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Intrastate Truck Driver Pay and Safety: A Longitudinal Analysis

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ABSTRACT

Truck drivers, their employers, and the public bear the costs of large truck crashes. Prior research finds that truck drivers tend to have fewer crashes when they are paid more, yet much of the U.S. industry operates with low pay and high turnover. We use carrier-level safety records and regional earnings information covering more than 40,000 carriers to show that the pay-safety relationship weakens during periods of labor market slack or heightened cost pressures. These findings suggest that upstream economic factors influence trucking safety and that recent economic regulation of trucking in other countries may inform U.S. policy.

Trucking is critical to the U.S. economy. Trucks transport over 60% of U.S. freight by weight and over 70% by value (U.S. Department of Transportation, Bureau of Transportation Statistics 2025). Approximately one in every 100 U.S. nonfarm workers is employed in truck transportation, with the majority of these being heavy and tractor-trailer truck drivers (U.S. Bureau of Labor Statistics 2025a, 2025d). Truck driving is also one of the most dangerous jobs in the U.S. Over the last decade, truck drivers have accounted for roughly 15%–20% of total U.S. occupational fatalities (U.S. Bureau of Labor Statistics 2023a). This is not just because there are a lot of truck drivers. Heavy and tractor-trailer truck driver fatality rates are also high per worker. For example, in 2023, heavy and tractor-trailer truck drivers experienced almost ten times as many occupational fatalities per full-time equivalent worker compared to the all-occupations average (U.S. Bureau of Labor Statistics 2024a).

According to the U.S. Bureau of Labor Statistics (BLS) Census of Fatal Occupational Injuries, most truck driver occupational fatalities are due to transportation incidents most of which are crashes (U.S. Bureau of Labor Statistics 2023a). Of course, other drivers, vehicles, and road users typically bear the brunt of the damage in collisions with heavy trucks. In fact, large truck occupants account for only about one-fifth of the annual fatalities resulting from heavy truck crashes (Federal Motor Carrier Safety Administration 2024).

Large truck crashes are expensive, and many of their costs are externalized. An estimate of the economic cost of medium- and heavy-duty truck crashes comes from Zaloshnja and Miller (2007). Adjusting their 2007 values to 2024 USD, the estimated average cost of a property-damage-only truck crash is $23,000; the average cost of a non-fatal injury truck crash is approximately $302,000; and the average cost of a fatal truck crash is approximately $5.7 million[1] (U.S. Bureau of Labor Statistics 2025c). Meanwhile, the minimum liability requirement for interstate carriers, a key benchmark for intrastate carrier liability requirements, has remained frozen at $750,000 per incident since 1985 (U.S. Code of Federal Regulations 2023). This minimum coverage figure accounts for only a small proportion of Zaloshnja and Miller's adjusted estimated average cost of a fatal crash.

In the presence of negative externalities, absent regulation, markets will not achieve allocative efficiency. Thus, externalities are often used as a justification for regulation. However, in the U.S., federal commercial motor vehicle (CMV) regulators primarily focus on policing downstream safety outcomes like driver and equipment violations. While these are undoubtedly important, their exclusive emphasis neglects the role economic incentives play in determining safety behavior. In the spirit of this, we turn our attention upstream, to analyze the relationship between truck driver income and intrastate motor carrier crash incidence. In examining this relationship, we place particular emphasis on the roles that labor markets and industrial organization play in shaping it.

1 | Literature Review

Deregulation of U.S. interstate trucking began in the late 1970s, culminating in the Motor Carrier Act of 1980, which prohibited economic regulation of interstate carriers (M. H. Belzer 2000). In 1994, following complaints that state regulation had limited the effectiveness of interstate trucking deregulation, the Federal Aviation Administration Authorization Act prohibited states from enacting or enforcing regulations related to the prices, routes, or services of any motor carrier. This act effectively mandated economic deregulation of intrastate trucking (England 2010). In both cases, deregulation ultimately led to the failure of existing carriers, promoted the influx of new carriers, increased price competition, reduced carriers' profit margins, and eroded driver pay. This disruption spurred the first inquiries into the relationship between remuneration and motor carrier safety performance. Originally, studies primarily focused on motor carrier financial wellbeing rather than driver pay, and recent studies have continued to refine this analysis (Beard 1992; Britto et al. 2010; Bruning 1989; Chow 1989; Chow et al. 1987; Corsi et al. 2002; General Accounting Office—U.S. Congress 1991; Miller and Saldanha 2016; Rodríguez et al. 2004).

In 1991, the Surface Transportation Subcommittee requested that the General Accounting Office (GAO) determine whether economic factors could predict safety outcomes (General Accounting Office—U.S. Congress 1991). This may be the first time in the U.S. that driver pay and working conditions were formally recognized in regulatory discourse. The GAO formulated a model that linked changes in economic conditions to declining motor carrier safety performance through factors such as lower average driver quality, wage pressure discouraging driver compliance with safety regulations, and reduced managerial emphasis on safety practices. However, the Department of Transportation ultimately rejected their findings and, consequently, U.S. research on pay and safety stalled (M. Belzer 2024).

In 1998, the Office of Motor Carriers of the Federal Highway Administration funded the first large-scale investigation into the relationship between truck driver compensation and safety, which developed multiple studies (see Belzer et al. 2002). The first study is a firm-level analysis of interstate truckload motor carriers. The authors use data from the National Transportation Institute's (NTI) 1999 National Survey of Driver Wages (NSDW), the Federal Motor Carrier Safety Administration's (FMCSA) Motor Carrier Management Information System (MCMIS), and a carrier-level telephone survey performed by the University of Michigan Trucking Industry Program (UMTIP). Using those data, they assessed the relationship between compensation, unpaid time, carrier size, vehicle miles traveled, and crash incidence. They found that compensation was negatively correlated with crashes and that unpaid work time was positively correlated with crashes. The second study examined a specific intervention at a single carrier, J.B. Hunt. Hunt raised the rates paid to drivers and phased in several other driver-centric policies aimed at reducing crashes and improving driver retention. The authors found that the new policies reduced turnover, increased recruiting and retention of more experienced drivers, and reduced the probability of drivers having crashes over time.

Several academic papers were published based on this work. In the first set, Rodríguez et al. (2003, 2004) reported the primary findings from the J.B. Hunt experiment examined in Belzer et al. (2002). They found that higher pay led to lower turnover and significant safety improvement. Faulkiner and Belzer (2019) extended this discussion by analyzing the change in the net present value of drivers vis a vis the J.B. Hunt experiment. They found that higher pay reduced recruitment costs, reduced retention costs, reduced crash costs, and, despite the added cost of increased compensation, increased average driver net present value by approximately $10,000. This suggests that higher pay is not a zero-sum game, but, rather, that drivers and managers can both benefit.

A fourth paper coming out of Belzer et al. used the 1997 UMTIP Survey of Truck Drivers (Belman et al. 2004) to construct a backward-bending labor supply curve for truck drivers (Belzer and Sedo 2018). This analysis suggests that low pay rates can induce truck drivers to work more hours and, conversely, that higher pay can cause drivers to work fewer hours, enhancing safety. After all, all else constant, longer hours cause workers to accumulate more fatigue; fatigue compromises neurological functions critical to the safe operation of a CMV; and this can lead to crashes (Blanco et al. 2011, 2016; National Transportation Safety Board Bureau of Safety Programs 1990; Panel on Research Methodologies and Statistical Approaches to Understanding Driver Fatigue Factors in Motor Carrier Safety and Driver Health 2016; Starnes 2006; Wylie et al. 1996).

Finally, Belzer et al. (2002) applied a probit analysis using UMTIP's Truck Driver Survey data. The authors estimated the likelihood that a driver reported having a crash during the past year as a function of compensation, among other factors. While pay rate and paid days off were significant predictors of crashes, their complete model findings were not. Monaco and Williams (2000), however, performed a similar analysis of UMTIP's Truck Driver Survey data and found that occupational characteristics were better predictors of safety performance than demographic characteristics. Specifically, hourly pay and higher pay were associated with better safety performance. In sum, Belzer et al. (2002), and its associated academic literature, suggest that higher pay is associated with improved retention, improved recruitment, safer hours of service, fewer crashes, and increased profit.

In 2010, the National Institute for Occupational Safety and Health's (NIOSH) conducted a long-haul truck driver survey (Chen et al. 2015). Two studies using these data are relevant to the current analysis. First, Kudo and Belzer (2019a) investigate the relationship between economic variables, demographic variables, operational variables, and the number of moving violations drivers received in the previous year. They found that driver income and employer-provided health insurance were inversely related to the number of moving violations. Second, Kudo and Belzer (2019b) test the relationship between economic variables, demographic variables, operational variables, and drivers' weekly work hours, finding that unpaid time was positively related to work hours. This adds to the literature suggesting that low compensation encourages truck drivers to work longer hours (Beilock 1995, 2003; Beilock and Capelle 1987; Belzer et al. 2002; Belzer and Sedo 2018; Chen et al. 2015, 2021; Monaco and Williams 2000), and that work pressure directly contributes to crashes (Belzer and Sedo 2018). This is a consequence of how truck drivers are paid. Most drivers are paid piece rates, most commonly a mileage rate. This creates a different incentive structure than that of hourly work, where there is some evidence that large minimum wage increases can be detrimental to workplace safety (Davies et al. 2024; Liu et al. 2024).

Another look at driver compensation came from the NTI's 2018 NSDW. The NSDW is a survey of pay packages for large truckload motor carrier employees. Ryley and Belzer (2023) use these data to investigate the relationship between specific aspects of driver compensation and carrier crash incidence. They found that better fringe benefits and paid time off were unambiguously associated with fewer crashes. However, they also found that the effect of higher mileage pay was nonlinear and, consequently, could be correlated with either higher or lower crash frequency—depending on each carrier's starting pay level. Crash elasticities for carriers offering below-average mileage rates were negative, while elasticities for carriers offering above-average mileage rates were positive. Unlike in Belzer et al. (2002), Ryley and Belzer (2023) were unable to observe work time and the prevalence of unpaid time. This likely confounded their results, as carriers often offer high mileage rates to offset exposure to unpaid time, and unpaid time itself has been linked to longer work hours (Kudo and Belzer 2019b) and increased crash risk (Belzer et al. 2002).

Scholars recently have turned their attention towards intrastate carriage. While intrastate trucking is understudied, it offers empirical advantages. Intrastate carriers' routes are restricted to their domicile states, making it easier to control for state-level differences in weather, terrain, enforcement priorities (Gimpel 2012; Weber and Murray 2014), and crash reporting (Blower and Matteson 2012a, 2012b, 2013). Intrastate carriers also tend to have a smaller hiring catchment area. This is useful because publicly available earnings data are aggregated at the regional level, and these regional estimates are less relevant to interstate carriers that may hire from across the country. Furthermore, publicly available compensation data is aggregated by occupation and, consequently, covers all industries that hire heavy and tractor-trailer truck drivers (SOC 52–3032). This matters because intrastate carriers operate across a broader set of industries than interstate carriers, and therefore, occupation-level compensation data better reflects their labor markets.

Ju and Belzer (2024) produced the first study to focus exclusively on U.S. intrastate driver pay and safety. They analyzed the relationship between median driver income, carrier compliance behavior, and crash incidence among small motor carriers, finding that more frequent violations and lower pay were associated with a higher number of crashes. Ryley and Belzer (2024) continued this work by examining the relationship between truck drivers' relative income and crash incidence for a much larger sample of intrastate motor carriers. They also used more granular MSA-level driver earnings information and found that carriers located in counties where driver earnings are relatively high tend to experience fewer crashes.

2 | International Context

Concerns regarding driver pay and safety are not peculiar to the U.S. Researchers have conducted substantial work examining pay and safety in the Australian case. Some studies also have been conducted in South Korea, India, and the European Union. Meyer et al. (2025) and Soro et al. (2020) provide a review of much of the existing literature for the US, Australia, and elsewhere.

Research on the relationship between safety and truck driver compensation emerged first in Australia (Hensher and Battellino 1990; Hensher et al. 1991, 1989). In 2000, the Motor Accidents Authority of New South Wales launched its own study of the causes of truck crashes. They concluded that the most important factor contributing to trucking crashes and crash fatalities stemmed from the growing economic pressure on truck drivers and trucking companies (Quinlan 2001; Quinlan and Wright 2008). Since then, Australian research has shown that economic incentives are among the strongest predictors of safety outcomes (Belzer and Peetz 2024; Friswell and Williamson 2019; Mooren et al. 2014; Peetz 2022; Soro et al. 2023, 2020; Underhill and Quinlan 2024; Williamson and Friswell 2013).

International organizations have also started to take notice of the relationship between pay and safety. In 2015 The International Transport Workers Federation and the International Labour Organization (ILO) convened a Tripartite Sectoral Meeting on Safety and Health in the Road Transport Sector. This meeting recommended that the ILO have a "...meeting of experts to elaborate and adopt a code of practice or guidelines on best practices in road transport safety (International Labour Organization 2020)." This ultimately led to the creation of the *Guidelines on the promotion of decent work and road safety in the transport sector* (International Labour Organization 2020). One of these guidelines (73) states that "the remuneration of wage earning and non-wage-earning... CMV drivers should be sustainable and take into consideration the goals of increasing the attractiveness and sustainability of the industry." Another guideline (81) recommends that "the calculation of rates for wage-earning CMV divers should also take into account remuneration for time spent on reasonably required subsidiary non-driving work activities (International Labour Organization 2020)." The first major effort to implement the emerging ILO agreement was the 2018 amendment to the South Korean Trucking Transport Business Act, which introduced a safe rates system for a narrow set of South Korean owner truck drivers (Liem and Baek 2024). The introduction of this system was associated with reductions in working time, drowsiness, and speeding (Baek et al. 2024).

In Europe, the development of the Common Market, which encourages the free movement of labor and capital between EU states, created governance challenges (Scharpf 1999) which have exacerbated the inequality between truck drivers from western and eastern EU countries (Belzer and Thörnquist 2020; De Smedt and De Wispelaere 2020; Vitols and Voss 2019). As market regulation replaced institutional regulation, concern grew about the labor market for truck drivers and road safety. While less academic literature has examined the EU case, a number of transport union reports have revealed cause for alarm (ETF 2013; VNB, ITF, and IUF 2020), and a 2021 study of truck drivers found that greater driver pay increases compliance with hours of service regulation (Škerlič and Erčulj 2021).

There has been little investigation of these issues in India. One study surveyed 453 truck drivers about their work responsibilities and how they were compensated (Mahajan et al. 2019). They found that some drivers would speed or avoid breaks due to financial incentives and that many would accept long hours and night work to increase their earnings. Both of these factors were associated with the propensity for drivers to fall asleep or nod off while driving.

Finally, Japan has seen some of the most recent policy developments. The 1991 Trucking Business Law, which deregulated trucking, resulted in low pay, long hours, and difficulty with driver recruitment and retention (Ministry of Health, Labour and Welfare 2023; Roren 2025). Since then, public concern with serious crashes has increased (Ministry of Land, Infrastructure, Transport, and Tourism 2024). Consequently, in 2024, truck drivers became subject to overtime caps ("Work Style Reform Bill Enacted (2018): Discussions Underway at the Council on the Contents of Specific Procedures"), and in 2025, the National Diet passed a "reasonable cost system". Under this system, the government will announce freight rates intended to preserve business viability and moderate intense price-only competition. Both cargo owners and truckers must adhere to the new regulations, setting specific freight rates that take wages out of competition. These reforms effectively reversed the deregulation of 1991.

3 | Data

This research integrates FMCSA's MCMIS and BLS's Occupational Employment and Wage Statistics (OEWS). These datasets are all publicly available, and brief descriptions of each are provided in this section.

3.1 | Motor Carrier Management Information System

MCMIS houses FMCSA's safety performance database for passenger, non-passenger, and hazardous materials carriers. Much of these data are publicly available on the FMCSA's website (Federal Motor Carrier Safety Administration 2025a, 2025b). All new interstate carriers and intrastate hazardous materials carriers must submit Form MCS-150 to obtain a DOT number and register with FMCSA. Regulations require them to update their record using Form MCS-150 every 24 months or within 30 days of any substantial changes (Federal Motor Carrier Safety Administration 2025c). For states to qualify for funding under FMCSA's Motor Carrier Safety Assistance Program, they must also require non-hazardous material intrastate carriers to register with MCMIS. All 50 U.S. states participate (Federal Motor Carrier Safety Administration 2025d), so most heavy-duty intrastate carriers are captured by the MCMIS database.

MCMIS contains three primary data sets, which we call the "census files", "crash files", and "inspection files". The census files contain, among other things, carrier names, operating addresses, vehicle miles traveled, power unit counts, and driver counts. Since carriers do not report mileage annually, we use a three-year rolling average. Other information, such as carrier location, cargo type, and hazardous material status, rarely changes year-to-year.

The crash and inspection files are gathered by different mechanisms than the carrier census. The crash files serve as a repository for crash reports, which are collected by state enforcement personnel and released by FMCSA monthly. A crash is reportable if a vehicle is towed away, somebody is injured and treated away from the scene, or somebody is killed, regardless of fault. Similarly, the inspection files serve as a repository for roadside inspection reports, also gathered by enforcement personnel. We use these for annual violation counts under FMCSA's Behavior Analysis and Safety Improvement Categories (BASICs) (Federal Motor Carrier Safety Administration 2025e). There are seven categories, with some pertaining to the driver and others pertaining to vehicle maintenance.

While MCMIS includes all intrastate carriers, given the administrative nature of the data, some records belong to inactive entities. To ensure that we are examining active and applicable records, we make a number of sample exclusions illustrated in Figure 1.

Starting with all US-based intrastate carriers, we exclude carriers who report zero employment or mileage to ensure that we have carriers actively engaged in trucking activity. We also exclude carriers that have not updated their MCS-150 within the past five years, which ensures more reliable data and serves as another filter to remove likely inactive entities. We also restrict the sample to carriers that report more than one driver and more than one truck. Small carriers are likely to be owner-operators. While owner-operators are an important part of the industry, with more than half of all intrastate carriers meeting this description, their incentive structure and operating conditions differ from those of employee drivers (Miller, Golicic, et al. 2018). Furthermore, since they are not employees, their earnings are not covered by the OEWS data used in this analysis. After exclusions, the full sample includes 1,300,426 observations covering 289,370 unique carriers between the years of 2006 and 2024.

We make one final exclusion for the regression analysis. Since we use a two-way fixed effects (TWFE) model, which exclusively estimates within-unit effects, the model requires within-unit variation in the crashes. Consequently, carriers that appear in only one year and carriers that do not experience any crashes are automatically excluded. After all exclusions, 42,376 intrastate carriers remain in the regression sample. The large number of

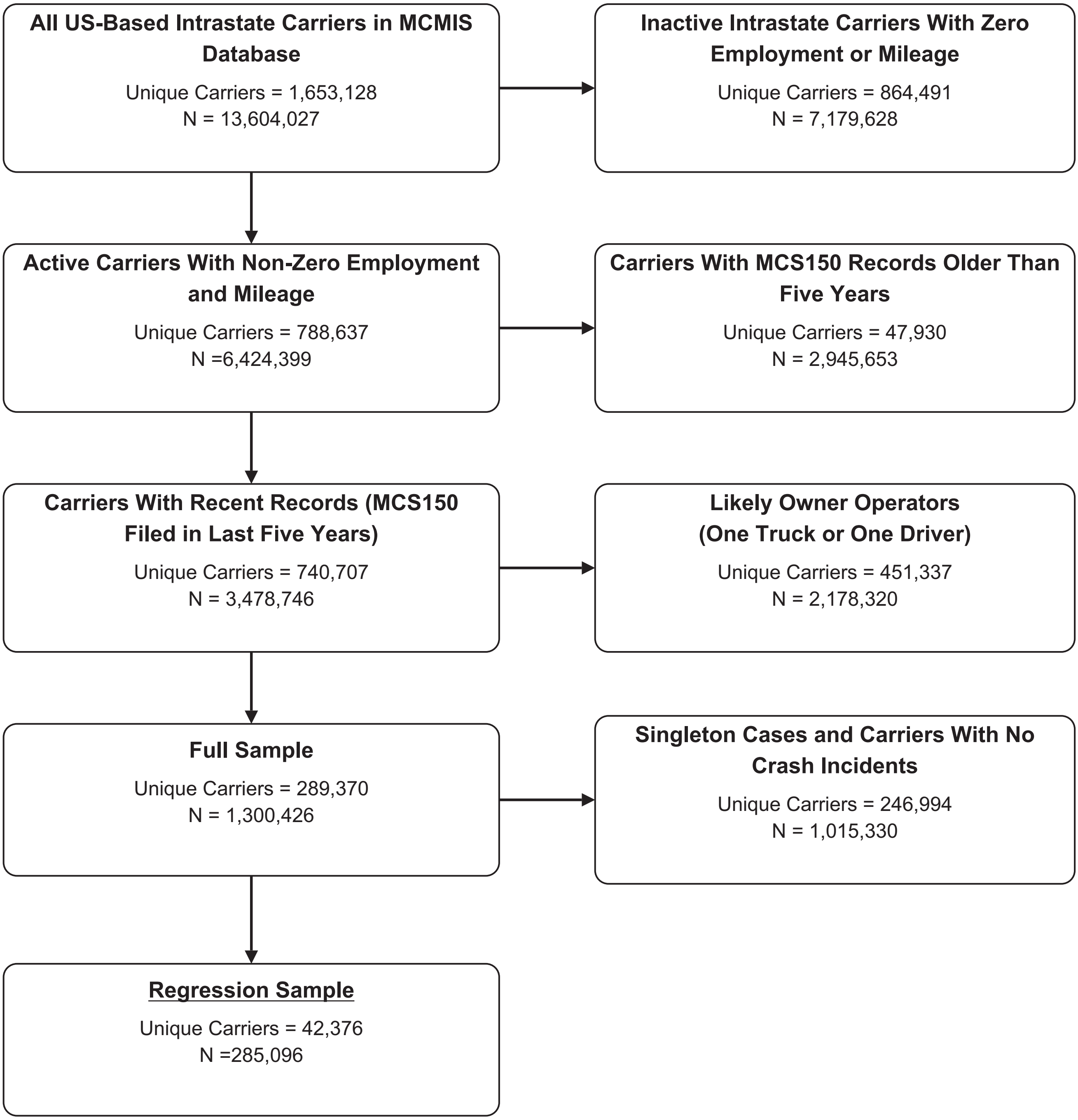

FIGURE 1 | Sample exclusions.

exclusions here is due to the substantial number of small operations, which, in having fewer trucks and drivers on the road, are less likely to experience a crash and more likely to exit the industry after a serious crash. In effect, our sample tends towards the more stable core of the industry, composed of relatively larger, longer-lived firms.

3.2 | Occupational Employment and Wage Statistics

MCMIS does not contain any compensation data, so we supplement it with the BLS's OEWS. The OEWS contains annual employment and wage estimates for roughly 800 occupations (U.S. Bureau of Labor Statistics 2024b). These data are based on semi-annual establishment surveys, the responses from which are used to impute wage and staffing information for unobserved and unresponsive establishments. The BLS publishes occupational wage estimates at the national, state, and core-based statistical area (CBSA) levels. We use the CBSA estimates, which include metropolitan and non-metropolitan statistical areas (U.S. Bureau of Labor Statistics 2023b; U.S. Census Bureau 2023). Using the carrier address information from MCMIS, we match each carrier to the appropriate CBSA-level estimate for the median annual earnings of *Heavy and Tractor-Trailer Truck Drivers* (SOC 53-3032) in the year corresponding to the MCMIS record. CBSA definitions change year-to-year, but in 2024, there were 521 CBSAs, 511 of which contained at least one intrastate trucking company. Of these CBSAs, 379 were metropolitan and 131 were non-metropolitan.

The OEWS earnings data are imperfect; they only capture drivers of heavy trucks hired in specific locations; they represent area averages rather than carrier-level labor earnings; they are self-reported by carriers; and often rely on imputation. However, more granular driver earnings data are not widely available, which has been a longstanding challenge for this kind of research (Committee for a Study of the Impacts of Alternative Compensation Methods on Truck Driver Retention and Safety Performance 2024). Despite these limitations, prior studies have used OEWS data to examine the relationship between pay and safety for intrastate carriers (Ju and Belzer 2024; Ryley and Belzer 2024).

While the regional scope of the data imposes some constraints, it also offers advantages. Since trucking companies are numerous and generally small, individual carriers have little ability to influence the median regional pay for truck drivers. It is then plausible that the CBSA-level wage data are exogenous with respect to firm-level wage setting. The median share of CBSA intrastate driver employment among carriers in our regression sample is only 0.22%, and only 4.12% at the 90th percentile. Additionally, since pay for interstate drivers tends to be set at the national level, variation in driver earnings at the CBSA level should be more strongly shaped by local labor market conditions for intrastate drivers. Finally, our earnings data is occupational, which aggregates across industries that hire heavy duty and tractor trailer truck drivers, not just truck transportation. Intrastate carriers tend to participate in a more diverse set of industries than interstate carriers, which, mechanically, lends itself well to occupational, as opposed to industry-level aggregation.

3.3 | Other Data

In addition to MCMIS and OEWS, we use state-level unemployment rates from the local area employment statistics to account for broader labor market conditions (U.S. Bureau of Labor Statistics 2025e). All nominal dollar values were adjusted to 2024 dollars using the Consumer Price Index for Urban Wage Earners and Clerical Workers (U.S. Bureau of Labor Statistics 2025b).

4 | Methods

Existing research examining the relationship between pay and safety consists primarily of cross-sectional analyses. These analyses include additional covariates to attempt to control for factors that may confound the relationship between driver pay and safety (Belzer et al. 2002; Ju and Belzer 2024; Kudo and Belzer 2019a; Ryley and Belzer 2023, 2024). The results of a simple regression can identify a causal effect when all confounding factors are controlled for, but researchers rarely have data capturing all relevant variables. Here, we use longitudinal analysis to better account for unobserved confounding factors. Specifically, we estimate a TWFE model predicting crash counts as a function of median annual driver earnings, carrier exposure, past safety performance, and the local unemployment rate. The model is specified:

$$
\begin{aligned}
&E\left(\text{Crashes}_{\mathrm{i}} \mid \boldsymbol{X_{it}}\right) = \exp\big(\beta_1 \ln\left(\text{Median Earnings}_{\mathrm{it}}\right)\\
&+\beta_2 \text{Unemployment}_{it} \times \ln\left(\text{Median Earnings}_{\mathrm{it}}\right)\\
&+\boldsymbol{\beta_{3t}} \times \ln\left(\text{Median Earnings}_{it}\right) + \beta_4 \ln\left(\text{Miles}_{it}\right)\\
&+\beta_5 \ln\left(\text{Drivers}_{it}\right) + \beta_6 \ln\left(\text{Power Units}_{it}\right)\\
&+\beta_7\left(\text{Driver Violations}_{it}\right) + \beta_8\left(\text{Vehicle Violations}_{it}\right)\\
&+\beta_9 \text{Unemployment}_{it} + \boldsymbol{\beta_{10} MCS150\ Gap_{it}} + \boldsymbol{\gamma_i} + \boldsymbol{\delta_t}\big)
\end{aligned}
$$

where the outcome variable is the expected value of the number of crashes for each carrier i, conditional on covariates $\boldsymbol{X_{it}}$. This count is estimated as a function of the log of median driver earnings measured at the CBSA-level (Median Earnings), which we interact with the state-level unemployment rate (Unemployment) and the year fixed effects to allow the income-safety relationship to vary over time and business cycles. To account for each carrier's exposure to crash risk, we include, in log form, each carrier's total mileage in thousands of miles (Miles); the number of drivers employed by each carrier (Drivers); and total power units. To account for safety management practices and safety culture, we include variables capturing driver violations per driver (Driver Violations) and vehicle violations per power unit (Vehicle Violations). We include the un-interacted state unemployment rate (Unemployment) to account for cyclical effects unrelated to driver remuneration. The model also includes carrier fixed effects $(\boldsymbol{\gamma_i})$ controlling for carrier-level time-invariant confounding factors, and year fixed effects $(\boldsymbol{\delta_t})$ that control for time-varying factors affecting all carriers similarly. Finally, a categorical variable captures the number of years since the carrier has updated its MCS-150 form (MCS150 Gap). Refer to Supporting Information for a comparison of this model with alternative specifications and a figure depicting the distribution of crash frequencies.

Because crash counts are heavily skewed, we use fixed effects Poisson estimation with robust standard errors adjusted for clustering on carriers (see Figure S1). Others have demonstrated that the fixed effects Poisson estimator is a consistent estimator even with unbalanced panels and multiplicative measurement error (Hoang and Wooldridge 2024). The estimator is robust, provided only that the conditional mean is specified correctly, even in the presence of overdispersion. In contrast, alternative models, such as the fixed effects negative binomial estimator, require additional and often unreasonable assumptions (Wooldridge 1999).

Conditional exogeneity would hold provided that, after conditioning on carrier fixed effects, year fixed effects, and observed controls, driver earnings are uncorrelated with unobserved, time-varying shocks in crash frequency. Given that each carrier is small in terms of employment relative to total CBSA employment, it is unlikely that unobserved shocks at particular carriers are driving changes in CBSA-level driver earnings. A similar argument implies that direct reverse causality is unlikely. Even if driver earnings responded to crash frequency, an individual carrier's crash record would be unlikely to meaningfully affect CBSA-level driver earnings. Unobserved region- or carrier-specific trends may still

TABLE 1 | Intrastate carrier descriptive statistics.

	Full sample			Model sample		
	Median	**Mean**	**SD**	**Median**	**Mean**	**SD**
Number of power units	3	7.84	186.526	6	14.63	52.725
Number of drivers	3	8.05	181.581	5	15.30	151.321
Miles (1000 s)	33	318.13	19,017.37	97	568.62	17,542.55
Number of crashes	0	0.08	0.440	0	0.33	0.864
CBSA driver earnings (Median)	$54,247	$54,496	$6246	$53,595	$53,987	$6116
State-level unemployment rate	4.6%	5.3%	2.161	4.6%	5.2%	2.024
Driver BASICS violations per driver	0	0.05	0.224	0	0.08	0.288
Vehicle BASICS violations per power unit	0	0.27	1.127	0	0.44	1.475
Years since MCS-150 update	2	2.21	1.460	2	1.97	1.322
Groups		289,370			42,376	
Observations		1,300,426			285,096	

Note: Estimates exclude carriers with a single truck or only a single driver, likely owner operators.

confound the analysis, but we include an array of carrier-level controls capturing many important operational characteristics. What remains at issue are potential regional spillover effects and the correct specification of effect heterogeneity. We address the latter by specifying a model that can absorb heterogeneity through interactions with unemployment and year fixed effects. So, while we adopt a cautious interpretation, our model addresses many threats to causal inference and would take on a causal interpretation under some not unreasonable assumptions.

While we do include time-varying control variables, these models are more sparse than the cross-sectional models common in this literature. Many common covariates, such as the form of organization, state, and cargo type, vary little over time within the same carrier and are thus captured by the fixed effects. We include some time-varying controls because, all else equal, more drivers, power units, and miles create more opportunities for crashes to occur. We use state-level unemployment rates to capture the potential impact of local business cycles, in addition to national business cycles, which we account for through year fixed effects. Carrier's violation records, in conjunction with carrier fixed effects, help control for carrier-specific qualities that influence safety. Finally, we include the number of years since carriers filed the MCS-150 to control for noncompliance and the unreliability of data that has not been recently updated.

5 | Descriptive Statistics

Table 1 contains descriptive statistics for the variables of interest. These summary statistics use the full sample of intrastate carriers, including those not used in model estimation because they were only observed for one period or had no crash incidents. This sample comprises nearly 290,000 carriers and more than a million individual observations. The model sample is smaller, but still substantial, including more than 40,000 carriers.

Intrastate carriers tend to be small; excluding likely owner-operators, the median carrier has three trucks and three drivers.[2] Research suggests that small carriers, on average, may operate less safely than larger carriers, controlling for other factors (Miller 2020; Miller, Golicic, et al. 2018; Miller, Schwieterman, et al. 2018). These statistics also underscore the rarity of crashes, with the median carrier reporting no crashes. The median carrier is located in a CBSA where heavy truck drivers earn $54,247 per year in 2024 USD, which is close to the median U.S. individual income. It is essential to note that this figure applies to heavy truck drivers in general, not specifically to intrastate drivers, who may have lower annual incomes in part due to shorter working hours compared to their long-distance counterparts. While the model sample tends towards larger carriers with more miles per driver, driver pay, and median crashes are similar to those in the full sample.

Because a carrier must have experienced a crash to be included in the model, small carriers are especially likely to be dropped from the analysis. Using the full sample, Figure 2 depicts some crash statistics for intrastate carriers broken down by carrier size. It shows that small carriers tend to have fewer crashes per mile, but because they are numerous, they account for a substantial proportion of crash incidents. Still, since so many have no crashes at all, the average number of crashes among small carriers is minuscule.

The largest intrastate carriers appear to have higher crash rates per mile. Two factors are likely to contribute to this pattern. First, large carriers have more capital and brand equity, making them less likely to exit the industry after a serious crash. Second, intrastate trucking operations, relative to interstate trucking operations, tend to be more varied in their specialization. Presumably, larger carriers would tend to

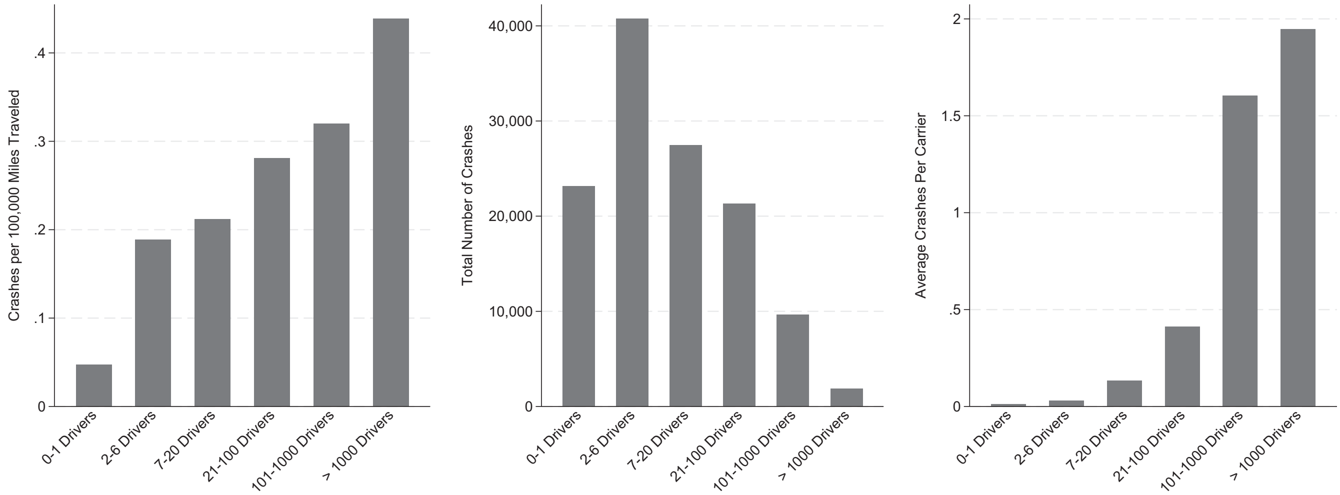

FIGURE 2 | Crash statistics by carrier size (2006–2024). [Color figure can be viewed at wileyonlinelibrary.com]

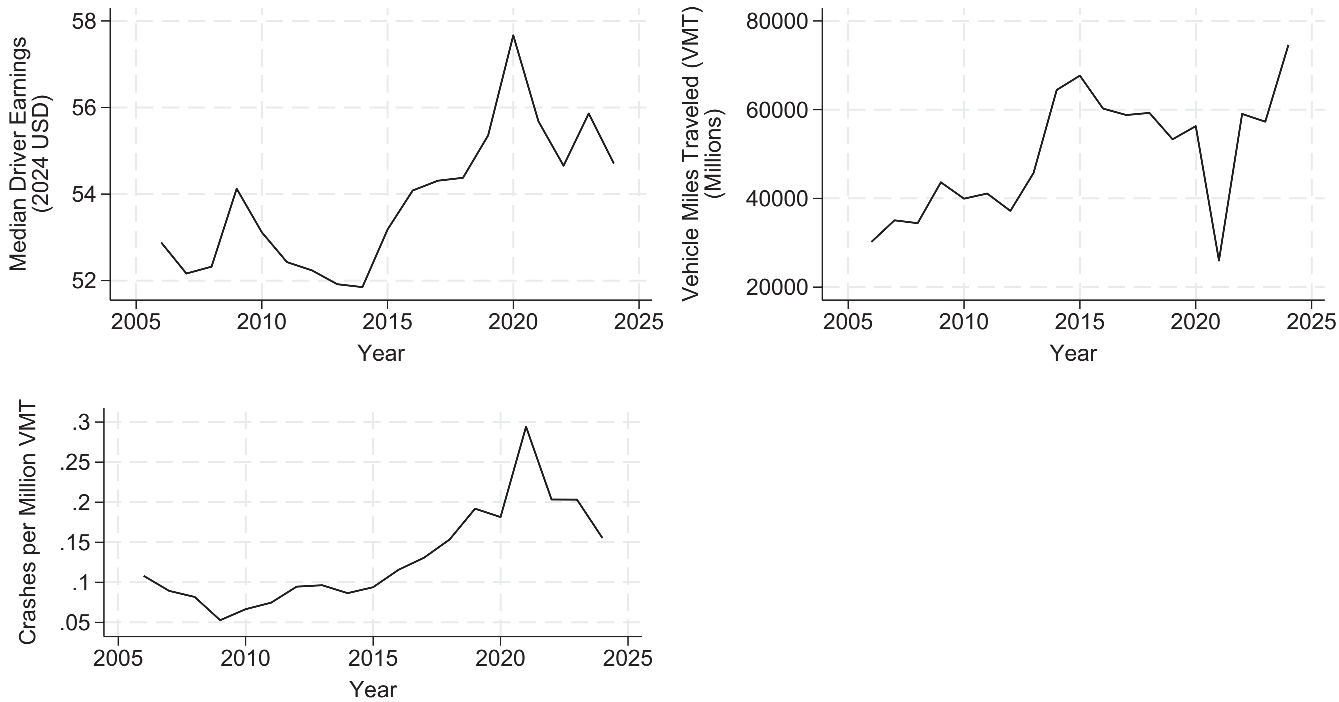

FIGURE 3 | Driver earnings and intrastate crash rates (2006–2024). Within-year averages of median driver earnings weighted by the number of intrastate drivers at each carrier, excluding likely owner operators. Crashes and VMT values are for all active intrastate carriers.

operate more combination trucks in a fashion resembling typical truckload carriage. Smaller carriers may be more likely to use straight trucks or carry loads to support other industries. This would expose combination-truck operators to additional crash risk and greater scrutiny from enforcement personnel. We control for these operational differences in our model using carrier fixed effects.

Longitudinal examination of the data reveals that intrastate trucking has become somewhat better remunerated but also more prone to crashes. Figure 3 shows that median driver earnings were approximately $53,000 per year in 2006 (in 2024 USD). While there was a short spike to $58,000 in 2020, by 2024, median earnings were still less than $55,000 per year. The average annual growth rate in real median driver earnings between 2006 and 2024 was only about 0.2%. Unfortunately, the crash rate per million vehicle miles has grown more rapidly. Total vehicle miles traveled have also grown, despite a short-term decline in 2021 related to the COVID-19 pandemic.

6 | Model Results

Table 2 contains the results from the Poisson two-way fixed effects model, which estimates within-carrier deviations in crash incidence associated with deviations in local earnings trends that cannot be explained by contemporary national averages. Because of the interaction terms, the coefficients are difficult to interpret directly (see Table S1 for alternative specifications without year and unemployment interactions). Setting aside interaction effects

TABLE 2 | Two-way fixed effects model of crash incidents.

Variable	Coefficient	Robust S.E.	Variable	Coefficient	Robust S.E.
Log median annual earnings 1000s (2024 USD)	−2.280***	0.316			
Earnings-unemployment rate interaction	0.363***	0.051	State-level unemployment rate	−1.484***	0.202
Earnings-year interaction (Reference: 2006)			Year (Reference: 2006)		
2007	0.153	0.255	2007	−0.669	1.015
2008	0.296	0.288	2008	−1.265	1.142
2009	−1.466***	0.376	2009	5.640***	1.501
2010	−1.670***	0.401	2010	6.508***	1.596
2011	−1.226**	0.374	2011	4.753**	1.488
2012	−0.877**	0.335	2012	3.363*	1.328
2013	−0.677*	0.312	2013	2.604*	1.237
2014	−0.00131	0.285	2014	0.0129	1.130
2015	0.200	0.275	2015	−0.781	1.090
2016	0.465	0.269	2016	−1.817	1.068
2017	0.750**	0.268	2017	−3.002**	1.067
2018	0.869**	0.264	2018	−3.464***	1.049
2019	0.832**	0.264	2019	−3.413**	1.048
2020	−0.981**	0.324	2020	3.845**	1.290
2021	0.346	0.288	2021	−1.501	1.145
2022	0.700*	0.277	2022	−3.049**	1.098
2023	0.0295	0.271	2023	−0.456	1.079
2024	0.182	0.274	2024	−1.095	1.092
Driver violations per driver	0.146***	0.017	Log of intrastate drivers	0.308***	0.021
Vehicle maintenance violations per power unit	0.026***	0.003	Log of power units	0.330***	0.023
			Log of miles	0.013	0.007
MCS-150 update year (Reference: Same year)			Regression information		
One year prior	0.0179	0.016	Observations	285,096	
Two years prior	−0.0132	0.017	Groups	42,376	
Three years prior	−0.115***	0.020	Wald chi squared	2674.45	
Four years prior	−0.205***	0.022	Prob > chi squared	0.000	
Five years prior	−0.290***	0.025	Deviance pseudo R^2	0.327	

*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

for the moment, the regression results suggest that, on average, carriers with positive deviations in median earnings have fewer expected crashes, controlling for other factors.

Things get more complex when incorporating the interaction terms. The positive coefficient on the unemployment rate interaction with median earnings indicates that this relationship weakens with increases in the unemployment rate. Similarly, the interaction of median earnings with the year fixed effects shows substantial differences in the relationship over time. The model results are robust to outlier removal and alternative standard errors, as shown in Table S2. We will examine this relationship conditional on year and unemployment rate, but first we will interpret the other coefficients.

Table 2 reports the raw coefficients, but interpretation is more intuitive in terms of incident rate ratios (IRRs). The IRR is the exponentiated coefficient (the constant *e* raised to the power of the coefficients reported in Table 2). All reported results in this section are in the form of IRRs. Each IRR should be interpreted as the proportional change in a carrier's expected number of crashes associated with a change in the corresponding covariate, measured as a deviation from that carrier's average over time, net of national trends and controlling for other factors.

Driver violations per driver and vehicle violations per power unit were associated with increased crash incidents. A one-unit increase in a carrier's driver-violation rate relative to its average is associated with a 15.7% increase in its expected number of crashes; a similar increase in vehicle violations per power unit is associated with a 2.6% increase. The magnitude of the vehicle maintenance relationship is smaller, likely due to the wide range of vehicle maintenance violations. Some, like violations related to braking equipment, clearly contribute to crash risks, while others are presumably less important, such as failure to display required markings.

As expected, positive deviations in the number of drivers or power units tended to be associated with an increase in the expected number of crashes. A 1% growth in a carrier's driver count is associated with 0.36% more crash incidents, and a 1% growth in power unit count is associated with a 0.39% increase in its expected number of crashes. Assuming that trucks and drivers are used in a fixed proportion to one another, a carrier that increases both trucks and drivers by 1% would, on average, see 0.75% more crashes. This less-than-proportional increase suggests some economies of scale in safety, all else held constant. Mileage, too, shows a less-than-proportional relationship to crash frequency.

The IRR on the state-level unemployment rate is negative and significant, but its magnitude shrinks when accounting for the interaction with driver pay. At the average of the log median driver pay (3.9), a one-point positive deviation in the state-level unemployment rate corresponds to a 7% decrease in the expected number of crash incidents. The relationship remains negative and significant until roughly the 70th percentile of driver earnings. Finally, carriers reported fewer crashes in years when their MCS-150 records were older compared to years in which the form had been updated more recently. This variable controls for residual inactivity in the MCMIS database.

Turning back to driver earnings, Figure 4 illustrates how the relationship between driver earnings and crashes evolves over time and at varying levels of the unemployment rate. The first three panels of the figure display the point estimate and confidence intervals for each year, accounting for both year and unemployment rate interactions. The first panel shows the estimates based on the 25th percentile unemployment rate calculated within each year. The second and third panels do the same for the 50th and 75th percentiles. The final panel shows the unemployment rates used to generate the graphs in the three other panels.

At the 25th percentile of unemployment, increases in driver earnings have a significant and negative association with crash incidents in almost all years. At best, in 2023, a carrier in a

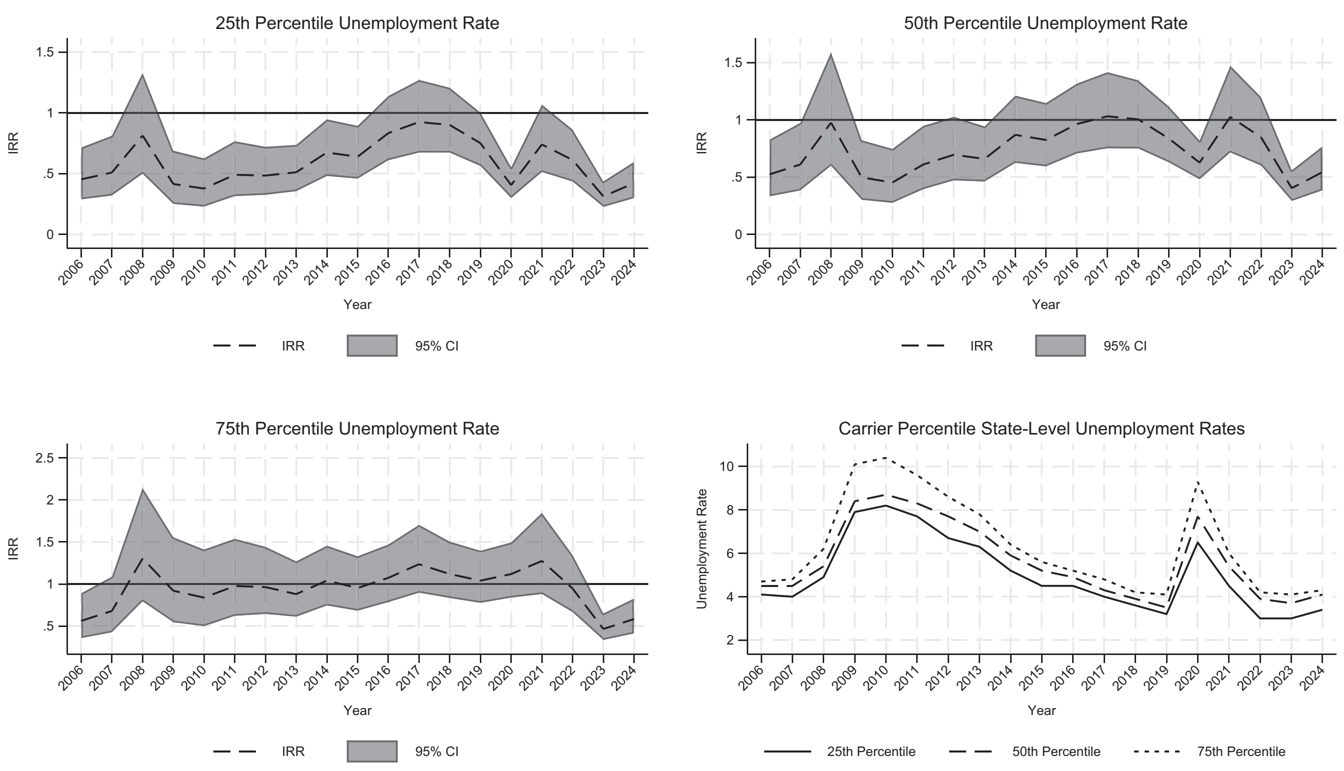

FIGURE 4 | Median earnings relationship to crashes over time and unemployment rates.

CBSA that experiences a 10% increase in driver earnings, relative to their long-term average, would be expected to have 6.9% fewer crashes. Moving from the 25th percentile to the median, fewer years show a significant relationship, and the magnitude of the IRRs is more modest. Finally, at the 75th percentile, the association is much attenuated and only significantly different from one in 2006, 2023, and 2024.

Averaging the IRR time series shown in Figure 4 for each unemployment percentile, at the 25th percentile of unemployment, a 10% increase in driver earnings relative to a carrier's long-term average corresponds to a 4.1% reduction in the expected number of crashes; at the median unemployment rate, the average reduction falls to 2.6%; and at the 75th percentile it declines further to 0.5%. Figure 4 shows that these averages conceal substantial year-to-year variation in both magnitude and statistical significance, especially at higher unemployment rates. Thus, these relationships are best interpreted with respect to specific years and labor market conditions.

The earnings-year interaction coefficients should not be interpreted on their own. While they reflect year-specific variation in the earnings-crash relationship, their sign and magnitude are indirectly shaped by unemployment. The model includes only a single time-invariant earnings-unemployment interaction term, which could cause any residual year-specific effect heterogeneity to be absorbed by the earnings-year terms. All else constant, this structure would be expected to produce more negative coefficients in years when the earnings-crash relationship is relatively weaker than what a constant unemployment interaction would impose. So, for example, in high-unemployment years like 2009–2012, the earnings-year interaction terms are apt to be more negative than they would be on their own, and in low-unemployment years, they would tend to be more positive.

7 | Discussion

A key consideration in interpreting this paper's results is understanding how truck drivers are paid. While not universal, the vast majority of truck drivers are paid piece rates, and they typically are not compensated for non-driving time or tasks (Belman et al. 2004; Kudo and Belzer 2019b). Consequently, truck drivers primarily achieve higher earnings through higher rates, longer hours, and/or more aggressive driving. In this study, we cannot observe rates, driving behavior, or work hours. Instead, we see only their product—total earnings. This is important because increased earnings achieved through higher rates are likely to be safety-enhancing. In contrast, earnings achieved through longer hours or more aggressive driving are likely to be hazardous. Business-cycle conditions reshape how firms allocate work and manage capacity, which changes the margins through which drivers can earn additional income.

In truckload operations, driver labor is a major operating expense, but because drivers are paid piece rates, falling volume can be absorbed via fewer dispatches rather than layoffs. Large swings in demand also tend to hit the spot market first, so owner-operators usually absorb the brunt of the shock. Even so, hiring freezes and the exit of financially weaker carriers will still negatively impact employment. In a deep downturn, that usually means slightly lower turnover, some redistribution of loads towards more experienced drivers, softer load availability, and more intense price competition among carriers. Presumably, this ought to shift earning opportunities away from higher-rate or higher-mileage loads towards tighter schedules and increased time pressure.

The interaction between driver earnings and state-level unemployment rates shows that the relationship between income and safety is attenuated by higher unemployment (see Table S3 for comparisons of total relationship with and without interactions). Presumably, this is because trucking is a derived demand industry and truck drivers appear to have backward-bending labor supply curves (Belzer and Sedo 2018). On the carrier-side, lower freight demand could give shippers more leeway to pressure carriers on rates. Similarly, the higher cost of job loss could give carriers more leeway to pressure drivers via lower rates, longer hours, or increased unpaid downtime. Even with electronic logging devices, carriers and drivers can still exploit loopholes to circumvent hours-of-service regulations (Belzer and Thörnquist 2020), and a cottage industry has emerged to assist drivers and carriers through "ELD editing services" (Lockie 2025). On the driver-side, other members of truck drivers' households may suffer negative income shocks during recessions, leading drivers to increase their earnings targets. Common to both the carrier-and driver-side mechanisms, drivers are incentivized to work longer hours or drive faster to maintain the same earnings.

Our estimates distinguish two conceptually distinct sources of moderation in the earnings–safety relationship. First, the state-level unemployment interaction captures local labor-market conditions. This affects how drivers earn income across different rates, hours, and driving intensities. Second, the earnings-year interaction captures the effect of industry wide cost pressures and allows heterogeneity in the business cycle to have a differentiated impact on safety outcomes. Figure 5 plots the year-specific earnings coefficients alongside two trucking producer price indices. Because trucking is highly competitive, increases in selling price can be interpreted as increases in costs. Note, the interaction with unemployment is included in the model, but omitted from the plotted series in Figure 5. So, the "coefficient values" in this figure should be interpreted as net of the effect of local unemployment–as opposed to being the full marginal effect of earnings on safety.

According to Figure 5, in years when cost pressures are low (i.e., when the PPI is low), the association between earnings and safety is more negative and, conversely, in years when cost pressures are high (i.e., when the PPI is high), the association is less negative.[3] We believe this pattern is consistent with an environment in which common cost shocks compress carrier margins and limit the extent to which higher prices translate into better pay. However, it is also worth noting that, because Figure 5 excludes the earnings-unemployment interaction effect, at least some of this year-to-year co-movement should also reflect the allocation of variation between interaction terms. Presumably, both effects are present. But it is

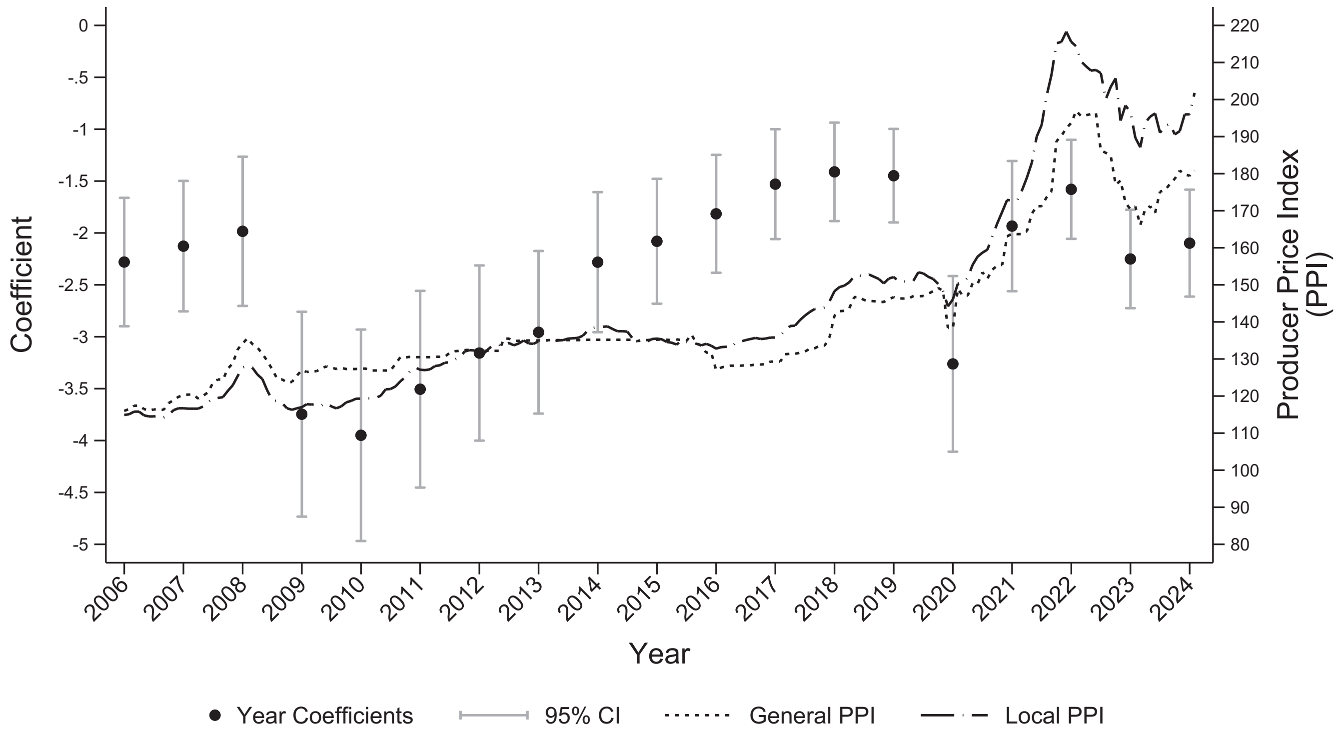

FIGURE 5 | Cyclicality of year fixed effect interaction relative to producer price indices. The plotted coefficients exclude the unemployment rate interaction.

not possible to parse them out, and thus Figure 5 should be interpreted with care.

Still, results suggest that part of the link between firm financial health and safety may stem from the weakening of the pay-safety relationship under greater cost pressures. These findings are consistent with the General Accounting Office—U.S. Congress (1991) economic model of motor carrier safety performance and the broader literature examining the relationship between motor carrier financial health and safety performance (Miller and Saldanha 2016). Similar patterns have also been observed in mining, where increased cash flow was associated with improvements in safety outcomes (Charles et al. 2022).

In summary, the interactions suggest two forces that influence the decision-making of carriers and their drivers. Specifically, the unemployment rate interaction points towards labor supply and freight demand. It shows that the pay-safety relationship is tamped down when there is a glut of potential truck drivers. Meanwhile, the year fixed effects point towards labor demand and show a similar decline in the pay-safety relationship when cost pressures are high. In sum, these results support previous research showing that increased driver earnings are associated with improved safety performance. However, this effect is modulated by conditions in the labor market and the market for trucking services.

8 | Research Contribution

This paper builds on existing cross-sectional evidence on the relationship between pay and safety by providing a longitudinal analysis that more fully controls for confounding factors. Cross-sectional estimates from Ju and Belzer (2024), based on data from 2017 to 2018, show that a 1% increase in driver earnings is associated with a 1.04% reduction in crashes among a sample of smaller intrastate carriers. Using a broader sample and a richer set of controls, Ryley and Belzer (2024) find that a 1% increase in truck driver earnings relative to county median household income is associated with approximately 0.2% fewer crashes among carriers in the county. Both studies identify between-carrier relationships, relying on comparisons across different carriers at a point in time. In contrast, the estimates in this paper are identified solely from within-carrier variation over time. While these approaches yield conceptually distinct estimates, our results demonstrate that the pay and safety relationship documented across carriers also holds within the same carrier over time, at least under certain business cycle conditions. Averaging across years, at the median unemployment rate, carriers that experience a 10% increase in driver earnings relative to their long-term average are expected to experience 2.6% fewer crashes, controlling for other factors.

Previous studies have not explicitly accounted for the confounding effect of business cycles on the earnings and safety relationship. By introducing the unemployment interaction, and this interaction being positive, we have found suggestive evidence that driver compensation may be a double-edged sword. We believe this is due to the preponderance of piece rate compensation in the industry, which could create an environment where higher earnings may not reflect better pay but instead represent longer hours or more aggressive driving. However, only in rare cases, at the deepest troughs of the business cycle, are increased earnings significantly associated with more crashes.

More general studies have shown occupational injuries to be cyclical across various countries and economic sectors (Asfaw et al. 2011; Chang et al. 2018; Davies et al. 2009; Kim and Park 2020), but to our knowledge, there has been comparatively little analysis of the safety impacts of broader economic and labor market conditions in trucking. This is important for two reasons. First, truck safety *is* public safety and, second, presumably, truck safety outcomes are particularly sensitive to fluctuations in the business cycle. This is because truck drivers are paid predominantly on a piece rate basis. A carrier paying piece rates may not lay off drivers when business is slow because idle drivers are not paid. However, drivers' incomes are more exposed to business cycles, as fewer trips also mean lower earnings.

Future studies will have to grapple with the limitations of the available driver earnings data. For example, public driver earnings information currently is not available at the carrier-level. This creates aggregate measure issues and precludes examination of the interstate segment of the industry, because local area earnings data are less applicable to carriers whose hiring is less geographically constrained. Measurement of drivers' working hours also will remain an issue. While some smaller surveys have gathered information on drivers' work hours, broad, representative information on hours that can be linked to carrier safety records remains elusive. Finally, reliance on the MCMIS database also comes with its own measurement issues (Panel on the Review of the Compliance Safety and Accountability (CSA) Program of the Federal Motor Carrier Safety Administration 2017).

9 | Conclusion

To the extent that safety is behavioral, a prima facie case can be made that economic incentives should influence safety outcomes. While definitive causal evidence of this relationship remains elusive, this study is the first to provide longitudinal evidence of the pay and safety relationship controlling for firm characteristics and a wide range of potential confounding factors. Furthermore, the longitudinal nature of the data also enables us to show how this relationship is moderated by business cycle fluctuations.

If increased driver pay does in fact improve safety, as our findings suggest, this does not necessarily mean that the visible hand of policy would elicit a more efficient allocation of resources than the invisible hand of the market. However, trucking services are produced on public roads; the costs of fatal crashes are high; and liability requirements are low. Thus, there is reason to believe that at least some portion of the cost of crashes is externalized. In which case, economic theory indicates that markets will have a hard time achieving allocative efficiency on their own.

Of course, in the U.S., trucking is not left to its own devices. It is heavily regulated, including weight limits, speed limits, driving time limits, and operational constraints covering truck leasing, safety management, and brokering. However, U.S. regulators largely overlook the role of upstream economic determinants of safety and instead focus on policing downstream activities. While these are undoubtedly important, neglecting the distal causes of safety outcomes risks treating the symptoms rather than the underlying condition. So long as cost-minimizing carriers can gain a competitive advantage through unsafe pay and drivers can increase their earnings by working unsafe hours, both drivers and carriers have a persistent incentive to circumvent the rules. Consequently, with their downstream focus, the FMCSA and state enforcement personnel have effectively locked themselves into a perpetual game of cat and mouse. This has been expensive and, at least in recent years, seemingly ineffective.

Indeed, despite spending millions of dollars on regulatory enforcement, crashes per vehicle mile traveled appears to be rising. According to Figure 2, intrastate carrier crashes increased by approximately 100% between 2010 and 2021. In the face of rising costs and mounting evidence that additional policy levers exist, U.S. regulators may no longer be able to ignore the importance of upstream economic determinants. In recent years, several other countries have grappled with this same dilemma and moved to protect road users from pernicious economic incentives and market volatility, implementing regulations to improve driver pay. South Korea's recent small-scale experiment, Australia's broader compensation regulations, and Japan's reasonable-cost rules may all serve as models. Perhaps it is time for the U.S. to do the same.

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Ethics Statement

The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study were derived from the Federal Motor Carrier Safety Administration's Motor Carrier Management Information System (MCMIS) and the Bureau of Labor Statistics Occupational Employment and Wage Statistics, which are available at https://data.transportation.gov/ and https://www.bls.gov/oes/, respectively. MCMIS contains live files that are regularly updated. The authors obtained past-year files by archiving them themselves or via FOIA request. Copies of the computer programs used to generate the results presented in the article are available from the corresponding author.

Endnotes

[1] These are likely conservative estimates, as they do not account for many non-pecuniary costs and include both medium- and heavy-truck crashes.

[2] While most carriers are small, a few very large carriers lead to expectedly large standard deviations in some variables.

[3] Bivariate regression in first differences is supported by both series having a unit root as indicated by Dickey–Fuller test. Both series test as stationary in first differences. On average, a one unit increase in local PPI is associated with IRR increasing by 0.035 (i.e., a weakening of the negative pay–safety relationship) The bivariate OLS regression uses Newey-West standard errors which are robust to heteroskedasticity and autocorrelation up to one lag as specified (p-value = 0.031, T = 18, and R-Squared = 0.264).

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Figure S1:** Distribution of Crash Frequency in Regression Sample (2006–2024). **Table S1:** compares the estimates of our preferred model, which includes both year and unemployment rate interactions (Model 1), with alternative specifications that omit one or both interactions (Models 2, 3, and 4). While all models have a similar pseudo-R-squared, the model with both interaction terms has a modestly better model fit, as measured by the log pseudo-likelihood. Across models, the coefficients on the log of median annual earnings are statistically significant and of the same sign. **Table S1:** Model of crash incidents with differing interaction terms. **Table S2:** Two-way fixed effects model with two-way clustering, outlier removal, and cross-sectional comparison. **Table S3:** shows that the total estimated relationships are much closer in magnitude across models once conditioned upon the year and the median unemployment rate in each year. The addition of the year interaction alone has a more substantial effect on the model estimates than including the unemployment interaction alone. The unemployment interaction is always positive, but the year interactions are often negative. By including both simultaneously, we can capture these separate forces and interpret their opposing effects. **Table S3:** Total relationships by year conditional on median annual unemployment rate.