers' compensation indemnity payments affected) of state income tax revenue is also estimated to be unavailable for state government to use for other spending. So, this tax revenue loss is also reflected in reduced state government spending.

Another source of economic impact are fatalities that result from worker injuries or illnesses as a result of immediate (as reflected in Census of Fatal Occupational Injuries or CFOI data) and delayed consequences of occupational injury and illness morbidities (***Mortality***). The immediate fatality effect is estimated using CFOI workplace fatality data while the delayed effect is estimated by using an empirical hazard rate equation from Boden et al. (2016) that shows elevated long-term death risk from worker injuries and illnesses. Increased workplace-related fatalities affect economic outcomes due to a reduction in the size of the population, labor force, and consumption. Lastly, while increased

medical costs raise firm production costs, this medically-related spending has a positive impact on the health care industry. This countervailing impact is accounted for by raising medical spending (***Medical Spending***).

TABLE 3.1 VOSH Inspection Economic Impact Component

Component	Description
Amenity	Reduction in worker quality of life due to reduced Quality Adjusted Life Years (QALY) from injuries and illnesses
Employee Compensation	Decrease in employee compensation (15% first decade and 10% second decade) due to workplace injuries and illnesses
Output	Decrease in firm output due to reduced worker productivity of injured or ill workers
Mortality	Increase in workplace fatalities and enhanced morbidity/mortality later on due to worker injury or illness
Production Costs	Increase in workers' compensation costs and temporary worker replacement costs due to workplace injuries and illnesses
Medical Spending	Increase in medical spending due to workplace injuries and illnesses
State Government Spending	Decrease in government spending to compensate for increased workers' compensation costs and temporary worker replacement costs due to workplace injuries and illnesses

Results

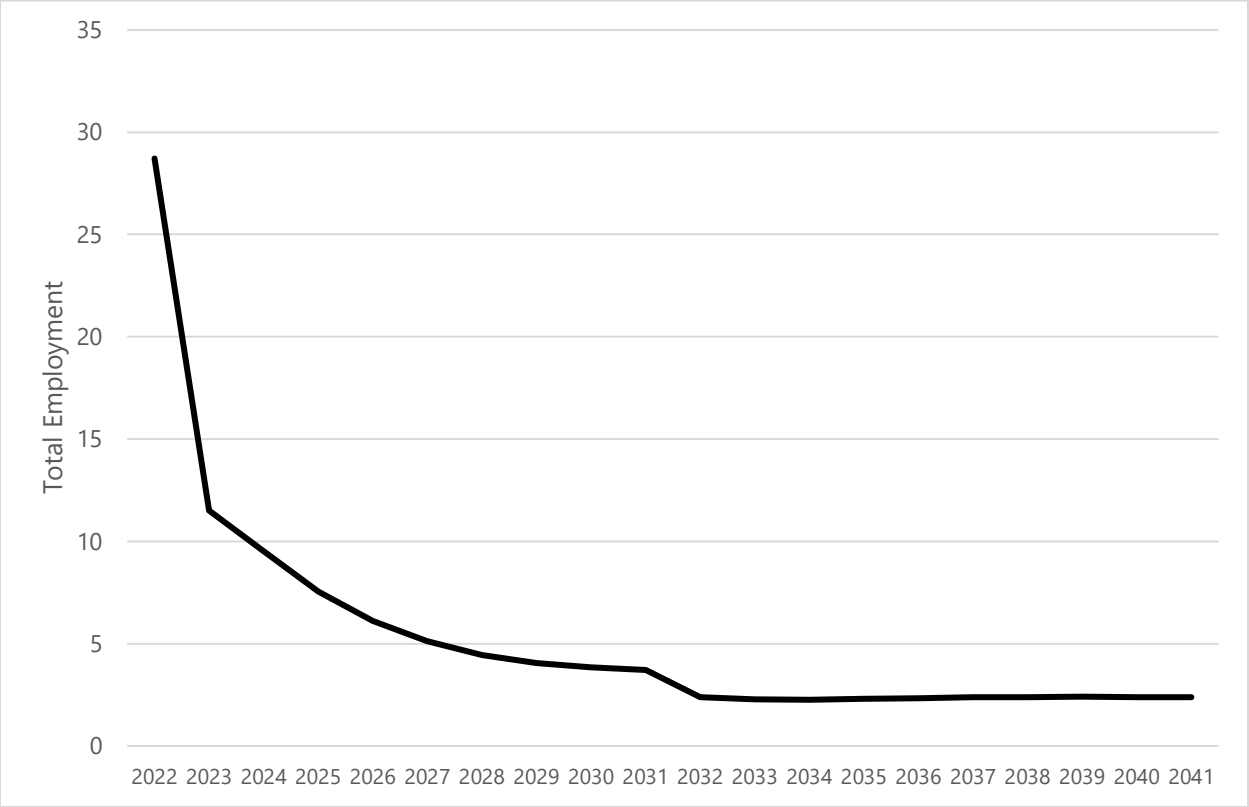
State economic impacts are represented by several different metrics: employment, population, labor force, real gross domestic product, real output, real personal income, and real state tax revenues. Dollar metrics are expressed in terms of 2022 (real) values. Employment includes full-time and part-time workers and the self-employed and is measured by place-of-work. Labor force is the portion of the population employed or seeking employment. Output represents the production of final as well as intermediate goods and services and is also in 2022 dollars. Gross domestic product (GDP) represents the value of final goods and services produced in Virginia and is expressed in terms of 2022 dollars. Real personal income includes wages and salaries, benefits, dividend, interest, and returns.[6] State tax revenue represents general and non-general fund revenue derived from taxes in 2022 dollars. In order to show the positive effect of VOSH inspection activities, the impact is

represented as a positive number (rather than showing the reciprocal but negative impact of the absence of these activities).

Table 3.2 provides the results of the economic impact results for each of the economic impact outcomes over the 20-year period 2022-2041, while **Figures 3.1 and 3.2 and Table 3.2** show results for employment, GDP, output, and personal income over time. These results reflect the multiplier effects (direct, indirect, induced, and dynamic) of VOSH inspections on the state economy. The largest year of employment impact is 2022 when the temporary costs of worker injuries and illnesses reflected in increased firm production and reduced government spending are realized. During the first year, VOSH inspections helped reduce the number of jobs lost by approximately 29 jobs in 2022, falling to nearly 12 jobs in the next year with incremental decline in each succeeding year until stabilizing near 2.5 jobs in 2032 (reflecting the effects of VOSH inspections conducted in 2022). Early year effects reflect immediate and lagged responses to production cost and other expenditure-related changes (state government, medical spending) while longer-term impacts reflect mainly the role of sustained reduction in workers' compensation, firm output, and mortality resulting from workplace injuries and illnesses. These employment decreases are mirrored in the output, GDP, and personal income economic metrics. The first downshift in economic impacts occurs in 2023 when production costs and temporary expenditure impacts largely dissipate. The second downshift occurs in 2032 when employee compensation and firm output recover further. The economic impact results also indicate that labor force is reduced by 14 workers in 2022, falling to approximately 2 workers by the end of the period. State population is reduced a nominal amount. Finally, VOSH inspections result in an increase in state tax revenues throughout the period, starting at $139,844 in 2022 and falling to $30,896 in 2041.

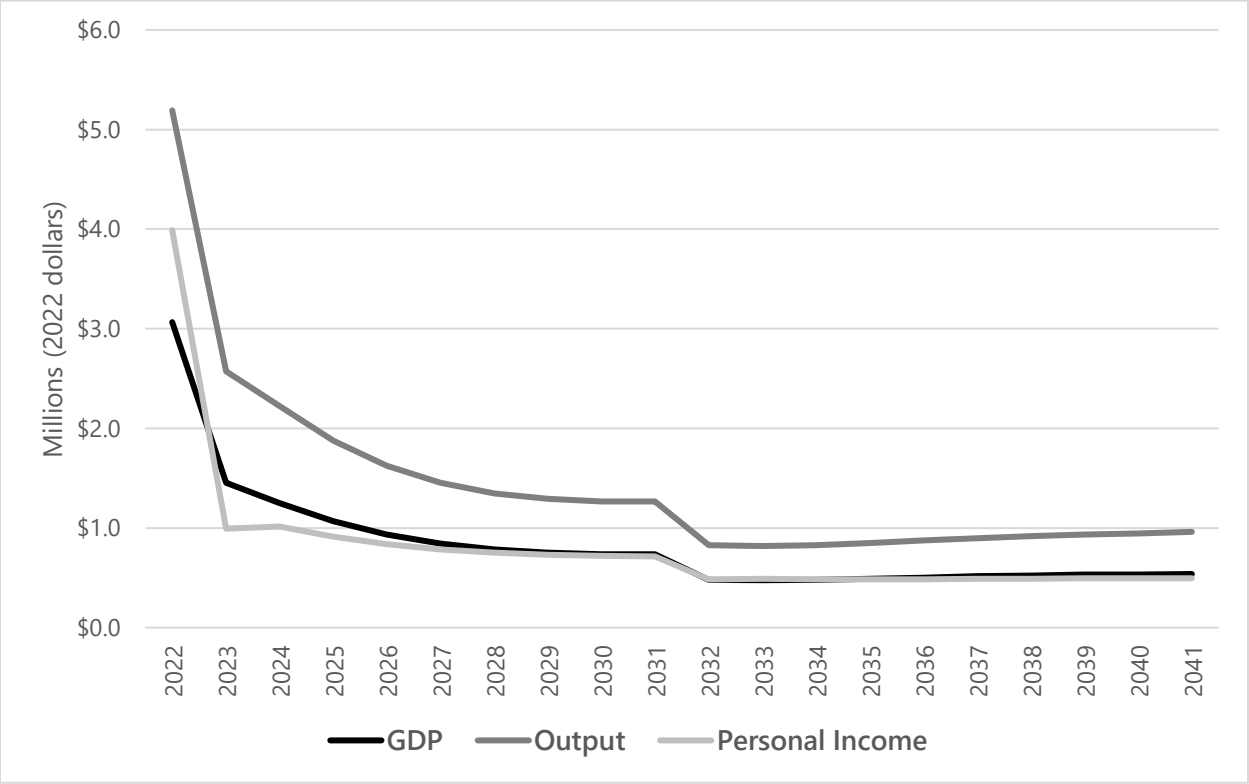
Cumulative economic impacts for the entire 2022-2041 period are also computed. The cumulative output impact is $28,967,538, GDP impact is $16,707,020, and personal income is $16,348,886. The cumulative state tax revenue impact is $931,521. For comparison purposes, the entire FY22 budget for VOSH programs according to the 23g Federal Grant Application was $10,271,600. Of that amount, the DOLI estimates $6,686,938 were compliance-inspection-related costs (see **TABLE D-1**). Approximately 57% of this cost was covered by state funding with the remainder by federal funds. This analysis suggests that approximately 14% of program costs would be recouped through revenues generated indirectly through improved economic activity resulting from workplace injury reductions stemming from VOSH inspection activities in 2022.

FIGURE 3.1 Employment Impacts of VOSH Inspections, 2022-2041



Source: Based on Weldon Cooper Center for Public Service Analysis using Virginia REMI PI+ Model.

FIGURE 3.2 Economic Impacts of VOSH Inspections, GDP, Output, and Personal Income, 2022-2041



Source: Based on Weldon Cooper Center for Public Service Analysis using Virginia REMI PI+ Model.

TABLE 3.2 Economic Impacts of VOSH Inspections by Year and Outcome (Dollar Values expressed in terms of real 2022 dollars)

Year	Employment	Population	Labor force	GDP	Output	Personal Income	State Tax Revenue
2022	28.7	2.0	13.8	$3,066,435	$5,192,346	$3,990,309	$139,844
2023	11.5	1.7	10.4	$1,452,659	$2,573,096	$995,654	$102,636
2024	9.5	1.6	9.1	$1,250,553	$2,222,425	$1,014,081	$83,558
2025	7.5	1.4	8.0	$1,069,145	$1,875,079	$911,199	$67,896
2026	6.1	1.2	6.9	$935,809	$1,624,776	$839,582	$56,366
2027	5.1	1.1	6.0	$843,192	$1,452,466	$786,214	$48,326
2028	4.4	1.0	5.2	$784,253	$1,346,049	$750,256	$43,259
2029	4.1	0.8	4.6	$752,845	$1,290,696	$729,652	$40,536
2030	3.8	0.8	4.0	$739,225	$1,268,560	$718,570	$39,400
2031	3.7	0.7	3.6	$737,292	$1,265,904	$713,718	$39,248
2032	2.4	0.6	3.1	$481,241	$825,805	$484,053	$24,669
2033	2.3	0.5	2.7	$476,352	$819,061	$488,530	$23,783
2034	2.3	0.4	2.4	$480,195	$828,750	$485,463	$24,116
2035	2.3	0.4	2.2	$491,228	$851,173	$486,370	$25,110
2036	2.3	0.3	2.1	$503,173	$875,169	$487,560	$26,278
2037	2.4	0.3	2.0	$514,642	$898,751	$490,233	$27,486
2038	2.4	0.3	1.9	$523,007	$917,141	$490,966	$28,499
2039	2.4	0.2	1.8	$530,576	$934,316	$494,045	$29,453
2040	2.4	0.2	1.7	$535,022	$946,294	$494,248	$30,161
2041	2.4	0.2	1.6	$540,176	$959,681	$498,185	$30,896
Total	--	--	--	**$16,707,020**	**$28,967,538**	**$16,348,886**	**$931,521**

Source: Based on Weldon Cooper Center for Public Service Analysis using Virginia REMI PI+ Model.

Table 3.3 shows a breakdown of cumulative GDP impacts by 2-digit North American Industry Classification (NAICS) industry. The results indicate that the economic impacts are fairly dispersed among industries, including many service industries with lower incidence of injuries and illnesses. The economic impacts tend, however, to be slightly higher for those industries where injury and illness rates are higher. For example, construction represents 7.2% of the cumulative GDP impact while

Transportation and Warehousing represents 3.5% of the cumulative GDP impact. For comparison purposes, these two industries represented 4.6% and 2.9% of Virginia GDP in 2022. The wider dispersal of economic impacts results from the knock-on secondary or indirect effects of wage, productivity, and other losses which are more likely to impact industries that are affected by consumer and industry spending decreases.

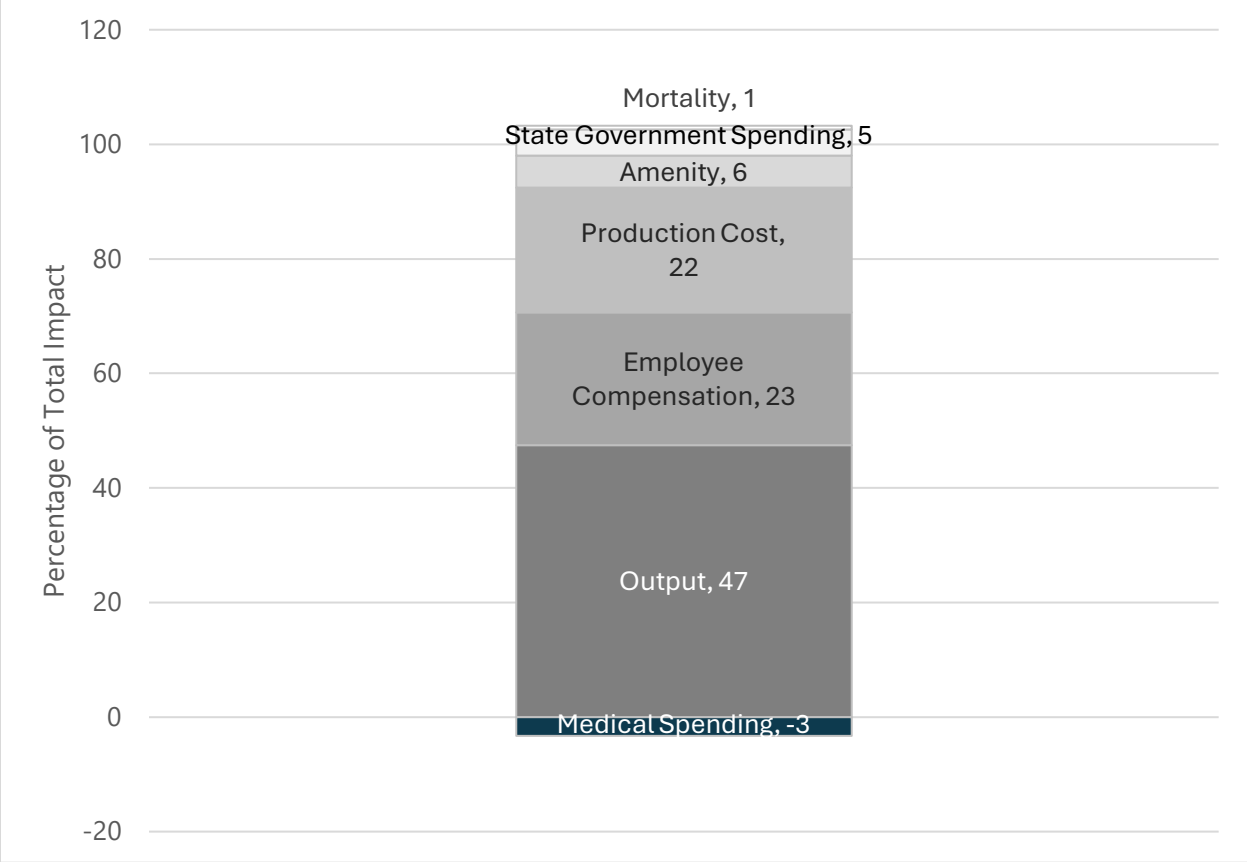
TABLE 3.3. Cumulative Economic Impacts by Industry (Dollar Values expressed in terms of real 2022 dollars)

Industry	GDP	Percent of Total
Agriculture, Forestry, Fishing and Hunting	$17,319	0.1%
Mining, Quarrying, and Oil and Gas Extraction	$20,040	0.1%
Utilities	$199,805	1.2%
Construction	$1,196,703	7.2%
Manufacturing	$990,903	6.0%
Wholesale Trade	$840,855	5.1%
Retail Trade	$1,705,391	10.3%
Transportation and Warehousing	$580,004	3.5%
Information	$515,932	3.1%
Finance and Insurance	$222,995	1.3%
Real Estate and Rental and Leasing	$2,091,027	12.6%
Professional, Scientific, and Technical Services	$1,095,715	6.6%
Management of Companies and Enterprises	$390,844	2.3%
Administrative and Support and Waste Management and Remediation Services	$592,313	3.6%
Educational Services	$285,836	1.7%
Health Care and Social Assistance	$2,150,906	12.9%
Arts, Entertainment, and Recreation	$174,923	1.1%
Accommodation and Food Services	$621,631	3.7%
Management of Companies and Enterprises	$390,844	2.3%
Public Administration	$2,549,532	15.3%
Total	**$16,633,517**	**100.0%**

Source: Based on Weldon Cooper Center for Public Service Analysis using Virginia REMI PI+ Model.

Figure 3.3 shows a breakdown of cumulative GDP impacts by component of impact (output, employee compensation, production costs, amenities, state government spending, housing, and medial spending). Medical spending has a negative impact since the effect of abating worker injuries is to reduce medical spending which has a negative economic impact. The largest source of economic impact is productivity associated with workers at 47% of the total followed by employee compensation at 23%. This is followed by production costs at 22%, amenities at 6%, state government spending at 5%, and mortality at just 1%. These results indicate that the bulk of economic impact (90%) is caused by the effects of lost worker earnings and productivity and increased production costs. This percentage is consistent for output and personal income too, although for personal income, 59% of the economic impact stems from the employee compensation component.

FIGURE 3.3 Composition of Total GDP Impact of VOSH Inspections by Component



Source: Based on Weldon Cooper Center for Public Service Analysis using Virginia REMI PI+ Model.

SECTION 4

COST-EFFECTIVENESS ANALYSIS OF VOSH INSPECTIONS

This section uses a cost-effectiveness analysis (CEA) model to estimate the value of the VOSH inspection program. It explains how CEA is modelled, estimates the expected value of the VOSH program, and describes how the outcomes would change if the input values varied.

CEA is a way to compare both the cost and the health outcome of an intervention, in this case worker safety and health inspections by VOSH. CEA estimates the value of a workplace inspection by estimating how much it costs to achieve one additional quality adjusted year of life (QALY). QALYs, which can vary from 0 for death to 1 for perfect health, are a common way to adjust or weight a year of life when an individual lives with less than perfect health. In CEA, the primary measure used to evaluate an intervention is the incremental cost-effectiveness ratio (ICER). The ICER estimates how much it will cost to achieve one additional QALY when there is a VOSH inspection compared when there is no inspection.

The formula for the ICER is:

$$ICER = \frac{(C_1 - C_0)}{(E_1 - E_0)}$$

C_1 = cost of inspection by VOSH + healthcare costs from injuries

C_0 = healthcare costs from injuries and illnesses when there is no VOSH workplace inspection

E_1 = expected QALYs when there is VOSH workplace inspection

E_0 = expected QALYs when there is no VOSH workplace inspection

The CEA analysis is conducted using assumptions outlined in **Table E.1** in Appendix E. These assumptions include probabilities of injury, illness and death, reduction in long-term QALY by type of injury or illness; costs of death, injury or illness and inspections; and VOSH effect on workplace injury and illness risk reduction. The parameters used in the analysis are drawn from BLS occupational injury and illness and fatality data for the U.S. and Virginia, studies by OSHA and the U.S. Department of Transportation on the costs of fatality and major injury, estimates of the marginal cost of an inspection from the VOSH budget, and studies on the underreporting of occupational injuries and illnesses (e.g., Leigh 2011) and the effectiveness of OSH inspections in reducing occupational injuries and illnesses (e.g., Dyreborg et al. 2022; Foley et al. 2012).

This information is used to compute an estimated ICER of inspection at $20,965 per additional QALY (**Table 4.1**). This means that if Virginia has a willingness to pay (WTP) at least $20,965 per QALY, then inspection is cost-effective. Although the WTP threshold when an intervention is 'worth it' is subjective, often health economics uses an ICER value of $50,000 per QALY. At a WTP of $50,000, inspection is cost-effective as it only costs $20,965 per QALY. For comparison purposes, several health and safety interventions have found costs per QALY of similar magnitude: $10,600 for 2009 changes to the US Special Supplemental Nutrition Program for Women, Infants, and Children (WIC)

food package (Lee et al. 2024); $23,310 for cochlear ear implantation in adults (Carlson 2020); $27,619 for treatment of adults with Oseltamivir (an antiviral medication) (Muennig and Khan 2001); and $28,000 for a program of clinical trial of intensive systolic blood-pressure control for adults at high risk for cardiovascular disease (Bress et al. 2017). A systematic review of interventions—such as screening, education, and other support by community health workers to prevent cardiovascular disease, prevent type 2 diabetes, and management of type 2 diabetes—found average costs per QALY of $17,670, $17,138, and $35,837 (Jacob et al. 2019).

TABLE 4.1. Cost-Effectiveness Analysis of VOSH Inspections

Strategy	Cost	Incr. cost	Effectiveness (QALYs)	Incr. Effectiveness (QALYs)	ICER (IC/IE)
No regulation/inspection	$1,379.40		12.6972		
Regulation inspection	$3,336.75	$1,957.35	12.7906	0.0934	$20,965.15

It is also useful to conduct a sensitivity analysis to consider how the model would change if different input values were used. A sensitivity analysis estimates how the model results change if a range of different values are used for one variable. Key parameter values for four variables are changed, including the cost of inspection, the probability of injury or illness, the cost of a fatality, and the degree of OSH inspections in reducing occupational injury and illnesses.

The calculation of inspection costs could range from $2,799 to $4,596, depending on which assumptions are used and whether the average or marginal cost is used. However, even at the highest inspection cost, the ICER is $35,066, which is still below the standard WTP threshold of $50,000 **(Table 4.2**). Therefore, regardless of the inspection cost, inspection remains a cost-effective option.

TABLE 4.2. CEA Sensitivity Analysis for Inspection Cost

Inspection	Strategy	Cost	Incr. cost	Effectiveness (QALYs)	Incr. Effectiveness (QALYs)	ICER (IC/IE)
$2,799.00	No regulation/ inspection	$1,379.40	$0.00	12.6972	0.0000	$0.00
$2,799.00	Regulation inspection	$2,856.25	$1,476.85	12.7906	0.0934	$15,818.52
$3,248.25	No regulation/ inspection	$1,379.40	$0.00	12.6972	0.0000	$0.00
$3,248.25	Regulation inspection	$3,305.50	$1,926.10	12.7906	0.0934	$20,630.43
$3,697.50	No regulation/ inspection	$1,379.40	$0.00	12.6972	0.0000	$0.00
$3,697.50	Regulation inspection	$3,754.75	$2,375.35	12.7906	0.0934	$25,442.33
$4,145.75	No regulation/ inspection	$1,379.40	$0.00	12.6972	0.0000	$0.00
$4,156.75	Regulation inspection	$4,204.00	$2,824.60	12.7906	0.0934	$30,254.24
$4,596.00	No regulation/ inspection	$1,379.40	$0.00	12.6972	0.0000	$0.00
$4,596.00	Regulation inspection	$4,653.25	$3,273.85	12.7906	0.0934	$35,066.15

The probability of injury or illness is also uncertain. The national probability of injury or illness rate is 0.027, but this rate likely undercounts injuries and illnesses that go unreported or not reported as a workplace injury or illness. The literature estimates that injuries and illnesses might be underreported by as much as 70%. **Table 4.3** provides the results of a sensitivity analysis varying the probability of injury or illness from 0.027 to 0.0459. Even at the lowest probability of injury or illness, the ICER is $34,993, which is below the standard WTP of $50,000. Thus, inspection is cost-effective for all probabilities of injury or illness.

TABLE 4.3 CEA Sensitivity Analysis for Probability of Injury or Illness

Injury Probability	Strategy	Cost	Incr. cost	Effectiveness (QALYs)	Incr. Effectiveness (QALYs)	ICER (IC/IE)
0.027	No regulation/ inspection	$985.29	$0.00	12.7251	0.0000	$0.00
0.027	Regulation inspection	$3,319.96	$2,334.67	12.7918	0.0667	$34,993.18
0.031725	No regulation/ inspection	$1,157.71	$0.00	12.7129	0.0000	$0.00
0.031725	Regulation inspection	$3,327.26	$2,169.55	12.7913	0.0784	$27,680.64
0.03645	No regulation/ inspection	$1,330.14	$0.00	12.7007	0.0000	$0.00
0.03645	Regulation inspection	$3,334.63	$2,004.50	12.7907	0.0900	$22,264.02
0.041175	No regulation/ inspection	$1,502.56	$0.00	12.6885	0.0000	$0.00
0.041175	Regulation inspection	$3,342.08	$1,839.51	12.7902	0.1017	$18,090.62
0.0459	No regulation/ inspection	$1,674.99	$0.00	12.6764	0.0000	$0.00
0.0459	Regulation inspection	$3,349.59	$1,674.60	12.7897	0.1133	$14,776.51

There are different ways to measure the cost of a workplace fatality. The estimates can range from $1,390,000 to $13,770,000. The low end is the estimate provided by the National Safety Council (NSC), which includes wages and lost productivity, medical expenses, administrative costs, and employers' uninsured costs. The higher end of the range is from OSHA (2004). Despite the large range of costs, there was little change in the ICER, varying from $21,142 to $20,965 (**Table 4.4**). The small change in ICER is likely because the probability of death, 0.000037, is so low.

TABLE 4.4. CEA Sensitivity Analysis for Cost of Fatality

Cost of Death	Strategy	Cost	Incr. cost	Effectiveness (QALYs)	Incr. Effectiveness (QALYs)	ICER (IC/IE)
$1,390,000	No regulation/ inspection	$1,362.09	$0.00	12.6972	0.0000	$0.00
$1,390,000	Regulation inspection	$3,336.03	$1,973.75	12.7906	0.0934	$21,142.91
$4,485,000	No regulation/ inspection	$1,366.42	$0.00	12.6972	0.0000	$0.00
$4,458,500	Regulation inspection	$3,336.39	$1,969.80	12.7906	0.0934	$21,098.47
$7,580,000	No regulation/ inspection	$1,370.74	$0.00	12.6972	0.0000	$0.00
$7,580,000	Regulation inspection	$3,336.39	$1,965.65	12.7906	0.0934	$21,054.03
$10,675,000	No regulation/ inspection	$1,375.07	$0.00	12.6972	0.0000	$0.00
$10,675,000	Regulation inspection	$3,336.57	$1,961.50	12.7906	0.0934	$21,009.59
$13,770,000	No regulation/ inspection	$1,379.40	$0.00	12.6972	0.0000	$0.00
$13,770,000	Regulation inspection	$3,336.75	$1,657.35	12.7906	0.0934	$20,965.15

The literature estimates that inspection reduces the risk of injury by 0.04. **Table 4.5** shows the change in ICER if the reduction in risk increased or decreased by 0.02. This variation in risk reduction makes little difference in the ICER, which ranges from $20,222 to $21,738.

TABLE 4.5. CEA Sensitivity Analysis for Inspection Effectiveness

Inspection Effectiveness	Strategy	Cost	Incr. cost	Effectiveness (QALYs)	Incr. Effectiveness (QALYs)	ICER (IC/IE)
0.02	No regulation/ inspection	$1,379.40	$0.00	12.6972	0.0000	$0.00
0.02	Regulation inspection	$3,308.15	$1,928.75	12.7926	0.0954	$20,222.20
0.03	No regulation/ inspection	$1,379.40	$0.00	12.6972	0.0000	$0.00
0.03	Regulation inspection	$3,322.46	$1,943.05	12.7916	0.0944	$20,589.85
0.04	No regulation/ inspection	$1,379.40	$0.00	12.6972	0.0000	$0.00
0.04	Regulation inspection	$3,336.75	$1,957.35	12.7906	0.0934	$20,965.15
0.05	No regulation/ inspection	$1,379.40	$0.00	12.6972	0.0000	$0.00
0.05	Regulation inspection	$3,351.04	$1,971.64	12.7896	0.0924	$21,348.32
0.06	No regulation/ inspection	$1,379.40	$0.00	12.6972	0.0000	$0.00
0.06	Regulation inspection	$3,365.31	$1,985.91	12.7886	0.0913	$21,739.64

APPENDIX A
LITERATURE REVIEW FINDINGS

TABLE A.1 Effects of OSH Inspections on Workplace Injuries and Illnesses

Paper	Region	Program	Units of Analysis	Dependent Variables	Method	Data Source	Findings
Andersen et al. (2019)	North America and Europe	Occupational safety and health regulation enforcement	Workplaces and employees	Injuries, illnesses, fatalities, compliance, other	Systematic literature review/meta-analysis	Articles published from 1966 to 2017	Moderately strong evidence that workplace inspections and enforcement reduced injuries and illnesses (odds ratio of 0.83) and improves compliance (odds ratio of 0.65). Found a research gap in regard to OSH regulation impacts of psychological and musculoskeletal disorders.
Bondebjerg et al. (2023)	OECD countries	Occupational health and safety regulatory interventions	Workplaces and employees	Compliance with regulations, incidence of work-related injuries, health and sickness absence	Evidence and gap map (EGM) of systematic reviews and primary effect studies between groups	Previous literature published up until Jan. 2023	Inconclusive. Authors suggest more research in the form of primary studies and systematic reviews in order to gain a better understanding of what constitutes the most efficient regulatory approaches to improve the work environment.
Bradbury (2006)	United States	Occupational Safety and Health Act, which gave the states the power to decide to enforce federal OSHA standards	States that adopted OSHA enforcement programs vs those under federal OSHA	Occupational mortality rates	Random effects regression that corrected for selection bias	National Traumatic Occupational Fatalities (NTOF) data from 1981 to 1995	The study found that states with their own OSHA programs had 25% to 35% fewer occupational fatalities than states under federal OSHA.

Paper	Region	Program	Units of Analysis	Dependent Variables	Method	Data Source	Findings
Dyreborg et al. (2022)	North America, Europe, Oceania, and Asia	Occupational safety and health (OSH) regulation enforcement	Workplaces and employees	Injuries, illnesses and fatalities	Systematic literature review/meta-analysis	11 articles published before July 2015	Limited evidence for a little effect of enforcement and compliance at short-term follow-up (odds ratio 0.86), moderate evidence of no or little effect and medium term follow-up (0.96), and strong evidence for a little effect at long-term follow up (0.96).
Foley et al. (2012)	Washington State	OSHA enforcement and consultation program	Fixed and non-fixed sire business accounts with 10+ employees	Workers' compensation claim incidence rates (CIR), medical costs, and wage replacement costs	Used 10 years of compensation data to estimate changes in CIRs and costs using a Poisson regression and linear regression models, controlled for workplace size, industry, and claims history	Washington State Department of Labor and Industry Workers' compensation claims data from 1999 to 2008	The study found that enforcement inspections were associated with a 4% decline in time loss claims rates compared to those not inspected, and that inspections with citations were associated with a 20% decrease in non-musculoskeletal claim rates.
Gray and Mendeloff (2005)	United States	Federal OSHA	Manufacturing establishments in 29 OSHA states	Changes in lost workday related injuries and illnesses	Regression analyzing (Scholz-Gray model), controlling for employment, industry effects, and autoregressive errors	Plant-level data on injuries from the Bureau of Labor Statistics (BLS) and data from OSHA's Integrated Management Information System (IMIS) from 1979 to 1985, 1987 to 1991, and 1992 to 1998	The study found that the impact of an OSHA inspection imposing a penalty was estimated to decline from a 19% reduction in 1979 to 1985 to 11% from 1987 to 1991, and to 1% from 1992 to 1998. (Declining efficacy over time).

Paper	Region	Program	Units of Analysis	Dependent Variables	Method	Data Source	Findings
Gray and Scholz (1993)	United States	OSHA enforcement	Large manufacturing plants	Workplace injury and illness rates	Panel data analysis using Chamberlain technique	OSHA inspection data, BLS injury and illness data for large manufacturing plants	Inspections imposing penalties caused a 22% decline in injuries in the following years.
Haviland et al. (2010)	Pennsylvania	OSHA inspections	Single-establishment manufacturing firms with 20-250 employees	Change in log of lost time injuries and illnesses	Linear regression modeling	Worker's' compensation first reports that were linked to unemployment insurance records	The study found an 8.2% reduction in lost-time injuries and illnesses more related to OSHA standards, and a 14.4% reduction in injury and illness rates not as associated to OSHA standard over the 2 years that followed inspections with penalties.
Haviland et al. (2012)	Pennsylvania	OSHA inspections	Single-establishment manufacturing firms with over 10 employees	Change in log of lost time injuries and illnesses	Used injury data from PA workers' compensation program along with employment data and OSHA inspection findings in order to calculate lost time injury and illness rates and the impact of OSHA on these rates with regression models	PA workers' compensation injury records from 1998 to 2005, Pennsylvania Unemployment Insurance employment records from 1993 to 2006, and OSHA IMIS inspection data from 1995 to 2007	Found that inspections with penalties reduced lost time injuries and illnesses by an average of 19% to 24% annually in the two years after inspection, for firms with 20-250 employees (not for larger 10-20 or smaller 250+ employee firms). The effects were also larger for programmed inspections than for complaints, and no significant effect was found for inspections without penalties.

Paper	Region	Program	Units of Analysis	Dependent Variables	Method	Data Source	Findings
Johnson, Levine, and Toffel (2017)	United States	OSHA SST Program	Firms inspected under the SST program and their corporate "siblings"	Days away from work (DAFW) injury and illness rate in units of 100 full time employees	Compared the injury and illness rates of corporate siblings assigned to SST to those not assigned (with an instrumented variables approach)	OHSA SST target lists, ODI injury and illness data, OSHA inspection data, and National Establishment Time Series (NETS) data	Found that one addition SST inspection caused a 2.2% decline in DAFW injury and illness rate for corporate siblings the following 4 years. The effect was stronger, 7.7%, for those in the same OSHA region.
Johnson (2020)	United States	OSHA press release policy	Facilities inspected by OSHA	Number of violations found in inspections	Regression discontinuity design	OSHA inspection records	Press release about violations led to 73% fewer violations at neighboring facilities within 5km in the same industry (3 year duration). Effects were not evidence in Right-to-Work states.
Johnson, Levine, and Toffel (2023)	United States	OSHA Site-Specific Targeting (SST) program	High-hazard, non-construction establishments with 40+ employees eligible for SST inspections	Number of serious injuries and illnesses (DAFW)	Randomized controlled trial, machine learning	OHSA inspection data and OSHA Data Initiative (ODI) injury and illness data	9% reduction, which was roughly 2.4 less injuries and illnesses on average, over 5 years per inspected establishment.
Lee and Taylor (2019)	United States	OSHA inspections	Manufacturing plants in 20 high-risk industries	Plant-level wages and fatality rates	Instrumental variables regression using randomized OSHA inspections	OSHA and Census Bureau data	OSHA inspections reduce plant fatality rates by about 1.4 fatalities per 10,000 workers. No evidence of spillover effects in sibling plants. Wages decreased by roughly 2%-3% after OSHA inspections reduced fatality risks.

Paper	Region	Program	Units of Analysis	Dependent Variables	Method	Data Source	Findings
Levine, Toffel, and Johnson (2012)	United States	Workplace Safety Inspection on California Firms	Randomly inspected firms	Number of workers' compensation claims	Logistical models of workplace injury and illness and employment (monitored over multiple years, and pre and post inspection) with matched controls	California Division of Occupational Safety and Health	Found that random workplace safety and health inspections reduced workplace injury and illness rates by 9.4%, and that they did not impact firm employment, sales, or overall survival.
Li and Singleton (2018)	United States	OSHA site-specific targeting (SST) plan	Firms near the 85th percentile in DART (days away from work, restrictions, and transfers) rate pre-inspection	DART rate	Fuzzy Regression Discontinuity design with local linear regression	OHSA Data Initiative (ODI) and IMIS data from 1996 to 2011	Found that OSHA inspection decreases the DART rate by 1.792 (20.8% decrease) per 100 full time employees in the year after inspection.
McCaffrey (1983)	United States	OSHA Inspections on Manufacturing and Construction firms	Firms inspected early in the year vs late in the year	Lost workday injury and illness rates	Analyzed injury and illness rates from firms inspected early in the year vs those who were inspected late in the year (control group). Controlled for employment changes, firm size, industry, and the rate of injury and illness from the prior year (regression analysis)	BLS annual survey data on occupational injuries and illnesses from 1975 to 1978	There was no evidence that the OSHA inspection reduced injury and illness rates in the same or following year for early inspected firms as compared to late inspected firms. There was an association found between an increase in state workers' compensation benefits and higher injury and illness rates, which suggests that changes in compensation could inflate injury and illness reporting.

Paper	Region	Program	Units of Analysis	Dependent Variables	Method	Data Source	Findings
Mischke et al. (2013)	North America and Europe	Occupational safety and health (OSH) regulation enforcement	Workplaces and employees	Occupational injuries, diseases, and fatalities	Systematic literature review	Studies from literature databases from the years 1979 to 2012	Inspections have inconsistent effects have inconsistent effect in short-term but there is more evidence that they decrease injury and illness rates after 3 years. Quality of evidence is very low.
Ruser and Smith (1991)	United States	OHSA inspections	Manufacturing establishments	Lost workday injury and illness rates	Analyzed longitudinal microdata in order to estimate the effects OSHA inspections had on injury and illness rates, while controlling for establishment characteristics, compared to the findings of earlier studies	BLS annual survey data on occupational injuries and illnesses from 1979 to 1985	Found little to no evidence that OSHA inspections reduced lost workday injury and illness rates in the period.
Scholz and Gray (1990)	United States	OSHA inspections	Large manufacturing plants	Percent change in lost workday injuries and illnesses, and percent change in lost workdays	Maximum likelihood estimation with autoregressive errors	OSHA records and BLS injury and illness data	The study found a 10% increase in OSHA enforcement being associated with a 1%-1.6% decrease in injuries and illnesses over a 3-year period for large plants that were inspected frequently.

Paper	Region	Program	Units of Analysis	Dependent Variables	Method	Data Source	Findings
Smith (1979)	United States	OHSA Inspections	Manufacturing plants inspected in 1973 and 1974	Lost workday injury and illness rates	Analyzed injury and illness rates of early inspected plants and late inspected plants, while controlling for prior injury and illness rates, employment changes, and the industry	OSHA plant-level inspection and injury and illness data	It was found that 1973 inspections reduced injury and illness rates by roughly 16% after roughly 3.5 months, whereas the 1974 inspections have no statistically significant impact. The largest effects were seen for small hazardous plants.
Tompa et al. (2016)	North America and Europe	Occupational safety and health regulation enforcement	Workplaces and employees	Injuries, fatalities, exposures, illnesses, compliance rates, etc.	Systematic literature review	Studies from literature databases from the years 1990 to 2013	The review found strong evidence that inspections with penalties reduce injuries and illness, while no penalties had limited evidence of no effect on those outcomes. There was moderate evidence that the first inspection had the largest effect on compliance, and that awareness campaigns improve compliance.
Van der Molen (2018)	North America and Europe	Various OSH interventions	Construction workers	Fatal and non-fatal work injuries and illnesses	Systematic review of time series, controlled for before/after studies	Various databases and company record	Found low quality evidence that introducing regulations may or may not prevent injuries and illnesses.
Weil (1996)	United States	OSHA machine guarding and handheld tool standards	Firms in the custom woodworking industry that received OSHA inspections (250)	Compliance with OSHA standards, measured by the number of violations	Logit models that analyzed the impact of OSHA inspections, penalties, and firm characteristics on compliance	OSHA Integrated Management Information System (IMIS) inspection data from 1972 to 1991	Probability of compliance with OSHA standards increase from 0.19 to 0.67 after the first inspection.

TABLE A.2. Effects of Workplace Injuries and Illnesses on Employee Economic and Demographic Outcomes

Paper	Region	Outcome	Category of Injuries/Illnesses	Years	Post-injury/illness years	Data Source	Findings
Boden and Galizzi (1999)	Wisconsin	Earnings	Lost-time injuries and illnesses of 11 days or more	1988-1993	6 years	Workers' compensation Records and UI records	WC replaces 89% of after-tax earnings lost during observed period for injured/ill men and 84% for women. Projected tax-year losses are 64% for men and 50% for women.
Boden et al. (2016)	New Mexico	Mortality	Lost-time injuries and illnesses (8 or more days)	1994-2014	20 years	Workers' compensation records and SSI records	Lost-time injuries and illnesses are associated with elevated mortality hazard (24% annual risk increase for men and 21% for women).
Bronchetti and McInerny (2023)	United States	Earnings and Labor Force Participation	Workers with "chronic" injuries and illnesses (i.e.., respondents report that they are work-limited two years after onset)	1992-2018	10 years	Health and Retirement Survey	Chronic injury/illness workers earnings losses are approximately 17.5% lower in year of injury or illness than six years before injury or illness with partial recovery thereafter. Non-chronic work injuries/illnesses, workers are approximately 14.2% lower with recovery by tenth year. Workers with chronic injuries/illnesses are 9 percentage points more likely to retire following injury in 1st year, 25% by second year and 32% after four years.
Dong et al. (2016)	United States	Earnings	Injured or ill workers reporting days away from work	1986-2008	10 years	National Longitudinal Survey of Youth (1979 cohort)	Average annual wage and salary loss was $3,700 (2000 dollars) (estimated as approx. 14-15% of total wages for workers with days away from work and $1,200 (estimated at approx. 4%) for workers without days away from work
Dworsky and Powell (2022)	California	Earnings and Labor Force Participation	Lost-time injury and illness workers who received benefits	2003-2019	14 years	Workers' compensation Records and UI records	Earnings loss 19.6% year 1-4 post injury/illness, 13.6% 5-9 years, to 10.9% 10-14 years. Workers 55 and older with lost-time injuries and illnesses more likely to drop out of labor force and collect SSDI.

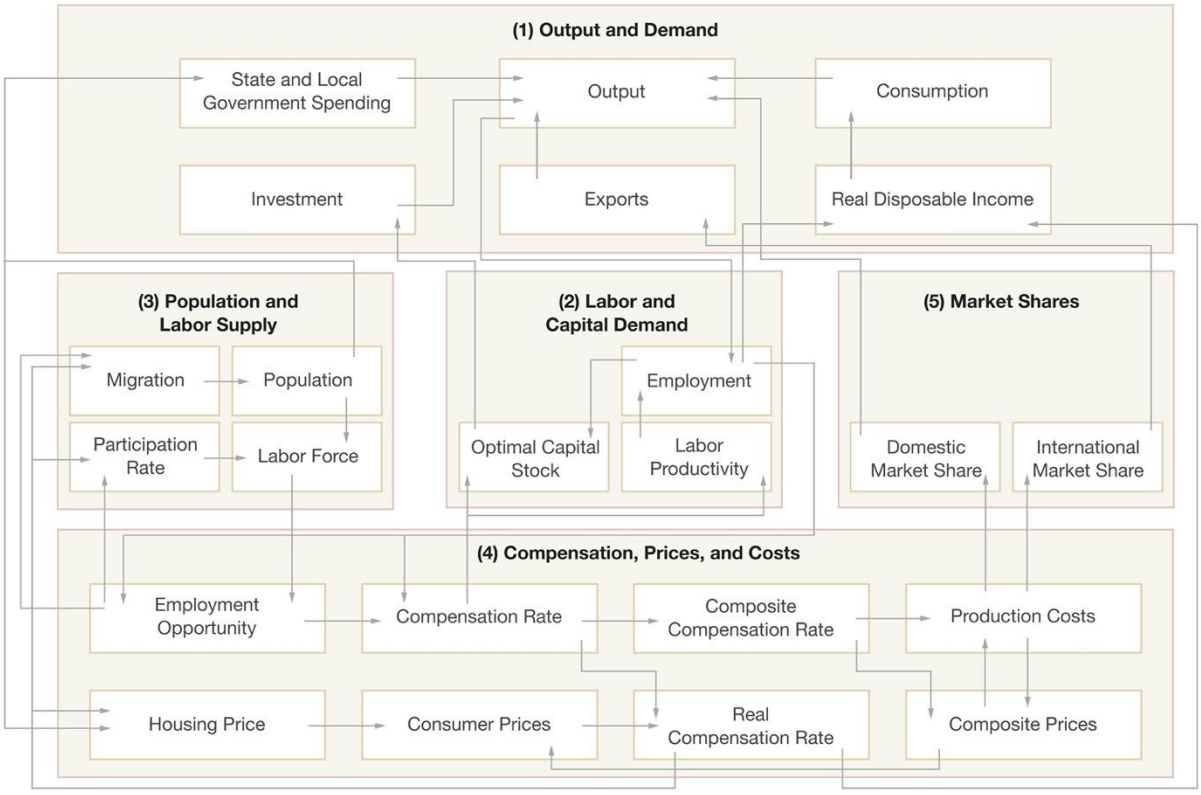
Paper	Region	Outcome	Category of Injuries/Illnesses	Years	Post-injury/illness years	Data Source	Findings
Galizzi and Zagorsky (2009)	United States	Wealth, Consumption	Lost-time or lost-wage injuries and illnesses	1988-2000	NA	National Longitudinal Survey of Youth (1979 cohort)	Injuries and illnesses that lead to wage losses or time off work are associated with a wealth reduction of almost 20%.
Reville (1999)	California	Earnings and Labor Force Participation	Permanent Partial Disability Claimants	1989-1994	5 years	Workers' compensation Records and UI records	Earnings loss (based on data provided) computed at 24.8% after 5 years.
Seabury et al. (2014)	New Mexico	Earnings	Lost-time injury and illness workers who received benefits	1994 to 2000 WC claimants and 1987 to 2007 earnings records	10 years	Workers' compensation Records and Social Security Master Earnings File	Earnings losses of 15% over 10 years after injury or illness.
Woock (2009)	United States	Earnings	Workplace injuries illnesses and work-limiting disability injuries and illnesses	1998-2000	6 years	National Longitudinal Survey of Youth (1979 cohort)	Earnings loss amounts to 8% for workplace injuries and illnesses and 16% for work-limiting disability.

APPENDIX B

REMI MODEL DESCRIPTION

The REMI model is made up of five major modules or blocks (see **Figure B.1**), which interact simultaneously. The Output Block determines expenditures for final demand, including consumption, investment, government, and imports as well as demand for intermediate inputs. Final demand responds to changes in other model blocks. This module contains a key engine in the model, an input-output model based on the Bureau of Economic Analysis (BEA) benchmark transactions table that measures flows of goods and services among industries. The Labor and Capital Demand Block determines employment, capital and fuel demand, and labor productivity. The Population and Labor Force Block models the population characteristics of the region, including age, race, and sex composition. Labor force participation adjusts in response to changes in wages and employment opportunities. A key driver of population change is migration, which is influenced by relative wage levels as well as amenities. The Wage, Price, and Costs Block determines factor and product price. The Market Shares Block helps to measure exports from and imports to the region. Changes in market share are driven by production costs, demand characteristics, distance to markets, and output.

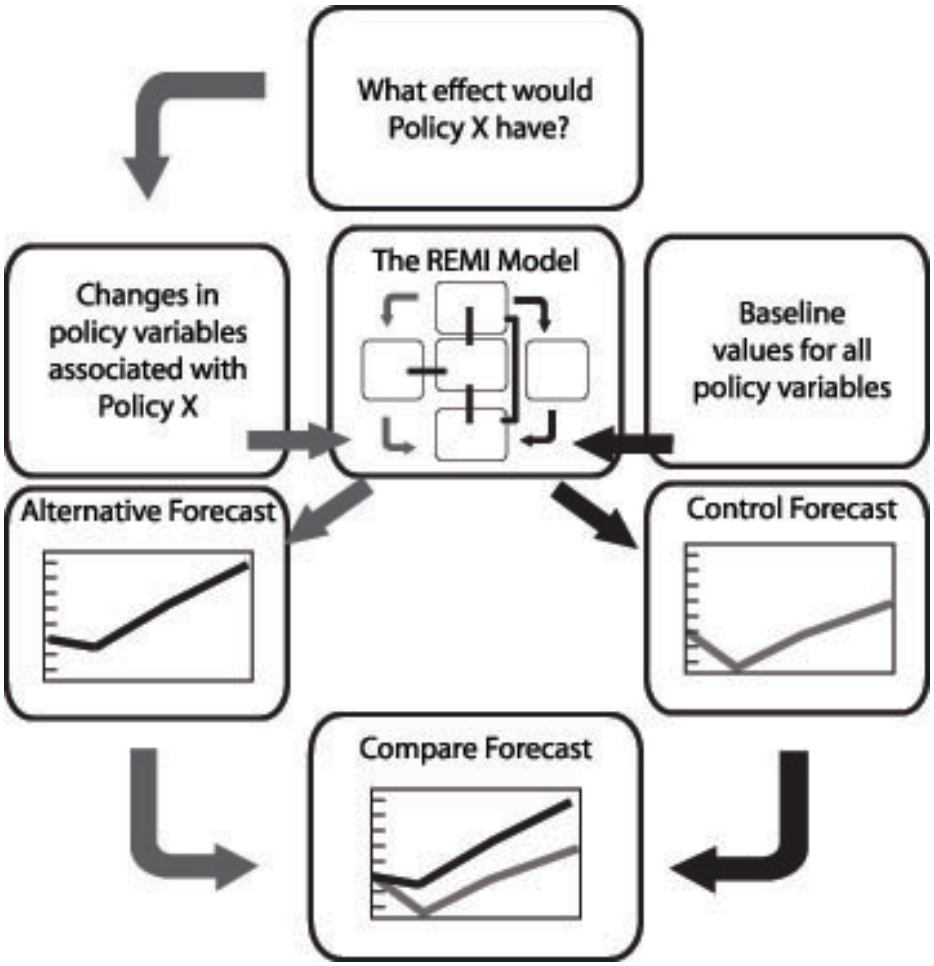
Figure B.1 Simplified Economic Structure of the Key Interactions in Regional Economies Based on the REMI PI+ Model



The basic procedure used to obtain VOSH inspection economic impacts is illustrated in **Figure B.2** and briefly summarized here. A control forecast for the Virginia economy was generated using REMI

PI+. An alternative forecast was then run in which the baseline data was changed based on the effect of VOSH inspections when REMI policy variables (e.g., earnings, output, mortality) were entered. For instance, the absence of VOSH inspections would result in 4% more injuries or illnesses in the inspected establishments and reduce the long-term earnings of lost-time injured or ill workers. Therefore, for this particular component of VOSH inspection impact, negative values were entered for the REMI PI+ employee compensation policy variable in the Output and Demand block (1) for 2022 to 2041. The difference between the baseline control forecast and the alternative forecast provides an estimation of the economic impact of reduced employee earnings over time.

Figure B.2 REMI PI+ Model Simulation Flow



REMI PI+ does not provide state tax revenue estimates. In order to conduct tax revenue analysis, this study utilized a method outlined in Regional Economic Models, Inc. (2012). State tax revenues were obtained from the Census of Government's *Annual Survey of State Tax Collections*. Revenue estimates are calculated by multiplying state revenue rates by the corresponding base quantity, which included state-level demand for selected industries (general sales tax, selective sales tax, license taxes) state-level personal income less transfer payments (individual income tax), corporate income tax (gross domestic product), and personal income (other taxes).

APPENDIX C
REMI MODELLING INPUT DATA

The modeling of VOSH inspection economic impact was conducted by altering several policy variables. **Table C-1** describes the REMI modeling inputs for each feature on REMI modeling blocks and policy variables.

TABLE C.1 REMI P+ Model Inputs

Impact Component	REMI Model Policy Variables	Modeling Description	Data Sources	Data Value(s)
Amenity	Population and Labor Supply->Migration->Non-Pecuniary (Amenity) Aspects	Model reduction in quality of life due to reduced QALY from increased workplace injuries and illnesses.	CDC WISQARS Cost of Injury or illness by cause/event of injury or illness.	$2,267,971
Employee Compensation	Output and Demand->Real Disposable Income->Compensation->Industry	Model employee compensation loss based on estimates of average wage and earnings loss for workers with increased lost time injuries and illnesses (-15% first decade, -10% second decade).	Average empirical literature estimates (see Appendix Table A.2) on worker earnings losses and REMI data on employee compensation by industry.	$11,448,447 (nominal dollars) over 2022-2041
Output	Output and Demand->Output-> Industry Sales (Exogenous Production) without Employment, Investment, and Compensation->Industry	Model decrease in firm output due to reduced worker productivity reflected in employee compensation scaled to value-added by industry.	REMI PI+ data on value-added and employee compensation.	$22,993,386 (nominal dollars) over 2022-2041
Mortality	Population and Labor Supply->Population->Survival Rate->Both Genders, All Races, Age 42	Model increase in workplace fatalities and enhanced morbidity/mortality due to increased lost-time workplace injuries and illnesses for average-age of injured or ill worker (42 years of age).	CFOI data on Virginia fatalities scaled to represent VOSH inspection impact. Boden et al. (2016) empirical hazard rate function applied to life table mortality rate from Virginia Health Department for 42 year old scaled to VOSH inspection reduced injuries.	VOSH inspections reduce .42 fatalities and additional 2.44 cumulative premature deaths 2022-2041.

Impact Component	REMI Model Policy Variables	Modeling Description	Data Sources	Data Value(s)
Production Costs	Compensation and Prices->Production Costs (lagged market share response)-> Industry	Model increase in firm production costs due to increased workers' compensation costs and temporary worker replacement costs.	Estimates of workers' compensation indemnity and medical payments by cause/event of injury or illness from National Council on Compensation Insurance (NCCI) for lost-time injuries and illnesses mapped onto cause/event of injury or illness for workers with 8+ DAFW. Estimates of worker replacement costs based on REMI average compensation per employee by industry multiplied by estimated FTE reduction from DAFW.	$2,807,297 in 2022
Medical Spending	Output and Demand->Consumption->Consumer Spending->Hospitals	Model increase in medical spending due to increased lost time injuries and illnesses.	Estimates of workers' compensation medical payments by cause/event of injury or illness from National Council on Compensation Insurance (NCCI) mapped onto cause/event of injury or illness for workers with 8+ DAFW.	$1,162,141 in 2022

Impact Component	REMI Model Policy Variables	Modeling Description	Data Sources	Data Value(s)
State Government Spending	Output and Demand->State and Local Government Spending	Model decrease in government spending to compensate for increased workers' compensation costs and temporary worker replacement costs.	Estimates of workers' compensation indemnity and medical payments by cause/event of lost-time injury from National Council on Compensation Insurance (NCCI) mapped onto cause/event of injury or illness for workers with 8+ DAFW. Estimates of worker replacement costs based on REMI average compensation per employee by industry multiplied by estimated FTE reduction from DAFW. Estimate of state income tax rate loss based on of 3% for workers' compensation payments received by injured or ill workers.	$445,637 in 2022

The impact of VOSH inspections on injuries, illnesses, and fatalities was estimated using information from studies reviewed in the previous sections; fatality, injury and illness data from the BLS SOII and CFOI for 2022; and information on inspection activities undertaken by VOSH in 2022. Reviews of the empirical literature indicate that inspection activities, on average, reduce injuries and illnesses by at least 4% over a counterfactual where just inspection activities are absent (Dyreborg et al. 2022; Andersen 2019). However, these effects may attenuate over long periods of time and are enhanced by the issuing of citations and penalties.[7] The assumption of 4% leans heavily on the most recent and comprehensive meta-analysis by Dyreborg et al (2022) of 11 studies that examined the effectiveness of enforcement and compliance efforts at the organizational level. They report average odds ratio by the time elapsed since inspection follow-up (short-term: approximately 1-year, medium term: 1 to 3 years, and long-term: 3 years or more) (Table 6, p. 49). An odds ratio (OR) represents the effect that an intervention has on the odds of an outcome. An average odds ratio of 0.96 indicates that the odds of the outcome occurring in workplaces that are inspected have 4% fewer injuries and illnesses than those that were not inspected. They found injury and illness odds ratios of .86 for one short-term study, .99 for one randomized control trial study, an average .95 odds ratio for five other studies, and an average odds ratio of .96 for four long-term studies. Pooling these results because of the relatively small number of studies and variations in the types of injuries and illnesses examined (e.g., lost time versus other categories) and aspects of the inspection regime results in a weighted average of (1*.86+1*0.99+5*0.95+0.96*4)/11=.949. This study makes the conservative assumption that the odds ratio of the VOSH inspection program is 0.96. This percentage reduction is the same as

the long-term follow-up inspection metanalytic result and is also consistent with an assessment of another state-office program (Washington State) that found that inspections reduced work-loss injuries and illnesses by 4% (Foley et al. 2012). Thus, we assume that 2022 injuries and illnesses would be 4% higher than they were in 2022 without VOSH inspection activities.

Estimates of the number of injuries and illnesses by industry for 2022 were obtained from BLS SOII and the number of fatalities were estimated by CFOI. It is estimated that a portion of these injuries would have occurred without the inspection activities. According to computations using U.S. Department of Labor OSHA enforcement data, there were 1,828 VOSH inspections conducted in 2022.[8] Of these inspections, 1,772 were unique establishments based on establishment names and addresses that collectively employed 250,649 workers. There are an estimated 3,028,000 workers covered in the 2022 SOII for Virginia.[9] This represents approximately 8.3% of these workers. For the purposes of this analysis, it is conservatively estimated that 8% of Virginia workers represented in the SOII and CFOI data were impacted by VOSH inspections in 2022. Furthermore, as stated earlier it is assumed that the number of injuries would have been 4% higher in the absence of those inspection activities. For example, using this information, it is estimated the VOSH program prevented 52.4 DAFW injuries and illnesses of various severities and durations during 2022 and prevented an estimated 0.42 fatality.

Because detailed injury characteristics (e.g., days of work lost, nature of injury or illness, injury or illness event) are not available in 2022 annual SOII data, the biennial injury and illness data on the distribution of injuries and illnesses by their characteristics were used instead and applied to the total number of DART and DAFW injuries and illnesses. These distributions were assumed to be the same across industries. The implicit assumption of this estimation methodology is that distribution of industry injury and illness types and severity, and duration in the SOII and CFOI data are representative of agency impacts.

This method may underestimate the number of injuries and illnesses abated by VOSH inspection activities for two reasons. First, no allowance was made for the possibility that VOSH activities target industries with higher injury and illness and fatality rates. If this is the case, then using the cross-section of industries represented by SOII may not be less representative of the types of industries inspected and the method may underestimate the impact of VOSH activities on injury and illness and fatality abatement. For example, a portion of VOSH inspections is programmed, which are targeted at more hazardous workplaces where injury and illness rates exceed industry averages, while others are conducted in response to accidents, complaints, referrals, and similar information. This could be adjusted by reweighting the SOII industries to align with VOSH inspections by industry. In addition, it is likely that the SOII significantly underestimates the number of workplace injuries and illnesses for regulated firms and industries.[10] For these reasons, VOSH inspection activities may have abated a higher number of injuries, illnesses, and fatalities than estimated here.

Production Costs

Production costs increase because firms experience higher injury and illness rates without VOSH inspection activities. These increased costs stem from two sources examined here: increased workers' compensation costs for injured and ill workers and the costs associated with replacing workers that were on disability leave. Increased workers' compensation costs for these were represented as a one-time savings cost in 2022 equal to the estimated workers' compensation costs.11 Workers' compensation costs were estimated using data from BLS SOII on the number of injuries with 8 DAFW or more, which would qualify them for indemnity payments. The average cost of medical care and indemnity benefits was drawn from National Council on Compensation Insurance (NCCI) data obtained from its Injury Characteristics and Insights Dashboard.12

Workers' compensation costs were divided into indemnity costs and estimated medical costs to avoid worker injury and illness due to VOSH inspections. These costs did not include medical-only costs, though these are thought to be much smaller in comparative size because the injuries and illnesses tend to be less serious and there are no associated disability income payments (though there may be sick leave costs that are not considered here).

The costs of replacement workers were estimated using information from SOII on the estimated number of VOSH impacted workers with any DAFW (1 or more).13 The total number of days lost by industry were estimated using the number of estimated injuries and illnesses by industry and DAFW. These were converted to FTE equivalents and multiplied by average employee compensation costs by industry from REMI for 2022 to obtain total replacement employee compensation costs that must be covered for short-term production continuity. These costs do not include other administrative, recruitment, and training associated with temporary replacements.

The estimated value of increased production costs by industry totaling $2,807,297 in 2022 were entered into the policy variable Compensation and Prices->Production Costs (lagged market share response)-> Industry by REMI industry.

Medical Spending

Workers' compensation medical benefits pay for medical expenditures which represent spending in health-related industries. Because this spending would not occur with reduced worker injuries and illnesses, these are considered to result in a positive economic impact. That is to say, without VOSH inspection activities, the medical expenditures funded by workers' compensation medical benefits would be spent and have a stimulating effect on the economy. This is represented as an increase in medical spending and entered into the policy variable Output and Demand->Consumption->Consumer Spending->Hospitals.

State Spending

Some VOSH injury and illness avoidance is experienced by state and local governments. Since government agencies are not profit-maximizing enterprises, REMI PI+ does not model the effect of production costs on government industry economic activity. Thus, the increased spending on workers' compensation and the employee compensation costs that would result from the absence of VOSH inspections were modelled as decreased state government spending. The funds that would have to be dedicated to covering these costs are assumed to have been secured from other state government general funds that are not available for other government spending purposes. In addition, workers' compensation payments from all sources are non-taxed benefits. To account for this, state tax revenues were reduced by an assumed state government income tax rate of 3% of estimated workers' compensation. This revenue loss was addressed in the model by reducing government spending by an equivalent amount to maintain a balanced budget. The total estimated amount of $445,636 in 2022 was entered as a reduction for the policy variable Output and Demand->State and Local Government Spending.

Employee Compensation

Research described in section 2 indicates that worker injuries and illnesses result in significant long-term reductions in earnings capacity. [14] The authors found that the average reduction in injured and ill workers' earnings was 16.7 percentage points within the first 10 years of injury/illness for six studies drawn from **Table A.2** where percentage reductions in earnings were reported or could be inferred from other data. The only data point for the second decade is Dworsky and Powell's (2022) finding of a 10.9% reduction in years 10-14. Thus, this analysis assumes a slightly more conservative 15% reduction in the first decade after injury and 10% into the second decade. This was modelled using information on VOSH impacted injuries and illnesses using SOII data with 8 DAFW or longer (a category of work loss/injury and illness severity similar to that used in many empirical studies that have shown these lasting earnings reductions) by industry. The amount of reduced employee compensation was estimated by assuming that average injured/ill employee compensation was reduced by -15% for 2022-2031 and -10% for 2032-2041 and multiplying it by the increased number of VOSH impacted workers injured or ill as a result of the absence of VOSH inspection activities. These reduced earnings over time were assigned to the REMI policy variable Output and Demand->Real Disposable Income-> Compensation->Industry by REMI Industry.

Output/Productivity

Output by industry was also reduced to account for reduced worker productivity over the longer term due to the absence of VOSH inspection activities. Output estimates were obtained by forming the ratios of value-added per employee compensation for each industry from REMI data for the period 2022-2041. These ratios were then multiplied by the estimated employee compensation impacts described in the previous section. These were assigned to the REMI policy variable Output and Demand->Output-> Industry Sales (Exogenous Production) without Employment, Investment,

and Compensation->Industry by REMI industry. This method is similar to that used in analyses of human capital impacts on productivity in studies of Oklahoma Higher Education (REMI Inc. 2008) and Virginia public higher education (Rephann 2023).

Mortality

VOSH activities result in an estimated reduction in .42 fatalities based on VOSH inspection activities out of a total of 144 reported workplace fatalities in Virginia in 2022 according to CFOI. In addition, Boden et al. (2016) indicates that lost-time injured or ill workers have a more elevated mortality rate over the long-run than uninjured or less severely injured workers. This was estimated for Virginia VOSH activities using lifetable mortality rates (for all races, both sexes) in 2015[15] and baseline probability of dying between 42 and 43 of .002078 (the average age of an injured or ill worker in Virginia in 2021-2022 according to biennial SOII data was approximately 42), and average male and female hazard rates of approximately 1.21 from the study (i.e., injured/ill workers have a 21% elevated rate of dying compared to the baseline probability). Using this information, estimates of the number of VOSH reduced DAFW of 8+ days or more injuries and illnesses and the estimated survival function over 20 years. VOSH inspection activities are estimated to prevent a further 2.44 premature deaths over the 20-year period.[16] These fatalities were represented as a reduced survival rate for 42-year-olds through the period. Thus, in addition to the immediate .42 fatalities abated, an additional cumulative 2.44 premature deaths are avoided over 2022-2041. These figures were converted to statewide survival rate reductions via the REMI policy variable Population and Labor Supply->Population->Survival Rate->Both Genders, All Races, Age 42 policy variable.

Amenities

Reduction in workplace injuries improves the quality of life of workers. Quality of life (QoL) is reported in the Centers for Disease and Control (CDC) Web-based Injury Statistics Query and Reporting System (WISQARS) Cost of Injury data by cause of injury or illness. The QoL monetary value is estimated in terms of quality-adjusted life years losses by injury or illness type valued at $540,000 per QALY (Peterson et al. 2023). These estimates were applied to estimated injuries and illnesses avoided by VOSH inspection activities for hospitalized and emergency room only injuries/illnesses by event (cause). The total value of Quality of Life reduction avoided was estimated at $2,267,971.[17] This was modelled in REMI as an amenity improvement, which has its initial effect in making Virginia more attractive for migration and increasing the size of the workforce. This is entered into REMI PI+ using the amenity policy variable (Population and Labor Supply->Migration->Non-Pecuniary (Amenity) Aspects).

Other Factors not Included in Analysis

This analysis did not take into account some costs and benefits of VOSH inspection activities. First, some studies indicate that workplace injuries and illnesses reduce the labor force participation rate

of affected workers, particularly for older workers who are more likely to seek permanent SSI disability benefits or retire (Bronchetti and McInerney 2023; Dworsky and Powell 2022). Because of the lack of clear-cut findings in this area, this was not modelled in REMI.

Second, this study looked primarily at the benefits that accrue to workers (improved earnings, reduced mortality) and reciprocal benefits accruing to firms (reduced production costs, increased output) and the state government (increased funds available for other spending), and collateral benefits accruing to Virginia (increased amenities from a safer and healthier workplace environment in the state). Some costs and benefits of reduced injuries and illnesses for firms, such as reduced liability, litigation, and property expenses, were not estimated. Also not estimated were the costs of firm compliance with inspection requirements or penalty costs imposed on firms for noncompliance (though penalty revenues would also represent an additional form of revenue accruing to the state that is available for government spending). Some studies of the financial benefits of firm OSH expenditures suggest that they can yield positive return on investment, thereby contributing to firm profitability (Mustard and Yanar 2023; Verbeek, Pulliainen and Kankaanpää 2009). Another study finds that that firm safety and health culture is associated with higher stock market valuations (Fabius et al. 2013). Thus, not all firm safety and health compliance expenditures should be viewed as a net cost.

Third, either because data was not available or research evidence was less complete, this study did not account for the possible positive economic impacts of abating injuries and illnesses without work loss. For example, no effort was made to estimate the avoidance of wage reduction for workers with fewer than 8 days of work losses or none at all. A few studies suggest that these injured and ill workers also experience negative long-term wage impacts, albeit smaller than for work-lost injury/illness workers. In addition, workers' compensation costs for medical-only workers were not estimated because of the lack of corresponding publicly available data from NCCI on this category of injured/ill worker. Thus, additional production costs incurred by firms from this source are not included. Similarly, possible losses in worker productivity/firm output associated with workers who were transferred or restricted are not accounted for. Lastly, this study assumed that injury and illness reduction occurred only for the cohort of workers injured in 2022. It did not consider the possible effect of continued multi-year establishment-level injury abatement.

The study did not take into consideration program delivery spending. Slightly less than half of program activities are funded by federal OSHA funds. However, both state and federal spending outlays would be paid for primarily by state and federal tax revenues. Therefore, these are regarded as equal and offsetting, affording no opportunity for net positive economic impact.

APPENDIX D
COST OF INSPECTIONS

Shown in the table D.1 below are costs of proving VOSH inspection services and revenues, which are derived from three sources: 23g federal base award, state match for this federal grant, and additional funding provided by the state.

On the expense side, costs are broken down by area, including ones that could not be directly attributed to compliance inspection activities. They include (a) Administration Headquarters (8 staff including Safety Compliance Coordinator and OIS Assistant), (b) Cooperative Program (6 staff), (c) Whistleblower Protection (2 staff), (d) Legal Support (7 staff), (e) Indirect Costs, and (f) Headquarters Office Rent.

The final expense category is Compliance-Inspection-Related Costs. They include all Compliance Safety and Health Officer (CSHO) positions (38 Safety and 21 Health) and first line supervisors (4 Safety and 4 Health Regional Directors). There were 14 Compliance Safety and Health Officer (CSHO) vacancies listed in the 2022 23(g) Grant application. Budget categories for Travel, Supplies, Equipment, Contractual and Other could not be broken down between Headquarters, Regional, and Field offices with the exception of the Rent for the Headquarters Office which was included under Non-Compliance Inspection Expenses.

According to DOLI, VOSH compliance inspections would be fully staffed with 59 personnel. However, it had only 45 staff in 2022. It is estimated that a CSHO position can complete an average of 40.5 inspections per year (1,822/45=40.5). Therefore, at full strength in 2022, VOSH would have been able to conduct an additional 567 inspections (14x40.5=567). These numbers can be used to represent a more accurate cost of inspection based on the budget figures. At full strength, VOSH could have inspected (1,822+567) 2,389 inspections.

Instead of providing a single estimate of compliance costs, a range of estimates are provided based on the marginal and average cost concepts and the level of assumed staffing. Four estimates are computed that represent: (A) marginal cost at 2022 staffing (with 14 vacancies (1,822 inspections), (B) the marginal costs of an inspection at full staffing (2,389 estimated inspections), (C) average cost at 2022 staffing and (D) average cost at full staffing. The former includes only the costs of inspection staff while the latter add the impute overhead (administrative and indirect costs).

The marginal costs of an inspection are based on compliance-related costs with no administrative overhead. They range from approximately a high of (A) $3,760 ($6.686,938/1,822) to a low of (B) $2,799 ($6,686,938/2389)).

To estimate average costs, most (82%) of the $2,070,096.58 administrative, rent, and indirect costs ($6,686,938/($8,201,503) would be apportioned to VOSH compliance inspections. The $8.2 million includes compliance, cooperative, whistleblower, and legal support. That would mean that average costs would be from a high of (C) $4,596 ($6,686,938+estimated overhead $1,887,833=$8,374,751/1,822) to a low of (D) $3,506 ($8,374,751/2,389)).

TABLE D.1. Virginia Occupational Safety and Health (VOSH) Program Funding and Expenses, 2022

Funding	
23g Federal Base Award	$4,410,800
23g State Base Award Match	$4,410,800
State 100% Funding	$1,450,000
Total	**$10,271,600**
Expenses	
Non-Compliance Inspection Expenses	
Administration Headquarters	$837,192
Cooperative Programs	$575,379
Whistleblower Protection	$169,153
Legal Support	$770,034
Indirect Cost	$1,174,386
Headquarters Office Rent	$58,519
Subtotal	$3,584,662
Compliance-Inspection-Related Costs	*$6,686,938*
Total	**$10,271,600**

Source: Virginia Department of Labor and Industry based on 23g Federal Grant Application

APPENDIX E

DATA AND SOURCES FOR COST-EFFECTIVENESS ANALYSIS

TABLE E.1 Data and Sources for Cost-Effectiveness Analysis

Variable	Parameter Value	Source
Probabilities		
Probability of injury or illness	0.0378	US rate 2022 private sector adjusted by 40%; Leigh (2011) describes an additional 40% "accidental or willful" underreporting based on his 1999 study (41% for no days lost and 36% for at least one day lost).
Probability of death	0.000037	US rate 2022 3.7 per 100,000 workers
Traumatic injuries and disorders	0.8201	Probabilities (fraction of injuries and illnesses in VA) Source: BLS SOII Virginia DART data
Diseases and disorders of body systems	0.0048	Probabilities (fraction of injuries and illnesses in VA) Source: BLS SOII Virginia DART data
Infectious and parasitic diseases	0.1647	Probabilities (fraction of injuries and illnesses in VA) Source: BLS SOII Virginia DART data
Symptoms, signs, and ill-defined conditions	0.0028	Default category to make probabilities equal 1
QALYs		
Base QALY if no injury or illness	0.86	Rauch et al. (2023)

Variable	Parameter Value	Source
Long-term traumatic injuries and disorders	0.361	31 or more days/total injury or illness by type. National data - TABLE R67. Number of nonfatal occupational injuries and illnesses involving days away from work, restricted activity, or job transfer (DART), days away from work (DAFW), and days of restricted work activity, or job transfer (DJTR) by nature of injury or illness and number of days away from work by case type, and median number of days, private industry, 2021-2022.
Long-term diseases and disorders of body systems	0.517	31 or more days/total injury or illness by type. National data - TABLE R67.
Long-term infectious and parasitic diseases	0.014	31 or more days/total injury or illness by type. National data - TABLE R67.
Long-term symptoms, signs, and ill-defined conditions	0.153	31 or more days/total injury or illness by type. National data - TABLE R67.
Costs		
Death using VSL	$13,770,000	OHSA data based on U.S. Department of Transportation estimates and converting to 2023 dollars (OSHA 2024).
Major injury or illness	$116,588	OHSA data based on Viscusi and Gentry (2015) converted to 2023 dollars (OSHA 2024).
Marginal cost of inspection 2022	$3,279.50	$3,760 ($6.686,938/1,822) to $2,799 ($6,686,938/2389)) based on 2022
Risk Reduction from inspection		
Risk reduction multiplier	0.04	"Effectiveness rate" based on literature consensus (e.g., Dyreborg et al. 2022; Foley et al. 2012).

TABLE E.2 Data and Sources for CEA Sensitivity Analysis

Sensitivity analysis	Base value	Range	Source
Probability of injury or illness	0.0378	.0324 to .0459	Leigh (2011) describes an additional 40% "accidental or willful" underreporting based on his 1999 study (41% for no days lost and 36% for at least one day lost); Underreported 20% to 70%. Various literature.
Cost of death	$13,770,000	$1,390,000 to $13,770,000	National Safety Council (NSC) https://injuryfacts.nsc.org/work/costs/work-injury-costs/; OHSA (2024) based on U.S. Department of Transportation estimates converted to 2023 dollars.
Cost of inspection 2022 (marginal to average)	3279.5	$2,799 to $4,596	$3,760 ($6.686,938/1,822) to $2,799 ($6,686,938/2389)) based on 2022; $4,596 ($6,686,938+estimated overhead $1,887,833=$8,374,751/1822) to low range of $3,506 ($8,374,751/2389)).

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ENDNOTES

[1] These figures were obtained the U.S. Department of Labor, OSHA Inspection Explorer (https://enforcedata.dol.gov/views/oshaLab.php). The 2022 count likely differs from VOSH reported inspections that year (1,822) because the data is more recently updated and also includes inspection cases where a scope of "not inspected" was reported due to establishment closure, inaccessibility, or some other reason.

[2] Levine, Toffel, and Johnson (2012) find that regulatory enforcement is not associated with decreased firm payroll and employment that would be expected in a perfectly competitive labor model, thereby calling into question the validity of its assumptions of perfect knowledge and labor mobility.

[3] https://www.osha.gov/safetypays/background. OSHA indicates that the indirect cost estimates are drawn from an older study by Stanford University (1981).

[4] A handful of studies have focused on the firm productivity effects of workplace regulation, finding mixed effects. An early study by Gray (1987) using aggregated data found that the OSHA inspection rate is associated with a Total Factor annual productivity decrease of .27%. One possible explanation for the finding is that workplace safety regulations constrain firms' production choices, increase uncertainty or reduce input productivity. In contrast, Dufour, Lanoie, and Patry (1998) find that Canadian OSH rules are associated with increased productivity growth, suggesting that regulation caused firms innovation that would not have occurred otherwise and reduced direct and indirect costs of worker injuries. A more recent study by Lee and Taylor (2019) using manufacturing plant-level U.S. data indicates that inspections reduce worker productivity total factor productivity by approximately 1.6%.

[5] Though the model has both demand and supply features, the model has been principally used to examine the effect of expenditures associated with federal, state, and local policies. However, it has been used as a tool in examining federal environmental/energy regulatory programs. Moreover, it has been used as a tool to examine the impact of demographic changes such as immigration (Treyz and Evangelakis 2018) and earnings/productivity improvements resulting from human capital investments in education (Rephann 2023, REMI 2008) and improved health care access (Rephann 2011)

[6] GDP (also known as value-added) is a subset of output, representing the residual portion of output not measuring intermediate inputs. Personal income overlaps with output and GDP but is not a subset of those measures. For example, transfer payments are part of personal income, but they are not counted in output or GDP.

[7] The Andersen et al. (2019) systematic literature review and meta-analysis found an average odds ratio of 0.83 (17% reduction) for the effectiveness of OSH inspections on workplace injuries. An independent analysis by the authors of 12 studies published from 1979 to 2023 (included in **Table A.1**) that reported effects of inspections on injuries and fatalities ranging from none at all (McCaffrey 1983; Ruser and Smith 1991) to a high of 22% (Gray and Scholz 1993; Havilland et al. 2012). The average reduction in various injury and fatality metrics was 10.4%. It should be noted that some of these studies analyze particular special categories of workplace inspections such as first-time inspections, site specific targeting, or inspections with penalties.

[8] These computations used osha_inspection table data from the OSHA Enforcement Dataset at https://enforcedata.dol.gov/views/data_summary.php, Note: federal sites and an inspection scope of "not inspected" were removed from the inspection data file) to reflect actual inspections undertaken by VOSH. This figure is close to the 1,822 reported by VOSH in their 2024 Strategic Plan and may differ because the data is continuously updated.

[9] This figure is significantly smaller than the total number of Virginia workers in 2022 because it excludes various workers who are out of scope (i.e., not covered by state office enforcement activities and counted in SOII) such as federal civilian and military, self-employed, farm workers and selected other smaller categories of workers.

[10] Past research conducted on workplace injury/illness data has determined that the Bureau of Labor Statistics survey of Occupational Injuries and Illnesses (SOII) underreports the incidence of injuries and illnesses. The extent of the underreporting ranges from estimates of roughly 20% to 70% (Ruser 2008). Reasons for underreporting include: injuries/illnesses falling outside the survey's scope (e.g., farms and self-employed); difficulties in assigning illnesses that manifest over long periods of time to workplace conditions; survey design issues, and employer failure to report injuries due to errors or a desire to avoid closer scrutiny, penalties and costs; and workers being discouraged to be report (Ruser 2008, Reindel and Fletcher 2023).

[11] The average establishment size of firms in the inspection database was 130 employees. Thus, the typical firm was either experience-rated or in the case where the establishment is part of a much larger firm, self-insured. While experience-adjusted insurance rates would be adjusted over time for an individual firm, it is assumed here that they are immediately offset in the year of the injury for all firms.

[12] The NCCI Injury Characteristics and Insights Dashboard can be found at: https://www.ncci.com/SecureDocuments/Injury_Severities_Dashboard.html

[13] The median number of days for each SOII DAFW category were used as approximations for the mean for bounded categories (i.e., 1 day (1), 2 days (2), 3-5 days (4), 6-10 days (8), 11-20 days (14), and 21-30 days (26)). For the 31 or more days, the median number of DAFW was 70, which is likely to severely underestimate the actual mean because the category is open-ended and DAFW are likely to be heavily skewed. For this reason, the assumption is made that the frequency of an injury lasting 31 or more days decreases exponentially. Thus, the density function is represented by: $f(t)=\lambda e^{-\lambda t}$, where t is the number of days and λ is a scale parameter. For an exponential distribution, the median is given by Median=λ/ln(2). Therefore, if the median of the distribution is 70, λ=.0693/70=0.0099. The mean (μ) of an exponential distribution is the reciprocal of the rate parameter: $\mu=1/\lambda=1/0.0099=101.01$. For the purpose of this analysis, the mean was rounded to 100. The average number of days lost for VOSH abated injuries (2,727 days) were converted to full-time equivalents in employment using an assumption of 240 days worked on average per year to estimate 11.362 FTE.

[14]Galizzi and Zagorsky (2008) find that work loss injuries also reduce injured workers wealth. This result suggests that other forms of non-wage income such as dividends, interest, and rent from accumulated assets could be negatively impacted. These additional potential income losses are not considered in this analysis.

[15]Virginia Department of Health. Life Expectancy/Statewide life table. (https://apps.vdh.virginia.gov/HealthStats/stats.htm).

[16]In a Cox proportional hazards model, the hazard ratio (HR) of 1.21 indicates that the hazard (or risk) of the event occurring increases by 21% for every unit increase in the predictor variable. To provide an estimate of the additional probability of dying, a baseline hazard rate λ_0=0.002078 (the probability of dying between ages 42 and 43 in Virginia according to the 2015 lifetable) was used to compute an adjusted hazard rate $\lambda=\lambda_0\times HR=0.002078\times 1.21=0.002154$. The computed survival function at t years is $S(t)=e^{-\lambda t}=e^{-.002154t}$.

[17] The Centers for Disease Control and Prevention's WISQAR method of estimating Quality of Life losses may slightly double count some earnings losses (Peterson et al. 2021).