Safety in Numbers?
An Analysis of Market Concentration and Safety in the Commercial Railroad Industry

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Abstract

In this paper, we examine the relationship between market concentration and safety incidents in the freight railroad industry in the United States. We measure safety incidents as the number of accidents and market concentration as the Herfindahl Hirschman Index. We test the model in the context of the commercial railroad industry, using a comprehensive data set spanning 40 years. We systematically control for correlated unobservables, and the results consistently indicate that a 1% increase in market concentration yields an approximately .4% decrease in the number of accidents. These results are robust to different measures of concentration, various time aggregations, and numerous model specifications. Furthermore, using bootstrapping techniques, we show that the relationship between safety and market concentration is mediated by the level of investment in capital expenditures, the total number of employee hours, and the amount of freight switching between railroad companies. An important implication of this study is that mergers may provide substantial value by reducing the number of accidents. These findings are relevant for firms, regulators, and consumers across all industries that suffer from safety incidents.

Keywords: safety; accidents; market concentration; HHI; quasi-experimental; mediators

1. Introduction

Surveys of the general population show that concerns about the safety and security of products and services are paramount to consumers (Mittal et al. 2017; Saad 2007). Saad (2007) found that over 80% of Gallup respondents were willing to "pay up to twice as much to buy [food and children's toys] made in the United States" due to safety concerns. Executives wrestle with product and service safety issues in many ways, from food contamination (Van Heerde et al. 2007) to counterfeit medication (Marucheck et al. 2011) to package tampering (Siomkos 1999), and so on. Safety incidents that affect a firm's customers and employees can be extremely costly. For example, accidents related to the Galaxy Note 7 smartphone in 2016 cost Samsung over $5 billion in recalls (Baig 2016). In 2017, Takata filed for bankruptcy after its airbags were deemed responsible for 12 deaths and it recalled 42 million vehicles. In another high-profile case, a pharmaceutical executive was sentenced to 9 years in prison in 2017 for his role in a meningitis outbreak that killed 76 people (Raymond 2017).

Not surprisingly, several regulatory agencies—including the Federal Trade Commission's Bureau of Consumer Protection, the Food and Drug Administration, the Consumer Product Safety Commission, the Consumer Financial Protection Bureau, and the Occupational Safety and Health Administration—want to better understand issues pertaining to safety incidents and accidents that affect employees and consumers. Due to the financial and reputational harm caused by these incidents, marketing executives are also keenly interested in understanding factors that can affect a company's safety incidents.

Within the marketing discipline, scholars have examined the downstream effects of consumer safety, showing that product recall (Chen et al. 2009) and product-harm crises (Laufer and Coombs 2006) have negative consequences for firms. Other studies examine the association of consumer perceptions of safety with demand (Boulding and Purohit 1996; Dawar and Pillutla 2000). Due to this predominant focus on the *consequences* of safety incidents, knowledge about the *antecedents* of safety incidents is limited. This paper examines the role of market consolidation on safety incidents, measured in terms of accidents in the U.S. freight railroad industry. As we explain in greater detail subsequently, the freight railroad industry represents one of the largest and most important business-to-business markets in the United States, with total industry revenue of $60 billion. Moreover, given the ubiquity of commercial railroads in the U.S., insights from this industry are likely to be applicable to many other industries and sectors.

We define market consolidation as occurring when the market shares of dominant firms increase. Theoretically, the most extreme form of market consolidation is a monopoly, and the least consolidated market is a perfectly competitive one. Theoretical and empirical studies have examined the effect of market consolidation on pricing (Bikker and Haaf 2002; Manuszak and Moul 2008; Seim and Viard 2011), product variety (Watson 2009), and customer satisfaction (Rego et al. 2013). However, studies have not examined the effect of market concentration on safety. Yet safety is an important outcome for executives in customer-focused organizations. One reason for the limited research on this topic may be a paucity of data—in addition to accident data, data on market consolidation from multiple markets is needed. We use a novel data set on railroad accidents that occurred in the United States from 1975 to 2016. This 40-year time series includes operational and economic data that enable us to focus on each state as a separate market and measure the effect of market consolidation on safety incidents.

Our results provide insights into the association between market concentration and safety. The results show that more consolidated markets can demand higher prices and increase revenue, which in turn can be invested in safety initiatives. We also identify specific mechanisms—

namely, the reduced switching of freight cars between railroad companies and capital expenditures—that lead to increased safety. These findings are robust to different measures of concentration and various time aggregations over the 40 years in our data set.

2. Related Literature

2.1. Firm Consolidation and Consumer Outcomes

Marketing scholars generally agree that industry competition, as opposed to consolidation, benefits consumers. Empirical studies show that an increase in industry competition lowers prices (Manuszak and Moul 2008; Singh and Zhu 2008) and increases quality (Cohen and Mazzeo 2004). Rego et al. (2013) show that lower industry consolidation is associated with higher customer satisfaction. Table 1 summarizes the empirical studies that examine the association of consolidation with several consumer and firm outcomes.

Several studies in Table 1 demonstrate mixed results—that is, the outcome of industry competition is not always positive for consumers. Watson (2009) shows that the variety of different eyeglasses each retailer carries declines as more firms enter the market; as new entrants steal business from incumbents, the latter reduce their product range to cut costs. This example contrasts with Seim and Viard's (2011) study of the mobile telecommunications industry, which shows that competition induces firms to offer larger menus. Payne and Frow (1997) analyze the history of utility deregulation in the United Kingdom and find that while deregulation increases operating efficiencies, the surplus is not always passed to the consumer.

[insert Table 1 about here]

Industry consolidation affects firms in different ways. First, competition spurs innovation and risk taking and thus increases returns (Hou and Robinson 2006). Second, firms that differentiate due to increased competition also benefit from increased market share (Mazzeo

2002). However, there are also detrimental consequences for firms when competition increases. Some studies report that supermarkets facing increased competition experience fewer store visits, lower in-store expenditures, and decreased profits (Cleeren et al. 2010; Singh et al. 2006; Zhu et al. 2009). An increase in competition also reduces the effectiveness of advertising (Gatignon 1984) and lowers profit margins (Ailawadi and Harlam 2004).

In summary, both competition and consolidation can be beneficial (and detrimental) in different and often counterintuitive ways. However, neither competition nor consolidation has ubiquitous and unconditional results. We examine this issue in greater depth in the context of safety.

2.2. Correlational Versus Causal Effects of Consolidation

In examining the causal effects of consolidation on a variety of consumer and firm outcomes (Berry 1992; Bresnahan and Reiss 1990; Evans et al. 1993; Mazzeo 2002), we recognize that consolidation is jointly observed with its corresponding outcomes. For example, a positive correlation between the number of firms and industry revenue may be naively attributed to increased competition, when in fact it may occur endogenously if successful and profitable firms decide to locate in profitable areas or join promising industries.

One approach to mitigating this potentially erroneous conclusion is to structurally model the occurrence of consolidation. For example, Zhu et al. (2009) model firm entry and its effect on market structure and thus control for the issue of strategic entry in models examining the downstream effects of market consolidation. However, this requires a model that specifies the correct objective function in the firm entry model (usually the first-stage model), which also affects subsequent results pertaining to the effect of entry (usually the second-stage model). In addition, entry models have many equilibria, and as such it is necessary to have simple yet accurate equilibrium selection rules to identify the model. Finally, computational complexity quickly grows when the number of potential competitors is unknown or when there are many competitors. Zhu et al. (2009) address this complexity by restricting their model to the three largest discount retailers and observe that the results drastically change if endogenous entry is ignored.

Another approach, which we follow in this paper, is to obtain quasi-experimental evidence for the causal effects of consolidation. The quasi-experimental approach can be implemented in many ways: instrumental variables (Chintagunta et al. 2010; Luan and Sudhir 2010; Shriver et al. 2013), difference in differences (Ailawadi et al. 2010; Manchanda et al. 2015), panel data (Bollinger and Gillingham 2012; Germann et al. 2015; Nair et al. 2010; Sridhar and Sriram 2013; Zhang and Liu 2012), and regression discontinuities (Hartmann et al. 2011; Narayanan and Kalyanam 2015). As we explain subsequently, we follow Bollinger and Gillingham (2012) and Sridhar and Sriram (2013) by taking advantage of the necessary variation in quarterly data that span all states and a period of 40 years, after removing a detailed set of institutional confounds that preclude identification.

2.3. Factors Affecting Product Safety and Security

Scholars have examined safety from many perspectives. One stream examines the effect of regulation and legal intervention on consumer safety. Viscusi (1985) find that regulatory agencies do little to improve safety for consumers, and Polinsky and Shavell (2010) suggest liability laws only have a marginal effect on safety because markets absorb the cost of liability insurance and because consumers purchase their optimal risk levels even without insurance. Daughety and Reinganum (2011) find that the level of safety provision decreases with the cost of safety and increases when substitute goods provide higher safety. A second stream of literature uses consumer surveys to identify factors that contribute to consumer perceptions of safety. Ching Biu Tse (1999) conducted a survey that revealed that higher prices, famous brand names, specialized promotion channels, source credibility, being manufactured in the United States, governmental product testing, and longer warranties all increase consumers' perceived safety. Boulding and Purohit (1996) estimate a hedonic price equation from consumer survey data and show that safety features, such as a side airbags, are valued more in larger than in smaller cars.

A third stream of literature examines the effect of safety lapses—manifesting as product harm crises—on firm financial performance. This research concludes that the market penalty for recalling poor-quality goods is relatively small to nonexistent (Thirumalai and Sinha 2011). Proactive strategies might negatively affect firm value because they may be interpreted as a signal of guilt (Chen et al. 2009). Other studies show that advertising is less effective following a product-harm crisis (Rubel et al. 2011; Van Heerde et al. 2007). Negative externalities might also spill over to the entire industry, as Jarrell and Peltzman (1985) find in cases of pharmaceutical and automobile recalls. Van Heerde et al. (2007) report that Kraft's main competitor tripled its sales when Kraft suffered a salmonella scare.

However, all three of these aforementioned research streams are silent about the effect of consolidation on safety. We posit that safety is a function of the competitive environment and disentangle the association between safety and consolidation in the railroad industry.

2.4. The Railroad Literature

Several literature streams have examined American railroads. The first stream of literature examines railroad operations, pricing, and labor. Freight pricing has been a popular topic, with early studies by Thompson (1951) and Dean (1961) attempting to explain increasing postwar freight prices. More recently, Ivaldi and McCullough (2007) showed that the margins of railroads since deregulation in 1980 have been relatively small, averaging 5.6%.

A second stream of literature, more relevant to the current work, examines the effect of deregulation and merger activity (which can increase consolidation). Smith and Grimm (1987) examine five railroads and find that before deregulation, these railroads had little incentive to follow profit-maximizing strategies because of the limited earning potential, which changed once railroads were no longer bound to rate setting. Ellison (1985) finds that deregulation in the U.S. hurt the regulated Canadian railroad industry and hampered expansion of transborder trade. Sun and Tang (2000) show that mergers do not increase the stock price of the acquiring firm, but the value of its industry counterparts does increase; although mergers do not provide efficiency or market power gains, they reduce the cost of enforcing a tacit collusive agreement.

Finally, some studies on railroad safety have examined railroad fatalities. These studies largely conclude that deregulation does not increase fatalities (Clarke and Loeb 2005), that alcohol is a significant factor in trespasser fatalities (Pelletier 1997), and that the benefit of implementing safety features is well below its cost (Evans 2013). Studying the industry prior to deregulation, Golbe (1983) finds that profitable firms suffer fewer accidents than unprofitable firms. More recently, Savage (1998) found that declining finances in the 1960s caused an increase in accidents. Continuing this line of inquiry, the current study uses a panel encompassing 40 years of railroad accidents. This is the longest such panel used to study accidents, and our model is well suited to draw strong conclusions about consolidation and railroad safety.

3. The Railroad Industry in the United States

3.1. Railroad Industry Background

The U.S. railroads have been regulated by the federal government since 1887. Currently, the Federal Railroad Administration (FRA) promotes safe railroad operations and levies fines against offending railroads. The Surface Transportation Board (STB) oversees economic and business activities in the railroad industry, such as mergers and price setting. The STB classifies railroads into Class I railroads (revenues exceeding $475.8 million), Class II railroads ($36.6 million–$475.8 million), and Class III railroad (<$36.6 million). Class I railroads are required to report annual financial statements to the STB and must comply with more labor regulations.

Railroads accounted for more than 60% of freight traffic following World War II. By 1975, this share decreased to 37%, largely with the advent of the interstate highway system in the 1950s. Regulation precluded railroad companies from signing shipping contracts, negotiating shipping rates, and abandoning unprofitable routes. This left the railroads with less freight to ship and a higher percentage of low-value freight, while still burdened by a large fixed-cost network. In 1970, Penn Central Transportation Company went bankrupt, and in 1972 Hurricane Agnes threatened the solvency of many railroad companies in the northeastern United States. At the time, these were the largest corporate bankruptcies and the costliest hurricane in U.S. history, respectively. The government responded with an infusion of cash and created the Consolidated Rail Corporation, or Conrail, in 1976. The government's direct interest in Conrail's solvency spurred additional deregulation, most noticeably the Staggers Rail Act of 1980.

3.2. The Staggers Rail Act and Railroads Today

The Staggers Rail Act of 1980 provided greater pricing and operational freedom to railroad companies. Specifically, it allowed railroad companies to:

- Freely establish rates for a rail service, unless the government determined that there was no *effective competition* for rail services. *Effective competition*, in this case, refers to another railroad company operating within 50 miles or reasonable alternatives, such as trucking or barge.

- Establish shipping contracts subject to no effective governmental review.
- Phase out across-the-board industrywide rate increases.
- Abandon unprofitable networks.

While there were over 70 Class I railroads in 1975, there were only 8 in 2015, and 4 dominant ones remain today—Norfolk Southern (NS) and CSX in the East and Burlington Northern Santa Fe (BNSF) and Union Pacific-Southern Pacific (UP) in the West. The number of smaller, regional railroads has increased, but the market has undergone significant consolidation. Table 2 shows the number of railroad companies in each class over time, the miles traveled, and the number of accidents. Notably, while some people feared that deregulation would lead to high shipping prices and the abuse of monopoly power, such fears never materialized.

Most U.S. railroad companies are Class III. They are generally short line and regional, operating only a few hundred miles of track. In 2015, the 50th percentile of Class III railroads traveled only 1000 miles each month. Class III railroads often connect raw materials to manufacturing sites or link markets to nearby Class I companies. This allows consumers to choose among different routes serviced by different Class I railroads.

The usage of railroad routes depends on the proximity to major cities and to maritime services. The heaviest movement of freight occurs in the Midwest through major cities and agricultural regions. While there is minimal competition for long-haul freight (often only one or two companies), there is competition from the other modes of transportation. Figure 1 shows the amount of ton-miles moved by the major transportation modes since 1980. Overall freight activity and the percentage of overall freight traffic moved by rail have increased since 1980.

Regarding safety, the railroad industry has made gains since the Staggers Rail Act. In Section 4, we describe safety and how we measure it in more depth. It is worth noting that less than 1% of the accidents involve fatalities, only 3% of accidents involve passenger trains, and (as Table 2 shows) nearly 80% of annual freight accidents in 2015 involved Class I railroads.

[insert Table 2 and Figure 1 about here]

4. Data

4.1. Accident Data

We obtained quarterly data on railroad accidents, our focal dependent variable, for the period spanning 1975–2016 from the FRA. Specifically, we obtained accident data from FRA Form 54: Railroad Equipment Accident/Incident.[1] The FRA defines a railroad accident as "a train accident involving one or more railroads that have sustained combined track, equipment, and/or structural damage above the reporting threshold. The reporting threshold, adjusted annually, is currently $10,500 (2014)." The costs are only those necessary to replace and repair railroad equipment and includes neither the costs for issues such as hazmat cleanup nor opportunity costs from loss of use of the track and equipment. The data include the location of the accident, the date and time, the railroad companies involved, the type of accident that occurred, and the cost of the accident.

Table 3 summarizes accident frequencies. The total of nearly 200,000 railroad accidents in the data set represents an average of 10 reported accidents a day for the past 40 years. While head-on collisions and highway-crossing accidents are often highly publicized, derailments account for more than 65% of all accidents. We define our focal dependent variable, *accidents*, as the total number of accidents (across all types of accidents) that occur in state s in quarter q.[2]

[1] Safety data can be obtained from http://safetydata.fra.dot.gov.

[2] For additional robustness, we conduct analysis by different types of accidents and different time aggregations in Section 7.

[insert table 3 about here]

4.2. Market Consolidation in the Railroad Industry

We conducted an exhaustive literature review of empirical research on market consolidation across various contexts (for a summary, see Table 1), covering 26 years and multiple disciplines, and found five common measures of consolidation. Among these, the Herfindahl–Hirschman Index (HHI), a function of market share, is the most popular and parsimonious metric of market consolidation, covering 40% of the studies. The HHI, as presented in Equation (1), is the sum of squares of market share for each firm in a market.

In our setting, Class I railroads compete for consumers in each state, who can choose among multiple railroad routes and other services (e.g., trucks, airfreight) for shipment transportation. Similarly, Class II and Class III railroads generally operate within a state, and their sole purpose is to connect shippers to different railroad routes serviced by potentially different Class I railroads. Thus, each state serves as a separate market. We define the HHI as:

(1) $$HHI_{s,q,t} = \sum_{i \in N_{s,q,t}} s_{i,s,q,t}^2,$$

where $N_{s,q,t}$ is the set of firms operating in state s in quarter q in year t, and each firm $i \in N_{s,q,t}$ has market share $s_{i,s,q,t}$. We obtained data on each railroad's market share in each state from FRA Form 55, which contains information on the quarterly miles traveled by each railroad (a proxy for the revenue of each railroad), and all the states in which a railroad operates. Data on the exact number of miles travelled by each railroad in each state are not alable to us. To convert the national mileage data for each railroad into state-level data, we allocate a railroad's total mileage evenly across all the states a railroad operates in for a given month. For robustness, we also used another measure, namely, allocating a railroad company's monthly mileage based on the population of each state in which the railroad company operates. Reassuringly, this alternative measure produced similar results.

We define the market share for a railroad company as the fraction of mileage that a railroad company traveled in the state divided by the total miles travelled in that state over a quarter, and accordingly we compute the HHI in each state and quarter for the entire length of the data. The data contain sufficient variation in market consolidation, which is necessary for identification. For example, grouping states according to the FRA's regional designation in Figure 2, we observe HHI values from 26.3 (the average of region 4) to 65.0 (the average of region 8). Furthermore, the average year-over-year change in consolidation is .8%, which itself ranges from –6.4% to 11.6%. The average within-year, within-state change in consolidation is 3.6%, which in any year may range from –72.2% to 289.5%.

[*insert Figure 2 about here*]

4.3. State-Level Variation in the Economic Climate

We supplement our data with covariates that capture state-level and temporal variation in the local economic climate, obtained from the Bureau of Labor Statistics. We obtained quarterly data on the state-level unemployment rate and total size of the labor force from 1976 to 2015. These data serve to mitigate confounding effects between market consolidation and accidents. Table 4 provides summary statistics for the variables in our data, and Table 5 describes each variable.

[*insert Tables 4 and 5 about here*]

4.4. Identification

Our primary objective is to establish the causal link between market consolidation and railroad accidents. In its most naive form, we can regress the number of accidents in state s during quarter q in year t, $y_{s,q,t}$, on market consolidation, as follows:

(2) $$y_{s,q,t} = \theta + \alpha HHI_{s,q,t} + \epsilon_{s,q,t},$$

where $HHI_{s,q,t}$ is our measure of consolidation and θ is the intercept. This simple model has several limitations. First, railroad accidents are driven by myriad factors not included in the model, and some of these factors are likely also correlated with market consolidation, creating the issue of correlated unobservables. For example, geography influences market consolidation as well as railroad accidents, as mountainous terrain might lead to more accidents and the high cost of constructing rails over a mountain may limit competition. Omitting this variable would likely lead to endogeneity due to correlated unobservables. Thus, we develop a systematic approach based on the available covariates and unobserved effects (e.g., Germann et al. 2015; Nair et al. 2010; Sen et al. 2012; Sridhar and Sriram 2013) to address this issue.

We include covariates that potentially vary with the number of accidents in the state. We denote this set of time-varying state variables as $X_{s,q,t}$, which includes *number of railroads*, *railroad mileage*, *unemployment rate*, and *size of the labor force*. *Number of railroads* is a proxy for the level of activity in a state—that is, more railroads are located where more freight activity occurs, which might induce more accidents due to equipment fatigue (FRA 2015). Furthermore, the number of railroads is not directly related to the market consolidation, as there can be a variety of market outcomes for a similar number of railroads. *Railroad mileage* is another proxy for the level of activity, as states that operate more mileage likely suffer more accidents. The two economic indicators, *unemployment rate* and *size of the labor force*, pick up across-state, over-time variation in activity not captured by other variables. For example, in times of high unemployment, such as the 2008 recession, Figure 1 and Figure 3 show that trains operate at roughly the same mileage but carry less freight and are lighter on the rails. The same argument applies to the *size of the labor force*; a state with a larger working population might suffer more accidents from more rail congestion and activity. Accordingly, we modify the basic model as:

(3) $$y_{s,q,t} = \theta + \alpha HHI_{s,q,t} + \beta X_{s,q,t} + \epsilon_{s,q,t},$$

where β is the vector of coefficients.

[*Insert Figure 3 about here*]

However, it is impossible to include an exhaustive set of control variables that vary across states and over time that also might be correlated with market consolidation. Thus, we turn to the unobserved-effects approach. This approach nonparametrically controls for heterogeneity using a rich set of fixed effects and frees up the variation needed to isolate the effect of interest (Sudhir and Talukdar 2004). Thus, as a second step, we include state fixed effects. State fixed effects capture idiosyncratic, state-specific characteristics that can affect accident rates; for example, treacherous terrain could be difficult for railroads, or a humid environment might lead to more rapid equipment deterioration (Wald and Schwartz 2012). The modified model is as follows:

(4) $$y_{s,q,t} = \theta + \gamma_s + \alpha HHI_{s,q,t} + \beta X_{s,q,t} + \epsilon_{s,q,t},$$

where γ_s is state-specific heterogeneity captured through state fixed effects.

Third, the length of our panel also raises the issue of the passage of time confounding our interpretation of competition. In particular, the model might be picking up time-varying effects that contemporaneously determine competition and safety. For example, federal legislation has an important effect on safety and the level of competition (Busch 1976; Warren 2008). Technology might also lower or raise barriers to entry and affect safety within the industry. The economic environment may determine the demand for freight shipping; for example, in times of recession, we would expect fewer freight companies operating and possibly fewer accidents. Thus, we extend the model as follows:

(5) $$y_{s,q,t} = \theta + \gamma_s + \eta_t + \alpha HHI_{s,q,t} + \beta X_{s,q,t} + \epsilon_{s,q,t},$$

with η_t accounting for year fixed effects.

Fourth, several within-year effects, such as seasonality, might contemporaneously affect both accidents and market consolidation. For example, freight's "peak season" generally runs from June to November, jointly affecting the level of market consolidation and the accident rate. We thus extend the model to include quarter dummies to the data, as follows:

(6) $$y_{s,q,t} = \theta + \gamma_s + \eta_t + \xi_q + \alpha HHI_{s,q,t} + \beta X_{s,q,t} + \epsilon_{s,q,t},$$

where ξ_q represents three quarter dummies.

Fifth, the model still has correlated unobservables that vary within states across years and within years across states. These unobservables are not picked up by persistent state fixed effects or by year fixed effects. For example, severe hurricanes—such as Hurricane Agnes, which devastated the Northeast in 1972—may only affect part of the country for a given year, and technological improvements might not affect all parts of the country equally. Rail stressing, a technique to ensure that the track does not fracture or buckle under extreme temperatures, only affects safety in areas with extreme temperature fluctuation. We thus extend the model to include state-region fixed effects, which capture time-varying unobservables specific to each region. The FRA defines 8 regions, which are groups of geographically close states (see Figure 2). Each region contains between 4 and 8 states. We write the modified model as follows:

(7) $$y_{s,q,t} = \theta + \gamma_s + \eta_t + \xi_q + \delta_{r_s,t} + \alpha HHI_{s,q,t} + \beta X_{s,q,t} + \epsilon_{s,q,t},$$

where r_s is the region of state s and $\delta_{r_s,t}$ is the year-region fixed effect.

Thus, the identifying assumption in Equation (7) is the use of time-varying covariates and a rich set of fixed effects to capture all sources of correlated unobservables that might affect both market consolidation and accidents. In Table 6, we summarize the potential confounds and how our model addresses them. After controlling for all sources of correlated unobservables, we use the residual within-year, across-state variation to identify the causal effect of market consolidation on railroad accidents.

[*insert Table 6 about here*]

5. Model-Free Evidence

We start with several model-free indicators of an association between market consolidation and railroad accidents in the data. Table 7 presents the number of accidents across different levels of market consolidation, different regions, and different time periods. For each subset, we split the data at the median of market concentration and create two groups, high market concentration and low market concentration. We report the average number of quarterly accidents for each group and perform a mean difference test. We look at the data (1) completely aggregated, (2) by geographic region subsets, and (3) by five-year subsets. Results from the state level, though not reported here, mirror the regional results. As Table 7 shows, highly concentrated markets experience significantly fewer accidents per quarter than less concentrated markets. Furthermore, in every group, the number of accidents is strongly and negatively correlated with market consolidation. Overall, markets with low consolidation have approximately 20 more accidents (285% more) per quarter than highly consolidated markets.

[insert Table 7 around here]

The mean difference of accidents in markets with low versus high consolidation is statistically significant within every subset. Yet the differences reveal considerable heterogeneity. Highly consolidated regions average 3–18 accidents per quarter, while regions with low concentration average 9–45 accidents per quarter. Heterogeneity across time is shown by a decrease in the average number of accidents per quarter over time. This supports the inclusion of year and state fixed effects as well year-region interaction terms in the full model.

Over time and across regions, the level of market consolidation also changes, as we discussed in Section 4. Figure 4 presents the scatterplot of quarterly accidents and market consolidation with the trend line for all five-year subsets in Table 7. They show a negative association throughout the groups, as represented by the negative correlations in Table 7.

[insert Figure 4 about here]

6. Results

We present the results from our model in Table 8. Model 1 does not control for any confounds. Market consolidation has a significant negative effect ($\alpha = -0.298, p < .01$), suggesting that safety increases with consolidation. Model 2 adds time-varying state-level data to the model. Accidents increase with the railroad mileage operated but surprisingly decrease as labor force increases in a state. A possible explanation for this finding is that the labor force grows at a relatively steady rate in the data, which could be picking up the time trend that we observe in the accident rate as well. The labor force effect disappears in the robustness checks when we only consider data since 1990. The unemployment rate is not a significant indicator of the number of accidents. In Model 3, we introduce state fixed effects, which makes the number of railroads operating insignificant. Model 4 incorporates year fixed effects, which absorb a lot of predictive power of the other variables. However, market concentration remains a significant determinant of the number of accidents ($\beta = -0.0977, p < .01$).

Model 5 in Table 8 controls for seasonality. We expect the accident rates and the freight industry to undergo changes throughout the year. Yet the inclusion of seasonality does not significantly alter the effect of the variables in the model. Finally, in Column 6, we report the full model, which includes year-region interaction terms in addition to all the previously discussed covariates. In the full model, only market consolidation ($\alpha = -0.0546, p < .03$), mileage ($\beta = .174, p < .01$), and size of the labor force ($\beta = -.546, p < .01$) are statistically significant.

Substantively, the coefficients from Model 6 show that a 1% increase in market concentration (at the mean value of 2016) yields an approximately .4% decrease in the number of accidents. Stated differently, a 20-point increase in the HHI score produces a reduction of 1 accident per state per quarter.

[*insert Table 8 about here*]

7. Robustness Checks and Falsification

This section contains several robustness checks for our model. First, we look at the results if we only consider Class I railroads in our analysis. Previous research on the railroad industry has focused almost exclusively on Class I railroads because of their high mileage and the difficulty of obtaining Class II and Class III data. We remove all non–Class I railroads from the data, dropping both their mileage and their accidents, and reestimate the models. The results from the robustness checks appear in Table 9. For each robustness check, we show the results from the full model (Model 6). Column 1 contains the results from only including Class I railroads. Because Class I railroads account for a large percentage of total mileage and total accidents, we expect that market consolidation will still be impactful when we exclude Class II and Class III railroads. Notably, the sign of market consolidation reverses, and the number of Class I railroads is very significant. We argue that the number of Class I railroads is highly correlated with market consolidation, as it serves as a proxy for the number of market-dominant firms. Theoretically, this serves as a warning that without data on the full market structure, the results might actually appear to reverse, which will have significant policy implications. In other words, focusing only on Class I railroads may provide misleading results.

Next, we consider only fatalities rather than all accidents. Fatalities account for only 0.5% of the accidents in our data, so we want to test the robustness of our results to this small subset of accidents that is often the focus of railroad research (Clarke and Loeb 2005; Pelletier 2007). Not surprisingly, Column 2 reports that market structure is a very small and statistically insignificant predictor of fatal accidents. Despite the variation in market consolidation, the total number of fatalities per year does not change much. The annual number of fatal accidents since 1980 has never averaged more than one accident per state per year. This implies that more than three-fourths of our state-quarter cells will have no fatal accidents. It also points to the danger of using fatal accidents as a safety metric, even though many studies focus purely on fatalities.

Next, we perform two robustness checks that focus on the temporal dimension of our data. First, we focus only on data since 1990. As Table 2 and Figure 3 show, the first few years after the Staggers Rail Act were tumultuous, and only after 1990 did the number of railroads and number of annual accidents stabilize. In Column 3 of Table 9, the results hold even when we only consider the post-1990 data and exclude the heavy variation in the early years. While the absolute value of consolidation's coefficient is lower, the effect is stronger ($p < .01$). Second, we aggregate the data into different time dimensions: monthly, half yearly, and yearly. We expect the link between consolidation and the number of accidents to weaken as we aggregate over longer periods. Columns 4, 5, and 6 of Table 9 show market that consolidation remains significant at all the level of aggregation. As expected, however, the strength of the effect weakens as we aggregate the data.

Finally, we examine the effect on our parameter values from two changes to the measure of consolidation. The original model evenly divided a railroad company's total mileage in a period between all the states that a railroad company operated in during that period. In this check, we first allocate the mileage proportional to the size of the labor force in those states. Column 7 of Table 9 shows the results from allocating railroad operating mileage by the size of each state's labor force. The results do not change. The assumption that states with larger populations receive a greater share of the freight traffic may be incorrect, as the coefficient of labor force on accidents is negative, potentially explaining the reduced statistical significance.

The final robustness check on consolidation eschews mileage as our measure of market share and instead focuses on employee hours. FRA Form 55 includes total employee hours per month, which we use similarly to construct the HHI for each state. Column 8 of Table 9 reports the results from focusing on employee hours instead of railroad mileage. While employee hours may not proxy firm revenues as well miles operated, the model still presents significant results for market consolidation of roughly the same magnitude as mileage.

In drawing the link between market consolidation and the number of accidents, we also rule out two alternative explanations: (1) increased number of employees and (2) decreased operating mileage. An increase in the number of employees is likely to reduce fatigue and help prevent human-error-related accidents. A decrease in the overall level of railroad mileage should reduce the number of accidents that occur as the level of activity decreases.

Figure 3 shows that since 1975, the annual miles operated has remained close to its initial level. However, miles travelled per employee hour has more than doubled, signifying far fewer employees than in the past. We conclude that the decrease in accidents is not a result of hiring more employees. Furthermore, recall from Figure 1 that total tons moved is increasing even though the mileage has not greatly increased. We must also refute the argument that a decrease in freight activity accounts for the increase in safety. The next section, discusses the mechanisms that we believe connect market consolidation and safety—namely, capital expenditures, savings from fewer employee hours, and less switching of cargo between railroad companies.

8. Uncovering Mediating Mechanisms

We propose that the relationship between market consolidation and safety is mediated through capital expenditures, miles of switching railroad cars, and employee hours. While we do not model the price-setting behavior of firms, we observe in Table 2 that after the 1980 Staggers Rail Act, the average revenue for shipping a ton-mile of freight increased. The immediate effect on firms was healthier balance sheets through higher revenues and the abandonment of unprofitable routes. We hypothesize that railroad companies then began investing heavily in capital expenditures, increasing the industry's safety record. Furthermore, as railroads had sufficient capital to merge, we expect employee hours to decrease as consolidated firms take advantage of economies of scale. The capital investment data come from the R-1 financials reported to the STB. As employee hours decrease, firms are focusing their resources more on their core business and realize cost savings, both of which contribute to safety. Finally, we believe that consolidated railroads will spend less time switching cargo between companies. The mediator *miles operated for switching* should decrease with the accident rate. Switching provides opportunities for accidents, including six railroad workers' deaths from 2009 to 2013 (FRA 2013). When markets become more consolidated, we expect less switching and fewer accidents.

To test the mediating role of capital expenditures, employee hours, and switching miles in the possible impact of consolidation on safety, we follow the Preacher and Hayes (2004) bootstrapping method. For this portion of the analysis, we only have annual data on our measures from 1978 to 2015, so our covariates are aggregated to the year level. For each mediator, we first regress our dependent variable, annual number of accidents per state, against our independent variable, the HHI, as presented in Equation (8):

(8) $$y_{s,t} = \theta + \gamma_s + cHHI_{s,t} + \beta X_{s,t} + \epsilon_{s,t},$$

where the coefficient c is the total effect of HHI on annual accidents and the other variables are the same as in Equation (4). Next, we regress the mediator against HHI, as specified in Equation (9). Finally, we regress the annual accidents on the HHI and each mediator, as presented in Equation (10). Let $M_{s,t}$ denote the focal mediation measure we want to analyze:

(9) $$M_{s,t} = \theta + \gamma_s + \alpha_2 HHI_{s,t} + \beta X_{s,t} + \epsilon_{s,t},$$

(10) $$y_{s,t} = \psi M_{s,t} + \theta + \gamma_s + \alpha_3 HHI_{s,t} + \beta X_{s,t} + \epsilon_{s,t}.$$

The direct effect of HHI on annual accidents is given by α_3, and the indirect effect is simply $c' = \alpha_2 * \psi$. To ensure the significance of our direct and indirect effects, we perform a bootstrap to get the standard errors. We repeat these steps for each of the three mediators. Table 10 summarizes the results from the mediation analysis.

The first mediator, capital expenditures, mediates 66.7% of the total effect of HHI on the number of accidents. The direct and indirect effects of HHI are negative and statistically significant (95% confidence interval [CI] of the direct effect ranging from –.45 to –.11). The second mediator, employee hours, accounts for 77.5% of the total effect. The indirect effect is negative and significant, while the direct effect is not significant (95% CI = –.43 to .15). Finally, mediation via total switching mileage presents similar results: 68.2% of the total effect occurs through mediation. Once again, the indirect effect is significantly negative, while the direct effect is no longer significant (95% CI = –.50 to .06).

The total effect of the HHI on accidents is negative and statistically significant ($c = -.81, p < .001$), in support of our main findings. We conclude that mediation occurs, as all the mediators meet these four requirements: (1) the HHI significantly affects the mediator, (2) the HHI significantly affects the annual accident rate in the absence of the mediator, (3) the mediator has a significant and unique effect on the accident rate, and (4) the effect of the HHI on the accident rate shrinks or is no longer significant after adding the mediator to the model.

9. Discussion

This paper investigates an under-researched relationship between safety and market concentration. Analyzing accidents from the freight railroad industry over a 40-year time span, we find a significant effect of market concentration on safety. The results are robust to different measures of concentration and various time aggregations. Furthermore, the results show that the effect is mediated via capital expenditures, employee hours, and switching miles.

Because safety is an important goal in nearly every industry, this paper yields useful managerial and policy implications. Managers should account for the cost savings of increased safety when considering mergers and acquisitions. While managers often pay attention to a merger’s effects on revenue and sales, the indirect savings from safety improvements can also be substantial. Table 11 shows the number of accidents for the four largest Class I railroad companies in 2015, the total costs, and the average costs per accident. Union Pacific spent more than $120 million just on equipment and track accidents in 2015, while the industry as a whole spent more than $400 million that year. By better understanding these costs and the effects of consolidation on safety, executives can improve their justifications for mergers and acquisitions.

Policy makers have an interest in protecting consumers both financially and physically, while minimizing societal costs. Our model predicts that a monopolistic freight industry will experience approximately 1000 fewer accidents a year than an industry with perfect competition, providing a previously undiscovered boundary condition to the notion that perfect competition is better suited to consumer welfare. As Table 11 reports, the average cost of an accident in 2015 was nearly $170,000. The shift to a monopoly would potentially save the industry hundreds of millions of dollars. If environmental and societal costs are included as well, the savings could be in the billions. We also find an association between railroad infrastructure investment and safety, which suggests that policy makers could incentivize companies to optimize investment.

While it is not possible to prevent every accident, market consolidation appears to be an effective safety tool. The railroad industry's detailed reports on accidents and its large variation in market structure over the years provide an exceptional opportunity to study the effects of market concentration on safety. It is important to keep in mind that increased market consolidation might have negative outcomes at a certain point. While the railroad industry has become greatly consolidated since 1975, it has never been a pure monopoly, so the conclusions, while broad, are limited to the range of market structures that we observe in the data.

Finally, the results of this analysis may provide insights relevant to other industries and settings, such as health care, airline transportation, and pharmaceuticals. Recognizing the idiosyncrasies of each industry, it is possible to develop models that examine the effect of consolidation on a variety of outcomes. These studies should be of interest not only to managers in their respective industries but also to regulators and policy makers, such as the Food and Drug Administration, the Federal Communication Commission, and the Federal Trade Commission. We hope this paper provides an initial step in that direction.

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TABLE 1
Literature Review of Market Consolidation

Authors	Context and Sample	Measure of Market Consolidation	Outcome	Findings
Gatignon (1984)	Airline companies	Number of firms and Herfindahl–Hirschman index (HHI)	Price elasticity	Competition accentuates the effect of advertising on price elasticity
Bikker and Haaf (2002)	Banking markets	k-bank concentration ratio, HHI, number of banks	Pricing behavior	Prices increase when markets consolidate
Ailawadi and Harlam (2004)	Retail chain stores	HHI	Margin on store brands	Store brands will demand lower margins to compete with market leaders as HHI increases
Rego et al. (2013)	200+ U.S. companies	HHI, number of brands	Customer satisfaction	Higher HHI leads to higher customer satisfaction
Hou and Robinson (2006)	Three-digit SIC classification	HHI using sales, assets and equity	Firm returns	Higher HHI leads to lower returns by engaging in less innovation
Zhu et al. (2009)	U.S. discount retail stores	Presence of Wal-Mart, Target, or Kmart	Firm profit	Competition lowers profits
Manuszak and Moul (2008)	Office supply stores	Presence of Staples, Office Depot, and OfficeMax	Prices	Competition lowers prices
Mazzeo (2002)	Motels	Number of firms	Product differentiation	Competition promotes product differentiation
Singh and Zhu (2008)	Car rentals	Total number of firms and an indicator variable for monopoly	Prices	Competition lowers prices
Cohen and Mazzeo (2004)	Depository institutions	Total number of firms	Quality	Consolidation increases quality
Watson (2009)	Eyewear retailers	Number of firms and Dispersion of distant rivals	Product range choices	Competition decreases per firm variety
Seim and Viard (2011)	Telecommunications	Total number of firms	Adoption and pricing	Competition decreases prices and accelerates technology adoption
Cleeren et al. (2010)	German supermarkets	Number of firms, presence of supermarket within 25km	Firm profits	Competition decreases profits
Singh et al. (2006)	Supermarkets	Entry of Wal-Mart Supercenter	Store visits and in-store expenditures	Competition decreases store visits and basket size per visit
Payne and Frow (1997)	British public utilities	Monopoly or deregulated indicator	Operating efficiency, prices, and quality of service	Competition makes consumers more elastic, but depends on the margins of the industry

TABLE 2
Railroad Operations Overview for Select Years

Year	Railroad Class	Number of Railroads	Percentage of Total Mileage	Average Annual Miles Traveled per Railroad (in 100K miles)	Percent of Total Accidents	Annual Number of Accidents	Revenue per Ton-Mile (1980 level = 100)
1976	1	80	97.0%	90.6	96.5%	12152	68.9
	2	362	3.0%	0.6	3.5%		
1980	1	41	93.2%	156.3	91.4%		
	2	20	2.2%	7.6	2.1%	10234	100
	3	370	4.6%	0.9	6.5%		
1990	1	18	85.7%	271.3	82.1%		
	2	16	1.0%	3.5	1.4%	3551	144.3
	3	524	13.3%	1.4	16.5%		
2000	1	9	85.3%	651.0	79.9%		
	2	8	0.7%	6.0	1.1%	3591	188.4
	3	652	14.0%	1.5	19.1%		
2010	1	9	81.9%	604.4	78.5%		
	2	8	0.9%	7.6	1.3%	2449	256.9
	3	774	17.2%	1.5	20.2%		
2015	1	8	80.6%	701.9	80.8%		
	2	5	0.3%	4.7	0.6%	2407	301.5
	3	778	19.0%	1.7	18.7%		

TABLE 3

Four Most Common Types of Federal Railroad Administration Form 54 Accidents

Type of Accident	N	Percent	Cumulative
Derailment	128729	66.9%	66.9%
Side collision	20674	10.8%	77.7%
Other impacts	16852	8.8%	86.4%
Highway rail crossing	7624	4.0%	90.4%

TABLE 4

Summary Statistics and Correlation Matrix per State-Quarter

		Mean	Std. Dev.	Min	Max	1	2	3	4	5	6
1	Number of accidents	18.16	25.45	.00	367.00						
2	100k mileage	32.42	23.94	.00	331.65	**.61**					
3	Unemployment rate	6.08	2.09	2.13	18.70	**.05**	.00				
4	Labor force 100k	26.75	29.06	1.58	191.63	**.36**	**.52**	**.12**			
5	Number of Class I railroads	2.55	2.28	.00	25.00	**.78**	**.69**	**.15**	**.22**		
6	Number of Class II and III railroads	11.54	11.08	.00	68.00	**.31**	**.55**	**.08**	**.77**	**.21**	
7	Herfindahl–Hirschman Index (0–100)	48.02	23.69	6.09	100.00	**-.48**	**-.55**	**-.05**	**-.36**	**-.61**	**-.41**

Notes: n = 8,113. 51 states and 164 quarters. Correlations significant at $p < .05$ are in bold.

TABLE 5

Description and Data Source for the Control Variables

Variable	Description	Data Source
Number of accidents	The total number of accidents occurring in a state per quarter	Federal Railroad Administration
100k mileage	The mileage all freight trains traveled in a state in a given quarter, measured in 100k of miles	Federal Railroad Administration
Unemployment rate	The percentage of the labor force that is currently unemployed in a given state at each quarter	Bureau of Labor Statistics
Labor force 100k	The total labor force is the number of currently employed plus the number unemployed, measured in 100k people	Bureau of Labor Statistics
Number of Class I railroads	The number of distinct Class I railroad companies operating in a state in a given quarter	Federal Railroad Administration
Number of Class II and III railroads	The number of distinct Class II and Class III railroad companies operating in a state in a given quarter	Federal Railroad Administration
Market consolidation	$HHI_{s,q,t} = \sum_{i \in N_{s,q,t}} s_{i,s,q,t}^2$, is the Herfindahl–Hirschman Index in state s in quarter q in year t. This sums across all railroads i operating in that state-time, $N_{s,q,t}$. The market share for railroad i in that state-time, $s_{i,s,q,t}$, is the fraction of state mileage in that period that railroad i operated	Federal Railroad Administration

TABLE 6

Confounds, Their Consequence, and Strategy to Address Them

	Confound	Consequence	Strategy
1.	Technology	Major changes in technology can affect the level of activity and the safety	Year FE, Year*Region FE
2.	Legislation	Federal regulation affects all regions equally	Year FE, Year*Region FE
3.	Geography	Mountains difficult to traverse	State FE
4.	Activity/Demand	Activity is shifting to safer areas, so we just see less safe rails used less	Seasonality, State FE, Year FE, Year*Region FE, Mileage, Unemployment Rate, Labor Force
5.	Experience of Trains/Learning	Trains get safer over time and better at business just from experience	Year FE, Year*Region FE
6.	Shifting population centers	Population increase in regions cause shifting demand. Like “Activity/Demand” section	Year FE, Region*Year FE, Labor Force
7.	Extreme Weather	Weather impacts the demand and the safety	Seasonality, Year FE, Year*Region FE
8.	Intermodal Competition	Less safe demand shifts to other modes of transportation. We would expect this to be permanent	Year FE, State FE, Seasonality, Year* Region FE

TABLE 7
Association Between Accidents and Consolidation Over Time and Across Regions

	Market Concentration	Obs	Mean Quarterly Accidents	Std. Dev.	Correlation
Overall	Low	4057	28.44	32.19	-.48
	High	4056	7.88	6.92	
Region 1	Low	619	9.26	14.53	-.26
	High	618	3.13	4.02	
Region 2	Low	551	27.38	32.87	-.48
	High	551	5.17	5.38	
Region 3	Low	656	23.82	23.53	-.47
	High	656	9.76	6.31	
Region 4	Low	410	54.07	52.33	-.56
	High	410	18.34	12.89	
Region 5	Low	410	49.75	41.30	-.55
	High	410	12.39	7.88	
Region 6	Low	410	32.86	25.56	-.52
	High	410	17.68	7.24	
Region 7	Low	345	25.03	23.47	-.56
	High	345	4.77	4.06	
Region 8	Low	656	14.29	11.15	-.50
	High	656	6.32	5.85	
1975–1979	Low	399	81.01	53.72	-.61
	High	398	20.05	18.28	
1980–1984	Low	494	42.53	33.98	-.55
	High	494	9.85	9.02	
1985–1989	Low	479	21.65	18.04	-.55
	High	479	7.22	5.45	
1990–1994	Low	488	18.99	16.68	-.53
	High	487	6.92	5.87	
1995–1999	Low	488	18.43	15.76	-.48
	High	488	7.56	5.80	
2000–2004	Low	496	22.40	19.82	-.46
	High	496	8.29	6.23	
2005–2009	Low	500	19.27	19.50	-.43
	High	500	8.04	6.30	
2010–2014	Low	510	13.61	13.78	-.44
	High	509	5.40	4.42	
2015–2016	Low	204	12.21	13.85	-.44
	High	204	4.54	3.98	

TABLE 8

The Association of Accidents per State-Quarter with Market Consolidation

Variables	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4	(5) Model 5	(6) Model 6
Herfindahl–Hirschman Index (0–100)	-0.298***	-0.267***	-0.219***	-0.0977***	-0.0980***	-0.0546**
	(0.0568)	(0.0554)	(0.0514)	(0.0335)	(0.0336)	(0.0248)
100k mileage		0.404***	0.336***	0.229**	0.229**	0.174***
		(0.139)	(0.130)	(0.102)	(0.102)	(0.0622)
Number of railroads		-0.684**	-0.562	-0.527*	-0.524*	-0.199
		(0.283)	(0.391)	(0.283)	(0.282)	(0.240)
Unemployment rate		0.0615	-0.199	-0.946*	-0.949*	-0.660
		(0.226)	(0.231)	(0.548)	(0.549)	(0.532)
Labor force 100k		-0.357***	-0.898***	-0.296**	-0.296**	-0.546***
		(0.0927)	(0.180)	(0.127)	(0.126)	(0.166)
Intercept	32.25***	36.39***	40.84***	59.27***	59.75***	27.72***
	(4.269)	(6.418)	(7.045)	(7.537)	(7.546)	(5.784)
Observations	8,113	8,113	8,113	8,113	8,113	8,113
Number of states	51	51	51	51	51	51
State FE			Yes	Yes	Yes	Yes
Year FE				Yes	Yes	Yes
Seasonality					Yes	Yes
Year*Region FE						Yes

Robust standard errors are in parentheses.

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

TABLE 9
The Association of Class I Accidents per State-Quarter with Market Consolidation

Variables	(1) Class I's Only	(2) Fatal Accidents	(3) Post 1990	(4) Monthly	(5) Half-Yearly	(6) Yearly	(7) Allocate by Population	(8) Employee Hours
Herfindahl–Hirschman Index (0-100)	0.162***	-0.000223	-0.0216***	-0.0217***	-0.0971*	-0.258*	-0.0381*	-0.0421*
	(0.0483)	(0.000216)	(0.00839)	(0.00621)	(0.0526)	(0.135)	(0.0199)	(0.0241)
100k mileage	0.0338	-5.45e-05	0.119***	0.175***	0.181**	0.176	0.289***	0.347***
	(0.0477)	(0.000422)	(0.0282)	(0.0353)	(0.0897)	(0.114)	(0.106)	(0.113)
Number of Class I railroads	6.758***	0.00371*	0.0344	-0.0286	-0.496	-1.216	-0.187	-0.171
	(1.378)	(0.00211)	(0.0687)	(0.0729)	(0.529)	(1.150)	(0.255)	(0.191)
Unemployment rate	-0.684	-0.00487	0.0151	-0.208	-1.294	-2.188	-0.699	-0.626
	(0.435)	(0.00503)	(0.231)	(0.168)	(1.134)	(2.662)	(0.501)	(0.489)
Labor force 100k	-0.278***	-0.00235	-0.126	-0.194***	-1.045***	-1.990***	-0.808***	-0.386***
	(0.0963)	(0.00322)	(0.0901)	(0.0548)	(0.346)	(0.757)	(0.228)	(0.135)
Intercept	-9.956	0.257***	7.914***	9.296***	54.15***	110.4***	34.47***	19.98***
	(7.656)	(0.0903)	(2.358)	(1.656)	(12.53)	(27.64)	(6.245)	(5.976)
Observations	7,071	8,113	5,370	24,114	4,068	2,038	8,113	8,113
Number of states	50	51	51	51	51	51	51	51
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Seasonality	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes
Year*Region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors are in parentheses.
****p* < 0.01, ***p* < 0.05, **p* < 0.1

Table 10
Mediation Results of the Herfindahl–Hirschman Index on Number of Accidents

Mediator	Total Effect	Direct Effect	Indirect Effect	% Mediated	Bootstrap's Direct Effect 95% Confidence Interval	Bootstrap's Indirect Effect 95% Confidence Interval
Capital expenditures	-0.81	-0.27	-0.54	66.7%	-.46 to -.11	-.75 to -.38
Employee hours	-0.81	-0.18	-0.63	77.5%	-.43 to .15	-.91 to -.42
Switching mileage	-0.81	-0.26	-0.55	68.2%	-.50 to .06	-.81 to -.35

TABLE 11
Accidents and Costs for 4 Largest Railroads and Industry Average, 2015

Railroad Company	Number of Accidents	Total Costs ($ Million)	Average Cost per Accident ($ k)
UP	660	121.51	184.10
BNSF	492	112.43	228.51
CSX	381	33.80	88.71
NS	259	31.38	121.14
Industry total	2409	409.42	169.96

Figure 1: U.S. Freight Traffic (Million Ton-Miles) by Mode

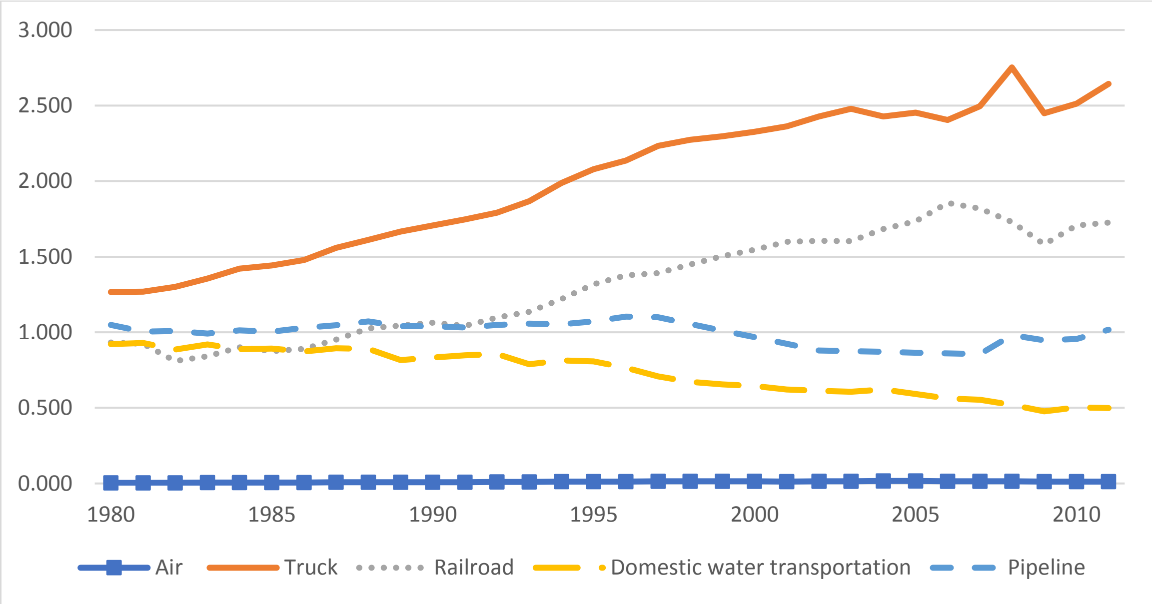


Figure 2: Regional Designation of the Federal Railroad Administration

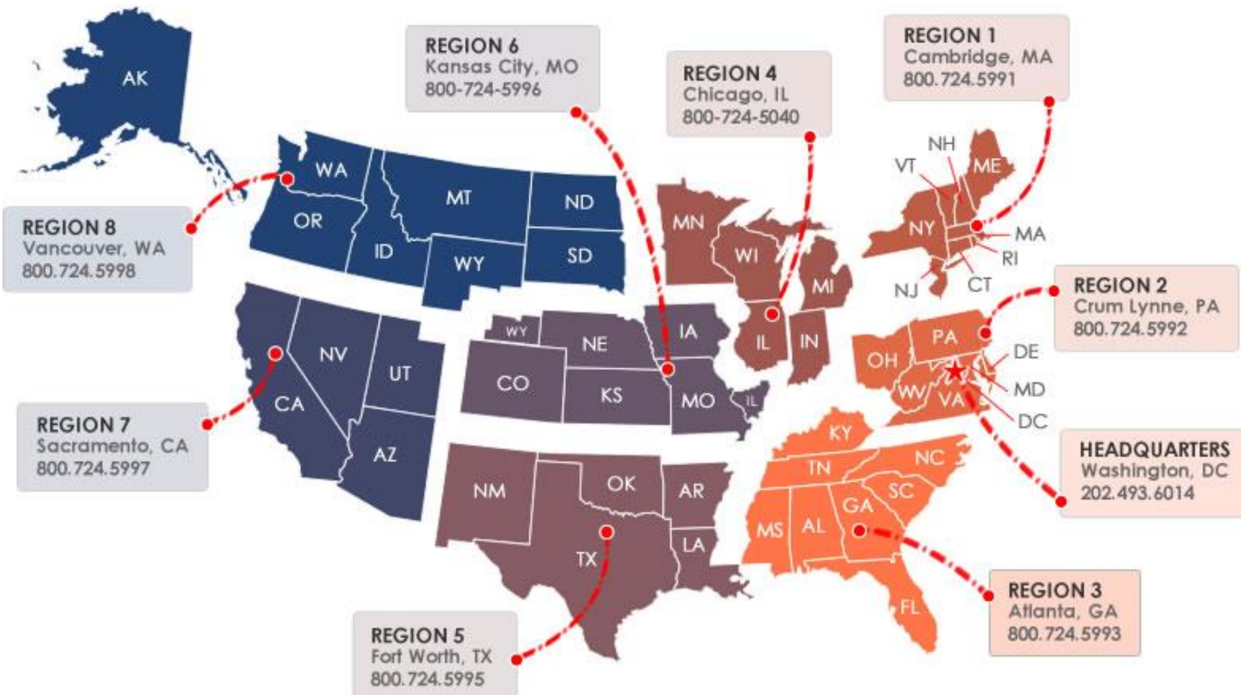


Figure 3: Miles, Accidents, and Miles per Employee Hour (1975 Level = 100)

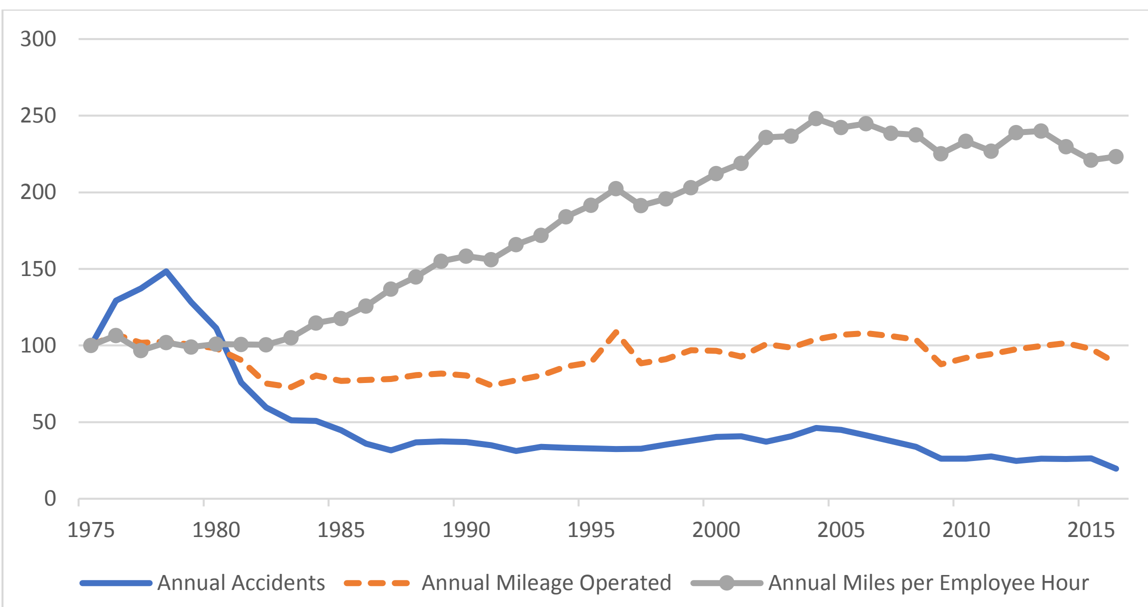
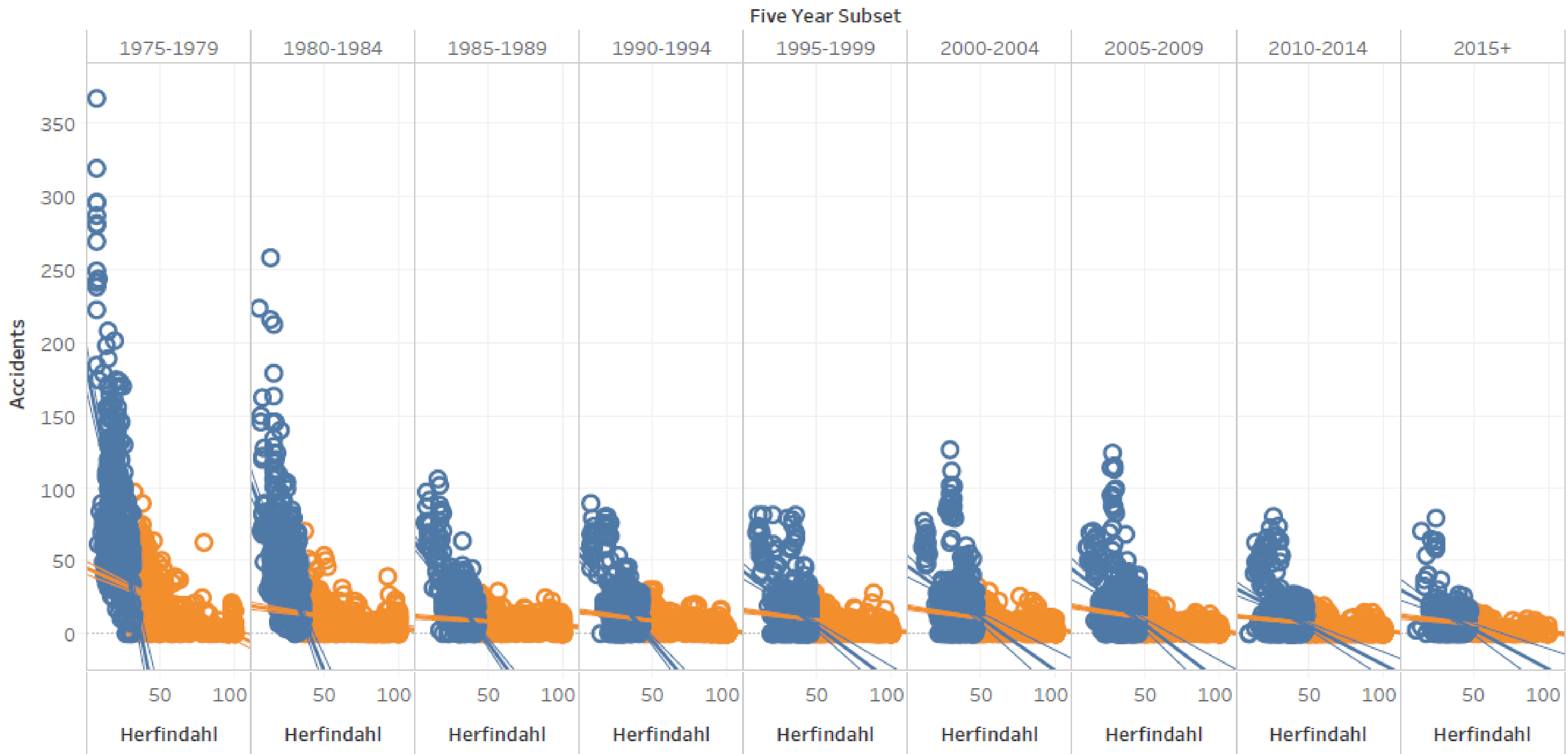


Figure 4: Scatterplots of Herfindahl and Accidents by 5-Year Subsets



The y axis is number of accidents per quarter. Within each five-year subset, higher HHI levels are associated with fewer accidents. The trend line for lower HHI levels (in dark) is much steeper than at higher HHI levels. Over time, there is a general decrease in the number of accidents