The Economics of Safety: How Compensation Affects Commercial Motor Vehicle Driver Safety

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Executive Summary

On June 1, 2011 a discount intercity bus carrying 59 people to New York's Chinatown crashed, killing four people and injured more than 50 others. The carrier had a long history of violations and crashes and a safety rating far worse than the rest of the intercity bus industry. A driver fatigue rating of 86 on a scale of 1 to 100 meant that before the crash, federal officials had rated it among the most unsafe bus carriers. Its driver fitness rating of 99.7 meant that it ranked in the bottom 1%.

Sky Express should not have been on the road and after the crash the FMCSA gave it an unsatisfactory rating and banned it from interstate service. Though the ban was too late for the victims, under US regulations this still did not prevent the company from continuing to operate intrastate. Safety advocates' calls to require seatbelts, stronger roofs, more driver training, and other regulatory changes do not address the problems that led to the crash and would not prevent future crashes.

Intensified competition created by deregulation, without proper safeguards, created this safety problem. We do not have to repeal deregulation to solve it, but we have to address the problems this intense competition creates. If insanity is "doing the same thing over and over and expecting a different result", we are insane. Preventable crashes like this will happen again for the same reasons, regardless of how many times we rework the algorithms of CSA or scrap it and replace the entire program altogether. In short, the safety problems that CSA attempts to address will not be remedied until we begin to address the systemic problems in the trucking industry.

I have examined the link between commercial motor vehicle (CMV) driver compensation and work pressure, and driver safety. Research establishes a pay-safety link that is important for policy because it shows that economic forces inherent in transport competition tend to produce unintended safety and health consequences drivers and passengers.

My full report on the economics of safety applies to both truck and bus. Transport deregulation brought lower consumer prices, but this bus crash showed the dark side. Deregulation has increased competition among carriers in all modes hauling both passengers and freight, and reduced compensation. CSA in its current form places pressure on drivers without addressing underlying causes. In the trucking industry, inadequate compensation for drivers causes a misperception of a driver shortage that isn't there, and causes many to look for cheaper labor, such as that found in Mexico. Everyone who has passed introductory economics knows that more drivers will be attracted to trucking by a better job package, including compensation. Opening the border to Mexican truck drivers will bring more of the same, as Mexican drivers compete with American small business drivers and employees at ¼ the cost, intensifying competition among US motor carriers and lowering driver hiring standards. No regulation can overcome the effect of markets that drive down price.

This creates a sustainability problem. The CMV driver's workplace is the public highway and unsafe drivers become a public hazard—what we call a "negative externality". While people buy transport services for an apparent market price, it does not include safety and health cost. Economic efficiency requires that price incorporate all costs and benefits associated with commercial movement, and failure to incorporate the full safety and environmental cost sends incorrect signals to the market, creating an implicit public subsidy of unsafe operators.

If the insurance market worked perfectly, the risk associated with low-paying carriers would show up in higher cost insurance. This market does not work well because insurance companies cannot rate motor carriers and charge accordingly. Big crashes are low-probability, high-impact events that insurance companies don't like. FMCSA regulations only require truckers to carry $750,000 of insurance per incident.

Economic forces play a strong safety role because carriers that pay more money can hire better drivers. Efficiency wages paid by these carriers leads to better performance because drivers know that their jobs are better than their alternatives, providing incentives to drive safely.

These findings are consistent with economic theory because we expect that carriers pay drivers their market value, determined by their personal employment history, driving record, training and education, experience, driving skills, temperament, and other factors. These factors explain the differences in safety outcomes.

For every 1% in pay, we have found 1% to 4% better safety. Higher pay produces better carrier and driver safety. We don't yet know whether safety pays, but clearly driver pay strongly predicts safety.

Low price doesn't necessarily mean low-cost. Since in an efficient market, price should include all costs, the environmental and safety costs associated with cheap labor and cutthroat competition create unsustainable supply chains that make everyone less well off.

Three solutions would go a long way to resolve this problem.

1. Get government regulators out of their silos. FMCSA and the Department of Labor should cooperate with the industry to engage in a dialogue to promote economic conditions that improve highway safety. The DOL has the authority to regulate compensation and perhaps it is time to reconsider certain exemptions for the trucking industry under the Fair Labor Standards act.
2. Implement Chain of Responsibility regulations like those enacted by the Australian Parliament to create a level playing field in a deregulated environment. The owner-operator model is a valuable one and we need to

preserve small businesses in the trucking industry. Other nations, like Australia, maintain a deregulated industry while supporting small business truckers and without compromising safety. One way to do this is to address underlying systemic problems such the failure to pay truckers for loading and unloading.

3. Tighten regulations on subcontracting that balances the power between contractors and trucking companies, as Australians have done. Court rulings 40 years ago usurped legislative authority, disallowing traditional cooperation among owner-drivers to negotiate with carriers. This would give owner-drivers a fair shake. In short, help level the playing field by giving small businesses more negotiating power to keep costs low and safety benefits high.

The Economics of Safety: How Compensation Affects Commercial Motor Vehicle Driver Safety

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Commercial motor vehicle (CMV) drivers usually paid on a piecework basis, which is a source of confusion and misunderstanding for public policy makers. While this is almost universally true for intercity truck and bus drivers, it has become routine in recent years to pay local drivers – especially owner-drivers – a flat rate per move or a percentage of revenue earned by the shipment, rather than an hourly wage. Generally road drivers are paid by the mile (or a percentage of revenue) and not paid for loading, loading, and other delays (Burks et al. 2010). This leads to strong incentives to lie on one's logs, logging only "paid" time (driving time) on duty and logging all other work time as "off duty" in order to conserve hours available to work. Since surveys suggest that 25% of the average driver's day is unpaid non-driving time, this can easily mean that truckers can drive as much as eleven hours and work an additional three hours more than they log every day, and still appear to be legal. But they're not. This undocumented fatigue and documented work pressure contributes substantially to crashes.

I. Introduction

Compensation can influence worker behavior in several ways. Yellen suggests that an employer paying higher than average "efficiency" wages (wages above the market-clearing level that serve to attract a superior workforce) will discourage workers from "shirking", or failing to put full effort into their work, since losing their job imposes a cost on the worker (they reduce their chances of getting another good job and risk sinking to a lower tier company). If the cost of monitoring workers is higher than that of increasing wages, Yellen argues that this can be a cost-efficient way for the employer to elicit effort from workers (Yellen 1984). In addition to the level of compensation, the type of payment also can influence worker behavior. The "piecework" payment system has a long history of providing an incentive for workers – especially transport workers in general and contract workers in specific – to increase their effort (Belzer 2000, 2011). While the efficiency wage argument appeals to the longrun interest of the worker to maintain employment, the piecework system is designed to create an immediate incentive to increase production by paying higher wages to those workers who are more productive.

Almost all both truckload (TL) and less-than-truckload (LTL) intercity drivers are paid by the mile or in some manner by the load, rather than an hourly wage. This method of pay is so pervasive that in the industry, mileage often is the sole determinant of compensation, regardless of what other work the driver does.

The treatment of loading and unloading time is a good example. Drivers frequently wait long periods of time for their loads, and in many cases must load or unload their own freight. However, these drivers are underpaid, relative to the value of their driving time, or not paid at all, for this work. This paper raises the hypothesis that while these compensation practices may be useful in getting drivers to work harder, they also create incentives that threatens public safety and security (Belzer and Swan 2011).

Both the method and level of compensation in the trucking industry create short-run economic incentives that may lead to unsafe driving practices. These behaviors may include neglecting safety inspections and repairs as well as driving too fast for conditions (and faster than legally allowed). Because long work hours, especially when driving, is associated with intensified health and safety risks, truck drivers' hours of driving and hours of work ("hours of service", or "HOS") have been limited since the 1930s (Belzer 2008; Belzer et al. 1999; Belzer et al. 2002; for a brief history of this regulatory framework, see Belzer 2000).

Piecework compensation practices, along with unpaid non-driving labor time, can lead drivers to work more than the number of hours allowed by the hours-of-service rules. Drivers may require a minimum or 'target' level of income that is necessary in order to meet basic living expenses. If the mileage rate is sufficiently low so that this target cannot be reached, drivers may feel compelled to work more hours than legally allowed, and economic theory supports this expectation. The risk created by these incentives may be greater under conditions where non-driving time earns a lower rate per hour relative to that earned when driving, or not paid at all for loading and unloading. In these instances, there is an incentive to underreport the amount of time spent on the lower- or un-paid loading time in order to conserve available hours for the relatively higher paid driving time. This underreporting of loading and unloading time, combined with additional driving time to make up for this unpaid time, means that drivers might often work – and drive – more hours than allowed by law.

While this may provide short-run economic benefit to the drivers, in the end it would cause truck drivers to provide an excessive supply of labor to the marketplace for a fixed number of workers, driving wage rates down and encouraging additional hours of work. Given a fixed labor market, each individual driver will tend to work more hours than allowable and this "sweating" of labor will encourage each individual driver to work even harder and longer, increasing the number of hours provided to the market and effectively expanding the labor market artificially, increasing all drivers' crash risk accordingly. These longer hours create safety concerns that affect not only the industry but the broader population as well. If the market for individual driver services insufficiently captures the cost of this additional safety hazard, it would create a market imperfection that might have significant policy consequences. In short, low driver wages and poor working conditions impose a real and tragic cost to the nation through decreased highway safety.

II. Theory and Evidence

Introduction

Employee earnings levels and the method of compensation likely have an influence on employee behavior. This research shows that the level and method of compensating truck drivers affects their driving and non-driving behavior, which ultimately influences their involvement in crashes.

Truck driver attitudes and behaviors have been studied in various contexts. In most cases, the motivation for these studies is to understand the immediate mechanisms that influence certain driver behaviors. These studies, however, often focus on particular behaviors (e.g., speeding, working – and especially driving – excessively long hours, and not getting enough sleep) rather than confronting the factors that motivate such behaviors at different organizational levels. Such factors can include economic pressures, personal characteristics, pay rate, and the compensation method itself, among others.

From the driver's perspective some consideration has been given to the compensation issue and its influence on safety. Pay level has been studied more consistently than pay method. Low levels of pay have been considered by many as a motivator of long driving hours, illegal substance use, the onset of fatigue, and other practices and phenomena (General Accounting Office - U.S. Congress 1991; Hensher et al. 1991; Saccomanno, F. F., Craig, and Shortreed 1997). Other studies, however, have suggested that truck driver compensation level has a less important role than the one regularly attributed to it (McElroy et al. 1993).

Groups of drivers participating in different focus groups have characterized the prevailing piece rate (per mile) compensation method as limiting income and encouraging cheating (Cadotte, Sink, and Chatterjee 1997; Mason Jr. et al. 1991) . Drivers readily identified the compensation system in place as a motivation for unsafe driver behavior. Piece rate systems coupled with hours of service regulations limit the income opportunities of drivers (Chatterjee et al. 1994). Forty-five percent of respondents to a New York State driver survey thought it would be useful to pay by the hour in order to reduce driver drowsiness (McCartt, Anne, Hammer, and Fuller 1997b).

Management also has recognized the importance of better understanding driver compensation. A 1995 mail survey of 1,464 drivers at 57 for-hire truckload dry van, flatbed, refrigerated, and tank carriers showed that an overall driver compensation factor emerged as the important dimension for human resources improvement (Stephenson Jr. and Fox 1996). Similarly, in a survey of 148 trucking company personnel managers, other researchers found that managers believed that pay level was the most important factor in drivers' choice of motor carriers for employment (Southern, Rakowski, and Godwin 1989).

Work pressure and economic pressure have contributed to workplace hazards and even "disasters" across many industries and countries. A recent report on the Massey mine explosion, for example, points directly to the role of economic pressure and the very real drive for profits as a primary cause of catastrophic industrial safety failures. A study by the West Virginia Governor's Independent Investigation Panel charges that the 2010 explosion that claimed the lives of 29 miners was an entirely preventable disaster that resulted from the fact that "Massey Energy put coal production ahead of safety" (Berkes 2011; Governor's Independent Investigation Panel 2011). Studies from Australia, which is in many ways similar to the United States, have consistently found economic pressure to be the root cause of safety problems in the trucking industry (Quinlan 2001; Quinlan, Mayhew, and Johnstone 2006). The same economic pressures have been found to be at the root of major safety failures in Australian mining (Quinlan 2007; see especially paragraphs 818 and 836), U.S. oil extraction (Crooks 2011; National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling 2011; Urbina 2010), and in airlines (National Transportation Safety Board - U.S. Department of Transportation 2010; Young 2010)

The Role of Employee Compensation

Compensation generally acts as a pricing mechanism, but compensation's impact on employees, especially drivers, is much more complex. As a method of allocating resources, employee earnings are a pricing mechanism used to direct labor to its most productive use. This function, very much in line with traditional microeconomics, explains variations in the distribution of earnings as emerging from the interactions of supply and demand where certain observable characteristics are taken into account.

A second role of compensation is to serve as a tool for social stratification and cohesion. In this role, employee earnings are seen as a prime determinant of standard of living. Earnings play the role of providing social legitimacy within organizations and society. Compensation policies play a role in determining what is a "fair" wage level (Akerlof, Rose, and Yellen 1988; Akerlof and Yellen 1988, 1990).

No previous study has utilized efficiency wage theory to explain CMV driver safety. Compensation can serve as a management tool to elicit higher employee effort and align employees' core skills with the organization's interests. Multiple theories attempt to explain the role of pay in the employment relationship. They include the transaction cost perspective (Williamson, Oliver E. 1975), where opportunistic behavior is to be minimized, as well as the efficiency wage approach (Holzer 1990; Lazear 1990; Weiss 1990; Yellen 1984), in which above-market wages result in desired behavioral outcomes for a group of employees. These outcomes can range from reduced shirking and enhanced effort (Yellen 1984) to adherence to hours of service regulations, behaviors oriented towards reducing risk of fatigue and dozing while driving, and generally safe-driving behaviors. However, safety research generally has steered toward behavioral explanations and avoided economic explanations, and efficiency wage theory may provide a better explanation for outcomes.

Recent changes in wage structures, such as the impact of economic deregulation, have created increased interest in the roles that compensation plays in society (Rubery, Jill 1997). Belzer traced the post-regulation transition from regulation-related truck industry segmentation to market segmentation, and the resulting impact on industrial relations, including compensation practices. He modeled wage levels as a function of a variety of firm-level factors including industry segment, average haul, unionization, market share, profitability, and location variables such as urbanism and regionalization. Unionization and industry sector (LTL) were most strongly associated with higher wages. He also found that market share affected wages positively (consistent with previous findings) as did location (Southern carriers had significantly lower wages) (Belzer 1995a).

Compensation Level

Compensation level is often framed in the context of a hierarchical conception of pay (Milkovich and Newman 1993), where the compensation system is disaggregated into its fundamental components, such as method, level, changes in earnings over increasing job tenure and similar factors. Employee compensation is understood as the overall employee earnings during a specific period, including direct compensation (e.g., wages) and deferred compensation (e.g., pension plans).

Direct Compensation

Organizations can have varying pay levels, depending on the flow of work and the organization, yet we often observe pay differences between similar jobs in similar organizations (Chen 1992; Leonard 1987; Seiler 1984). Weiss provides a useful summary of issues associated with direct compensation (Weiss 1990). The literature consistently shows that increases in relative wages (after controlling for occupation and human capital) are associated with increases in productivity.

In a series of studies of driver compensation using individual driver-level data, cross-sectional motor carrier data, and individual driver survey data, researchers showed that the relationship between compensation and safety ranges from .92:1 in the cross-sectional study of 102 TL carriers to as much as 4:1 in the firm-level case study of JB Hunt (Rodriguez et al. 2003; Rodriguez, Targa, and Belzer 2006; Belzer, Rodriguez, and Sedo 2002). In the Hunt study, researchers found that for every 10% higher driver pay rate, at the mean, drivers had a 34% lower probability of crash, month-to-month. In addition, for every 10% of pay raise, drivers had a 6% lower crash probability (Rodrigue 2006; Rodriguez et al. 2003; Rodriguez, Targa, and Belzer 2006). In the cross-sectional study, for every 10% higher compensation level for truck drivers working for non-union truckload carriers, the carrier had a 9.2% lower crash rate. The driver's mileage pay rate explained half the difference and other compensation factors explained the remainder (Belzer, Rodriguez, and Sedo 2002). Finally, an individual survey conducted by the University of Michigan Trucking Industry Program showed that at the mean, a 10% higher compensation level predicted a 25% lower crash probability for the year.

There is less agreement about the magnitude of the effects and whether the increase in productivity can pay for the wage increase (Levine 1992). It also is difficult to disentangle cause and effect, or whether the effect is due to selection or performance incentive.

Efficiency wages

A "market-clearing" wage clears the market of unemployed workers – absorbs all available unengaged labor or achieves full employment in a specific labor market – at a compensation level sufficient to attract enough workers to the jobs that pay enough to attract labor to do them. Markets do not clear when companies offer workers a lower package of compensation than they could get doing something else. This is why economists argue that there is no such thing as a "labor shortage" in any labor market but rather a shortage of compensation sufficient to attract labor. As demand for labor increases, companies should be willing to raise wages enough to attract the necessary labor.

Theorists of "efficiency wages" argue that some employers do not pay market-clearing wages. Instead, they offer above market-clearing wages that induce employees to be more efficient. This efficiency increase can occur in several ways.

<u>Reduction in shirking</u>. Since employees have a higher compensation level with efficiency wages than they would have otherwise, the cost of discharge due to shirking behavior is higher. This reduces worker shirking because the job they have already rewards them above the average market-clearing wage for the industry, and if they lose their job because of poor performance they likely will

have to take an inferior job.[2] Some research suggests that greater wage *premia* are in fact associated with lower levels of shirking as measured by disciplinary dismissals (Cappelli and Chauvin 1991; Yellen 1984) . However, shirking and discipline also are dependent on whether a worker sees the relationship between shirking and the difficulty in finding alternative employment (Groshen and Krueger 1990).

Quality of workers. It is reasonable to expect, and empirical research has shown, that high compensation levels attract more qualified workers than do lower compensation levels (Chen 1992; Groshen and Krueger 1990). This is the "creaming effect." Acting as a mechanism for selection, the compensation level attracts more productive employees. Positive consequences often associated with having a more qualified pool of workers include the reduced need to supervise employees and a reduction of employee shirking. For example, Groshen and Krueger found that hospitals that paid high wages to staff nurses employed fewer supervisors (Groshen and Krueger 1990). It is unclear, however, if this is due to greater work effort from the average existing nurse workforce (the efficiency wage) or because higher wages attract better nurses who needed less supervision (the creaming effect).

Turnover costs. Higher wages may tend to reduce turnover. Turnover costs include advertising, search, and training costs (Arnold, Hugh J. and Feldman 1982; Becker 1975; Chen 1992; Cotton and Tuttle 1986; Salop and Salop 1976) One study of high school graduates correlated higher wages with longer job tenure (Holzer 1990). The turnover effects frequently are hard to determine because few companies evaluate their recruiting programs well enough to show that higher wages did in fact allow them to choose superior applicants.

Wage-deferral

Scholars who advance the wage-deferral model argue that, in order to invest in human capital, firms need to obtain long-term commitments from their workers. Firms under-invest in employee training because of the turnover threat. Requiring workers to share in the firm-specific investment in human capital is a way of receiving this commitment. Such a sharing arrangement is achieved, for example, by having workers earn below-market wages during the early years of employment in the firm; during later years they earn above market wage, reflecting a return on this investment. This is similar in nature to the use of deferred compensation to encourage lower turnover, as shown later. Proponents argue that the wage deferral profile can be used to favor older workers (Ippolito 1991), dissuade workers from shirking (Lazear 1979), or attract a higher quality of workers (Salop and Salop 1976).

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[2] In economic language, "shirking" is failure to work to one's maximum capacity or, conversely explained, to reduce one's effort to match one's own image of his/her value. If someone thinks he/she is underpaid, then he/she will "shirk" to reduce output accordingly, in reciprocal fashion.

Incentive theory

Incentive theory is related closely to efficiency-wage theories for motivating higher employee effort. There are several incentive-based theories among which content and process theories are very relevant. Content theories focus on what motivates employees. The two most popular content incentive theories, Maslow's hierarchy of needs (Maslow 1954) and Herzberg's hygiene theory (Herzberg 1966), include pay as an important factor in employee motivation (Milkovich and Newman 1993). In the former, pay supplies a series of basic needs: e.g., the need to acquire food and shelter. Beyond attending basic needs, pay also can be associated with other higher needs, such as recognition and satisfaction at the workplace.

Equalizing differences theory

This theory is based on the thought that low employee monitoring goes hand in hand with low wages. The theory assumes that employees dislike being monitored, and therefore closely supervised workers will insist on higher wages because they need to be compensated for the lack of privacy. The romantic notion of truck drivers as "highway cowboys" who enjoy a high degree of independence to a degree supports the assumption of the equalizing differences theory.

In the context of the trucking industry, the equalizing differences theory may be linked to the argument behind *Pedal to the Metal: The Work Lives of Truckers* (Ouellet 1994), though this link may not be straightforward and may be ambiguous. In his book, Ouellet argues that truck drivers are a unique group with specific tastes that are significantly different from the tastes of the average workforce. Drivers who work for extrinsic value work for the money, and earn more money in trade for greater supervision and lower status equipment. Drivers who work for intrinsic value, on the other hand, will trade substantially lower earnings to get independence. Recent data collected by the author in cooperation with the Owner Operator Independent Drivers Association strongly supports this hypothesis, since they are among the lowest paid truck drivers in the U.S. (Belzer 2006), although this same result may be attributable to the myth of the "American Dream" (Chinoy 1965) or the need to "buy" a job, since a substantial fraction of trucking has shifted to subcontractors across many sectors.

Fair wage theory

This is yet another conception of efficiency wages based on the idea that "fairness" provides explanations for (a) wage compression, (b) the positive correlation between industry profits and industry wages, and (c) the inverse correlation between unemployment and skill. The fundamental hypothesis is that in industries where it is advantageous to pay some employees highly, it is considered fair also to pay other employees well and hence the "fair wage/effort hypothesis" (Akerlof, Rose, and Yellen 1988; Akerlof and Yellen 1990; Milkovich and Newman 1993; Rice, Philips, and McFarlin 1990). In other words, in some industries and firms, high wages paid to one group must also be paid to another or tensions may arise due to the perceived inequity. Other theories incorporating the notion of fairness and similar social norms include the rent-sharing (Levine 1992) and reciprocal-gift models (Burks 1999; Milgrom and Roberts 1992). .

Compensation Method

We now move from compensation level to the way workers are compensated. Compensation methods that deviate from the traditional time rates and salaries have become more popular. Most of these new compensation methods attempt to align the employee's interests with those of the firm. While performance-based methods have a long history in some areas of manufacturing, the have become increasingly common in other industries and particularly in the service sector. Piecework, where pay is related directly to specific units of output, is a common performance-based pay measure, as is incentive pay, which provides bonuses for meeting or exceeding a target output. In the next section we focus on piece rates and time rates and their implications for individual and firm productivity. We focus on these two methods of direct compensation because of their prevalence in the trucking industry.

Direct Compensation

Applied at the individual level, piece rates give individual financial recognition to more productive or harder-working employees who are thus encouraged to work more intensively. Because they are tied so closely to output, piece rates provide incentives for employees to exert themselves to produce more output and generate firm revenues.

Research on compensation methods and piece rates vis-à-vis time rates has developed over nearly 40 years (Keselman, Wood, and Hagen 1974). In most of the work reviewed, individuals receiving pay contingent on performance were more productive than individuals on a time-pay basis (Fernie and Metcalf 1996; LaMere et al. 1996). For example, in a recent study of tree planters in British Columbia, workers compensated under piece rates produced more, on average, than those on time rates. Interestingly, however, the productivity of piece-rate planters fell with the number of consecutive days worked; a similar result was obtained in a study of copper miners (Paarsch and Shearer 1997; Shearer 1996). This result becomes especially important in understanding the effects of long daily and weekly working hours on the trucking industry, in terms of both driver productivity and safety.

If piece rates produce higher output, one would think this should be reflected in higher worker earnings. In a study of over 100,000 employees in 500 firms within two industries, Seiler (1984) examined the effect of piece rates on employee earnings and the impact of incentives on earning. He observes two incentive effects. First, incentive workers' earnings are more dispersed (i.e., the distribution is wider) than identical hourly workers' earnings. Second, on average the incentive workers earn 14% more money, controlling for other factors. This premium is partly a compensation for the greater variation in their income and partly a result of an incentive-effort effect (Seiler 1984).

Two interesting questions emerge from these results. First, does contingent pay, or more broadly, do productivity-based incentives, actually increase productivity (the motivation effect) or do they simply attract the most productive workers (the sorting or selection effect) because they seek the opportunity for greater earnings given their current level of human capital (Blinder 1990; Lazear 1995)? This is similar to the issue raised by compensation-level affects on workers' productivity and behavior. Second, the contingent pay passes part of the earnings risk to workers. Therefore, risk-averse workers may prefer time-rates, which further strengths the sorting mechanism described above.

Advocates of the sorting effect argue that piece rates differentially attract workers who are harder working, or who are more productive, than are those attracted by hourly rates, *ceteris paribus*. By eliciting higher effort levels, the effect of piece rates on earnings produces an "earnings effect." Piece rates also affect other non-earnings situations. For example, a break or a visit to the restroom has a high opportunity cost for the employee working in a piecework compensation system; for a truck driver, who earns his living only when the wheels turn, a rest-stop or "pit stop" during the day has a substantial productivity and hence earnings cost. Therefore, given the choice, people who are more apt to increase effort intensity and effort duration may choose piece rate methods, while individuals who value the negative non-earning consequences more than the positive earnings consequences of piece-rates may tend to select time-based pay schedules. In a study of agricultural workers, Rubin and Perloff found that the non-earnings effect captures the change with age in a worker's relative taste for piece rate work. For the very young and very old, the non-earnings effect of age dominates the earnings effect (Rubin and Perloff 1993). For trucking, with almost all intercity drivers and an increasing fraction of intracity drivers working on incentive-based pay systems, the "choice" may be to accept the piece rate system or choose another line of work.

Piece rate compensation is attractive to business because it seemingly solves the problems associated with adverse selection and moral hazard.[3] In addition, by paying piece rates, the firm allows workers to receive the full value of their own marginal product, thereby eliminating some of the firm's *a priori*

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[3] In economics, "moral hazard" is the tendency of people to spend more of the money that is not theirs or the time for which they do not pay. Moral hazard cuts both ways, however. From the employer's perspective, shirking is a moral hazard. From the employee's perspective, unpaid time is a moral hazard. From the trucking firm's perspective as well as from the driver's perspective, unpaid loading and unloading time and shipper or consignee delays are moral hazards. Shippers and consignees will waste such time because they do not pay for it.

need for information on productivity, thus reducing monitoring costs (or transferring that cost to the worker). Arguably, these incentives may also reduce the need for employee monitoring and observation to determine individual merit or performance pay necessary when using other compensation systems.

Piece rate compensation, however, can bring some disadvantages. As indicated above, it introduces a source of randomness into workers' earnings. In addition, piece rates alone encourage employees to ignore other valuable activities. As a result, piece rate workers are tempted to reduce quality to increase measured quantity and engage in other non-productive activities (Burawoy 1979). Another commonly cited disadvantage of piece-rate compensation is the difficulty of observing actual productivity (information and observation problems), which may lead to shirking behavior in the short term (Gibbons 1987).

Bloom and Milkovich suggest that adverse selection and moral hazard, as described above, only tells part of the story of the effects of piece rates. The problem is one of "principals" and "agents", where the firm is the principal and the employee or subcontractor is the agent. That is, firms might act to align the workers' interest with their own through the use of payment incentives, but its effect on agent behavior may be more complex than typically assumed by agency-based research. The incentives and earnings risk-sharing tradeoff, for example, might lead to the imposition of "greater uncertainty in the employment relationships" or other adverse outcomes (Bloom and Milkovich 1995). Other responses to incentive payments may also affect the individual and organizational climate. We review these in subsequent sections.

A 1991 National Research Council Panel study commissioned by the U.S. Office of Personnel Management to assess the contemporary research literature on employee job performance and performance-based pay concluded that individual incentives (including piece-rates) can have positive effects on performance, though the context of implementation remains important (Milkovich et al. 1991). The report cites some negative consequences of incentive pay, including the neglect of aspects of the job not covered in the incentives, encouraging gaming or reporting of invalid data, and a potential clash with group norms (as suggested by Burawoy above). Scholars conclude that individual incentive plans are inappropriate in the presence of high task complexity (Brown 1990, 1992) and the focus on quality rather than quantity. For trucking, of course, the safety risk associated with piecework has been a long-standing issue.

There is limited literature associating compensation methods and safety outcomes. Hopkins, as cited in Hofmann, argued that incentive pay was not the root of unsafe behaviors in several coal mines studied (Hofmann, Jacobs, and Landy 1995). Instead, the organizational climate fueled unsafe behaviors, as did the workers' perceptions of the nature of the job (e.g., being unmanly to be careful and safe) (Hofmann, Jacobs, and Landy 1995); Ouellet alludes to this paradox in his research on truckers' culture (Ouellet 1994).

Research on safety in the trucking industry has shown that compensation level, however, is associated with safety, as drivers will tend to work exceedingly long hours when compensation is low – contributing to safety risk – and the ability to earn substantially more than in a comparable hourly-paid job simply by sweating one's labor and working more hours will make the industry attractive to workers who cannot get comparable earnings elsewhere (Belzer, Rodriguez, and Sedo 2002; Rodriguez et al. 2003; Rodriguez, Targa, and Belzer 2006).

Deferred Compensation

The lower labor turnover found in large firms relative to smaller firms has been cited by some as evidence that large firms pay workers above their opportunity cost (Even and Macpherson 1996a). Large firms, they argue, can afford efficiency wages. Several studies have disputed this claim by investigating an alternative possible explanation: size-related differences in the availability, portability, or generosity of pension plans (Even and MacPherson 1996b). Pensions, as wage-tilts discussed in the previous section, can be a mechanism for encouraging long-term employment relationships beneficial to firms. Other mechanisms, such as up-front fees and bonds, are rarely actually observed, but steep age-earnings profiles and deferred compensation plans are equivalent to bonding in their effects on behavior. Several scholars argue that deferred compensation (e.g., pension plans, profit sharing, contribution thrift, ESOPs) directly substitutes for employee wages (Lazear 1979, 1995; Salop and Salop 1976). Arvin argues persuasively, however, that in imperfect capital markets where individuals cannot borrow freely, deferred compensation and wages are not perfect substitutes (Arvin 1991).

Research in the worker mobility literature finds lower turnover in jobs covered by defined benefit pensions than in other jobs. Turnover is only about half as great for workers covered by pension plans as for workers without pensions, supporting the hypothesis that pensions (which act as deferred compensation) discourage turnover. This relationship remains consistently strong even after controlling for other factors such as pay level, union membership, and tenure (Gustman and Steinmeier 1994). Ippolito found that pensions increased tenure in the firm, on average, by more than 20 percent (Ippolito 1991). Lazear argues persuasively that the pension plan's vesting provisions affect turnover the most and constitute the real incentive effect (Lazear 1990). Other research shows that capital loss is the main factor responsible for lower turnover in jobs covered by pensions, but self-selection and compensation levels also play an important role. Allen provides direct evidence that bonding is important for understanding long-term employment relationships (Allen, Clark, and McDermed 1993).

This research on truck driver pay and safety will support these findings, with the added caveat that few non-union truckload drivers and virtually no owner-drivers can look forward to pensions. Their current rate of turnover, in excess of 130% per year, supports this hypothesis as well. In sum, the only truck drivers with defined pension benefits today work for unionized – generally Teamster – motor carriers, and those pensions are at risk due to declining participation rates at a vanishing number of unionized carriers. While one may argue that deunionization has pushed the argument to the margins, the high truck driver turnover rate and the alleged "truck driver labor shortage" (Global Insight Inc. 2005) have helped to exacerbate the safety problems that safety advocates have articulated.

A self-selection concern similar to the effect of efficiency wages also occurs with pensions. Employees prone to have lower career mobility (such as truck drivers) would tend to prefer deferred compensation. The study cited above found virtually no association between firm size and labor turnover for workers not covered by a pension (Even and Macpherson 1996a).

Two alternative interpretations are plausible. First, larger firms may tend to select a method of compensation (Soguel 1995) that actually increases turnover and crash rates (Brown 1990, 1992). Second, pensions were not included in the study, so the correlation may be a result of the mere existence of a pension plan or its vesting characteristics (Lazear 1990, 1995).

Several unresolved questions about deferred compensation remain. First, the pension loss involved in quitting could be offset by a salary increase. This means that deferred compensation is relevant in the context of the entire level of compensation. Some scholars argue, for example, that firms offering deferred compensation tend to have higher compensation levels overall. For this reason, perhaps it is not the existence of deferred compensation (which is merely a compensation method), but its existence in the context of other compensation and the overall level reached (Gustman and Steinmeier 1993). Second, low turnover rates have been observed for employees under both defined contribution and defined benefits plans, which suggests that pension portability is not an issue but rather this may reflect an unobserved sorting mechanism that is causing the turnover reduction (Arvin 1991). This may be an issue in trucking, however, since turnover generally is high in the non-union TL sector and therefore drivers may be unable to vest and to take advantage of defined contribution pensions (Belzer 2000). In other words, it may not be the presence of a pension plan but rather the individual's anticipation of a pension (or anticipation of the absence of a vested pension) that may govern turnover.

Finally, this discussion has assumed that compensation levels and methods are independent of one another. Chen tested inter-industry wage differentials across different methods of pay. He argued that his evidence showed that efficiency wage considerations are less important for piece-rate wages than for time-rate wages under three efficiency-wage-related models:

adverse selection or worker-quality, turnover, and shirking models. In the main, he concludes that industry wage differentials are less prominent in piece-rate compensation (Chen 1992). The importance of this finding will be apparent in subsequent sections.

Other studies assume that compensation method is an exogenous variable. A limited number of studies viewed compensation method as a firm policy variable (Brown 1990, 1992; Gustman and Steinmeier 1994). Along these lines, Brown found lower inter-industry wage differentials among workers under piece rates than under time rates. Gustman and Steinmeier argue that wages and pensions (or other forms of deferred compensation) are determined simultaneously by the firm and therefore single equation models tend to bias this relationship.

Economic Competition and Work Pressure

Compensation method and level of compensation may both be related to the general economic pressures associated with competition. The customers of trucking and other freight transportation operations are the shippers and receivers ("consignees") of goods; for passenger transportation, the customers are those buying the tickets to ride the conveyance. Since deregulation, these customers increasingly have become the controlling parties in freight and passenger transportation. Indeed, conventional theory of welfare economics considers markets efficient when consumer welfare is maximized. Shippers and consignees effectively act as agents of the consumer, so theoretically our system is working efficiently.

Problems arise when costs embedded in this competition lie external to the market. This occurs when regulations governing the assignment of these costs fail to incorporate all the cost. Deregulation of surface freight transportation sought to promote innovation and competition but did not deal either with the externalized environmental or safety costs. Indeed, evidence suggests that metropolitan sprawl may have been encouraged by deregulation, as the cost of port drayage dropped so low that shippers and consignees moved their warehouse operations far away from ports of entry. In Southern California, for example, commonly drayage trucks haul containers 100 miles away to the Inland Empire, creating congestion (and the demand for more highways), pollution, and safety costs that unregulated markets failed to capture (Belzer and Christopherson 2008; Christopherson and Belzer 2009).

Problems also arise when work pressure created by competition causes CMV drivers to make mistakes that lead to crashes. In a recent study, Belzer found that interstate bus companies in the most competitive sectors – "curbside" bus companies – have more than twice the safety risk than the national average, and compare even more unfavorably with traditional established intercity bus companies, both unionized and non-union (Belzer 2010a). Similarly, in a study of the carhaul sector of the trucking industry, Belzer found that driver safety ratings, measured as driver out-of-service rates and carrier-level analyses of safety management, were significantly better at unionized carriers than at non-union carriers. Non-union carriers are more likely to subcontract their work to brokers or owner-operators and pay lower rates for the same work (Belzer 2010b).

In a study using the Large Truck Crash Causation Study dataset, Belzer also found that work pressure strongly contributed to the CMV driver's likelihood of being assigned responsibility for being the last driver whose action might have prevented a crash from occurring. Data for the cross-sectional analysis of the causes of large truck crashes come from the Federal Motor Carrier Safety Administration's Large Truck Crash Causation Study (LTCCS).[4] The LTCCS collected approximately one thousand truck crashes intensively, collecting a substantial amount of information. While data were inadequate to determine crash causation based on compensation, substantial evidence supports the conclusion that work pressure contributes significantly to truck crashes. Data were collected from 2005 through 2007 and this study was completed in 2009. It shows that work pressure helps to predict whether the truck driver is assigned the "critical reason for the critical event" associated with the crash. For this study, Belzer consolidated all of the work-pressure factors identified by the LTCCS data-gathering team into an index, and that index, along with Aggression Count, Fatigue, Class Years, Safety Bonus, Hours Driving, and Mileage Pay This Trip (as reported by driver) together predicted 15% of the likelihood that the CMV driver would be identified as the driver responsible for the critical event that precipitated the crash (Belzer 2009b). Work pressure, aggression, and fatigue were the factors positively associated with crash responsibility.

Economic Competition and Subcontracting

Some researchers have focused on the role of subcontracting in determining safety outcomes. While widespread in many industries, subcontracting has been used intensively in trucking because the work traditionally has been difficult to monitor, making subcontracting (like contingent compensation) a useful way for a principals to structure relationships with agents that align self-interest and reduce shirking and moral hazard. It also is rooted in the history of the "teaming" business, since trucking developed out of horse-drawn wagons, and it made sense for "teamsters" to own and care for their own teams of horses and their own wagons.

Many scholars have long considered subcontracting a vehicle for labor-market segmentation that creates a two-tier system of internal and external labor markets as well as core and periphery labor markets (Doeringer and Piore 1971; Edwards, Reich, and Gordon 1975; Gordon 1972; Gordon, Edwards, and

[4] For more on this study, see http://www.fmcsa.dot.gov/facts-research/research-technology/analysis/ltccs.htm and the report of the National Research Council's evaluation of that study (Council et al. 2003), located at http://trb.org/publications/reports/tccs_sept_2003.pdf.

Reich 1982; Osterman 1978; Piore 1973; Reich, Gordon, and Edwards 1973; Rubery, J. 1984; Sabel 1979; Vietorisz and Harrison 1973). These conceptions of the labor market, and of subcontracting, commonly find that primary or core labor market participants, employed by firms, have significantly better employment and compensation packages, including health and pension benefits, than the packages of similarly situated subcontractors. Indeed, an intensive analysis of owner-operator cost-of-operations in trucking recently showed that owner-drivers who own and drive their own truck and do not employ other drivers or operate multiple trucks earn approximately $21,000 annually in a combination of net profit and wages, which is about 60% of the compensation earned by non-union employee drivers (Belzer 2006; Belzer and Swan 2011). They often do not have health benefits and rarely have pension plans (Belman and Monaco 2001; Belman, Monaco, and Brooks 2004).

In research conducted in the mid-1990s, and building on research conducted by other Australian researchers (Williamson, Ann M. et al. 1992), Mayhew, Quinlan and Ferris showed the relationship between safety and truck ownership. Identifying problems such as the fragmentation of the industry and the intense competition facing owner-drivers in Australia, they laid out a paradigm that explains the health and safety risk posed by economic conditions in this market, exacerbated by inadequate regulatory controls in Australian long-haul trucking (Mayhew, Quinlan, and Ferris 1997; Mayhew and Quinlan 1997). In a survey conducted a decade later, Mayhew and Quinlan found that the problems facing owner-operators had, if anything, intensified (Mayhew and Quinlan 2006), with even worse consequences for subcontractor owner-drivers as well as other highway users. These findings on the dangers of subcontracting have recently been supported by an examination of growing safety problems in the subcontractor ("regional") sector of the U.S. airline industry (Young 2010) following the Colgan/Continental Airlines plane crash in Buffalo, New York, in 2009 (see the full NTSB report; National Transportation Safety Board - U.S. Department of Transportation 2010).

III Driver Compensation and Driver Safety: Evidence from Trucking Research

This section addresses the empirical evidence linking compensation level and method to worker safety in the trucking industry. First, we review studies which focus on the effect of various firm characteristics on trucking safety, but which do not directly address the role of compensation level and method. Next we review the studies and papers that have included either compensation level or method in the study of trucking crashes. We also extend the review to include those studies that have correlated compensation with behaviors traditionally associated with high crash rates, such as speeding and violation of hours-of-service regulations.

In perhaps the most comprehensive study of compensation and safety, Belzer, Rodriguez and Sedo studied the effects of compensation using three methods: case study, cross sectional, and survey (Belzer, Rodriguez, and Sedo 2002). The authors looked at driver pay rates, driver raises, and retention in their analysis of J.B. Hunt, using a semiparametric hazard function in an event history analysis (a variant on survival analysis), finding that at the mean, for every 10% in truck driver pay rates there was a 40% lower probability of driver crash on a month-to-month basis (Rodriguez et al. 2003; Rodriguez, Targa, and Belzer 2006). They also found in a cross-sectional study of more than 100 truckload motor carriers, using a logit model that at the mean, every 10% in driver compensation was associated with a 9.2% lower carrier crash rate. This study found that not only was driver pay rate significant, but so were the number of hours of unpaid labor time per mile, the value health and life insurance, and safety incentive bonuses (Belzer, Rodriguez, and Sedo 2002).

Safety Studies of the Trucking Industry: Firm-Level Characteristics

A study by the Office of Technology Assessment of the U.S. Congress, *Gearing Up for Safety,* charted the complex possible causal paths of large truck crashes in a comprehensive manner as early as 1988 (Office of Technology Assessment - U.S. Congress 1988). This study traced the factors in the overall causal mechanism influencing truck crashes to macro-social factors such as societal values and market forces, and their impact on macro-structural features such as government policy and legislation, motor carrier industry segment goals, and shipping and distribution interests. The authors of this study saw large-scale social forces and structures influencing two major sets of micro-structural sources of organizational action. On the one hand, federal and state agency actions such as regulations, roadway design, inspection and enforcement had an influence. On the other hand, firm actions related to road operations, driver selection and training, and vehicle maintenance and specifications also played a role. Finally, at the level closest to the actual set of crashes, these researchers focused on factors such as roadway conditions, traffic conditions, other highway users, driver performance, vehicle performance, load characteristics, weather and unpredictable situations. Another causal model also identified management operating practices as a key element in the crash causation chain (U.S. Department of Transportation and Clarke 1987).

In both models, driver error, haphazard road conditions or equipment failure were the immediate determinant of a crash. But Loeb *et al.* pointed out that the direct causes of crashes “may have been influenced by a prior occurrence (for example, insufficient driver training) that may have been affected by an earlier policy action (for example, regulation on driver qualifications). Furthermore, societal values or economic considerations may have prompted adoption of a particular policy” (Loeb, Talley, and Zlatoper

1994). There has been increased attention recently to the importance of the economic conditions facing the trucking industry, and how they can be manifest in after-inflation declines in freight rates, tightening of schedules to meet shipper demands, and increased interfirm competition (Belzer 2000; Hensher, Batellino, and Young 1989; Quinlan 2001; Quinlan and Bohle 2002; Quinlan, Mayhew, and Johnstone 2006; Quinlan, Wright, and National Transport Commission 2008). The National Research Council's Committee for the Review of the Large Truck Crash Causation Study (LTCCS) conducted by the U.S. Department of Transportation's Federal Motor Carrier Safety Administration (FMCSA) likewise expressed concern that data on many such factors potentially influencing truck crashes should have been a priority of the FMCSA (Council et al. 2003) , but FMCSA did nor collect data with which to do an analysis (Belzer 2009b).

Despite awareness of the complexity of the policy environment and the stochastic nature of the crash environment, the predominant sets of variables found in large truck safety research have been driver characteristics and behavior, load characteristics, vehicle characteristics, and roadway conditions. Relatively little research attention has addressed motor carrier operations (such as compensation level and method) and driver selection and training. Yet both were identified as important in the OTA report (Office of Technology Assessment - U.S. Congress 1988).

A new literature thus is emerging which seeks to take firm characteristics such as these into account in modeling trucking safety. This new literature identifies a number of firm-level characteristics other than the compensation-related variables reviewed in the next section. These include firm profitability, specific firm safety practices, fleet ownership, demographics of the firms' driver force, firm age, union presence, firm size and industry segment.

Firm profitability

Research suggests firm profitability is one firm characteristic related to safety of transportation operations. Corsi, Fanara and Roberts found that net operating income was not a statistically significant predictor of crash rates, although there was an inverse relationship (Corsi, Fanara Jr., and Roberts 1984). Chow *et al.* found a suggestive association between a carrier's financial condition and its safety performance. They suggested that carriers close to bankruptcy skimp on maintenance, use older equipment, and use owner-operators (Chow et al. 1987). Blevins and Chow further studied the profitability-safety relationship during the post-deregulation era. Using bivariate analyses, they compared results for bankrupt and non-bankrupt firms, and found that bankrupt firms did in fact spend less on insurance and safety, maintenance, and equipment replacement, and also were more likely to have unsatisfactory compliance ratings, but the results were not statistically significant (Blevins and Chow 1988). Corsi, Fanara, and Jarrell found operating ratio (operating expenses divided by operating revenue) as having a statistically significant and positive relationship with crash rates for Class I and II carriers in 1977 and 1984 (Corsi, Fanara Jr., and Jarrell 1988).

Seeking to improve on these earlier, rather inconclusive studies, Bruning (1989) found that higher return on investment was associated with lower crash rates. He used a 1984 database based upon Bureau of Motor Carrier Safety records of crashes causing at least $2000 in property damage and federal Financial and Operating Statistics from the Form MCS-50T report of 468 Class I and II general freight and specialized carriers. Bruning made two linked assumptions: (1) that managers substitute among various production-related expenses in order to maximize profits, and (2) that the level of substitution of such expenses as maintenance and training would be reduced given higher flows of revenue. Bruning found that for large firms, carrier profitability was inversely related to the crash rates for all general freight and specialized carriers. He also found that profitability in preceding periods (measured in 1980 and 1982) explained safety performance in 1984 (Bruning 1989).

Moses and Savage utilized a large dataset of 75,577 federal safety audits and crash records from the 1986-1991 period, but did not report statistically significant effects for carrier profitability (Moses and Savage 1994). However, in an earlier analysis the authors found that carriers identified in safety audits as unprofitable did indeed have significantly more crashes (Moses and Savage 1992). Their analyses differed in the type of statistical procedure used and the industry segments examined. They point out the importance of stratifying for or controlling for firm size and industry segment.

Hunter and Mangum measured carrier financial stability using three variables: revenue per mile; net debt to equity ratio, and operating ratio (total annual operating expenses divided by annual gross revenue). They viewed operating ratio as an indicator of a firm's long-term profitability (Hunter and Mangum 1995).

Golbe showed the difficulty of establishing such a relationship in any industry (Golbe 1986). Golbe's own cross-sectional study of the airline industry found no statistically significant relationship between profitability and the square root of total crashes, although note that the number of firms and number of crashes is much smaller in the airline industry than in trucking. In addition, higher levels of federal oversight of maintenance in the airline industry may result in less between-firm variance in crashes. Most importantly, however, Golbe concluded that data on firm risk preferences and the specific cost and demand conditions in the industry are necessary in order to test the relationship between profitability and safety (Golbe 1986). Furthermore, Chow has pointed out that short-term profitability is but one dimension of the financial condition of a firm, and may not reflect the longer-range strengths or weaknesses of a firm (Chow 1989).

More recently, using driver compensation data from Signpost, motor carrier crash data from the Motor Carrier Management Information System

(MCMIS), and from the US Department of Transportation's (DOT) Financial and Operating Systems (F&OS),[5] along with the National Motor Carrier Directory, Rodriguez, Rocha, and Belzer found that small motor carriers (fewer than 100 power units) with low liquidity and a lower share of employee compensation per dollar of freight revenue, are at significantly greater risk of crash (Rodriguez, Rocha, and Belzer 2004).

Direct measures of firm profitability are difficult to obtain for those firms that do not submit financial and operating statistics to the federal government. However, one proxy measure of firm financial condition is the ratio of sales volume to power units or sales volume to number of employees, data which are readily available over a period of several years for firms filing federal financial and operating statistics as well as for firms of all sizes from Dun and Bradstreet's TRINC file.

Specific Firm Safety Practices

While safety best practices have never been established scientifically (weighting all possible factors across firms over time), certain specific firm safety practices likely have safety consequences. Oversight of the driver and oversight of equipment, for example, appears to predict safety performance (National Transportation Safety Board - U.S. Department of Transportation 1988). Moses and Savage identified as particularly significant several other safety practices: compliance with requirements to file accident reports; taking action against drivers involved in preventable crashes; and carrier ability to explain hours of service rules (Moses and Savage 1994).[6] However, such studies often produce counter-intuitive results. For instance, like Moses and Savage, Corsi and Fanara and Corsi, Fanara and Roberts also used safety audit data to study the influence of firm safety practices (Corsi and Fanara Jr. 1989; Corsi, Fanara Jr., and Roberts 1984). They found a significant and positive relationship between crash rates and carrier spending on maintenance. They attributed this to another known factor, age of fleet: the older the fleet, the higher the unavoidable repair expenses. Furthermore, in some of their models, the authors found that substantial hours of service compliance and demanding driver qualifications were associated with statistically significant and higher crash rates. The authors explained this result by arguing that the evolution of an unsatisfactory crash rate may lead to subsequent and costly improvements in safety management practices, but that cross-sectional data may not take into account a time lag in the eventual improvement of the crash rate. More recently, research by Rodriguez, Rocha and Belzer suggests that small firms with low liquidity and low driver compensation may have a significantly higher risk of crash (Rodriguez, Rocha, and Belzer 2004). On the other hand, these weak and sometimes contradictory results may indicate

[5] The F&OS is an invaluable resource for motor carrier analysis that the DOT terminated in 2004.
[6] Carrier-reported profitability again was not significant.

researchers are looking in the wrong place for safety effects; carrier profitability may not drive safety.

Fleet Ownership

One important data element for firm-level studies is the proportion of a firm's fleet which is represented by company-owned vehicles driven by company employees, leased vehicles driven by company employees, and vehicles operated by owner-operators.

For Class I and II firms, Corsi, Fanara and Roberts (Corsi, Fanara Jr., and Roberts 1984) and Corsi, Fanara and Jarrell presented findings that suggested that higher use of owner-operators was significantly related to higher crash levels (Corsi, Fanara Jr., and Jarrell 1988). Chow also concludes that higher proportion of owner-operators may negatively affect crash rates (Chow 1989). However, Bruning did not find a significant effect for the natural log of the number of rented power units with drivers as a ratio of total power units (Bruning 1989). With recent research showing that owner-drivers earn far less money than do employee-drivers (Belzer 2006), the problem may not lie with the use of owner-drivers themselves but rather with their low compensation and the effects low compensation has on drivers' pressure to take more work and work too fast and too long.

Demographics of firm driver force

Individual factors such as driver age, experience, and job tenure can contribute to both individual-level analysis as well as firm characteristics. Since length-of-service with the firm is a data element in the MCMIS crash file, a number of studies have sought to examine its impact. Although one study sought to portray this as an indicator of firm turnover rates, the raw measure used showed a significant and inverse relationship between length of firm tenure and crash rates, with over half of nearly 200,000 DOT crashes involving drivers with less than a year of tenure with the firm (Feeny 1995). Bruning also found that drivers with less than one year with a reporting carrier accounted for more than 50% of crashes in a similarly sized database (Bruning 1989). Such measures cannot be treated as proxies for firm turnover, even in the presence of controls for firm growth from year to year, nor may they be utilized as measures of the minimum experience requirements for firm hiring. Belzer et al. found that driver tenure is an important individual-level safety predictor and that driver tenure reduces crash probability, *ceterus paribus* (Belzer, Rodriguez, and Sedo 2002; Rodriguez et al. 2003; Rodriguez, Targa, and Belzer 2006).

Firm age

The ready availability of data on firm age suggests the value of the inclusion of the year the carrier was established (and a calculated variable for firm age) as a firm-level control variable in fire-level safety research. Such data permit us to distinguish between a firms established before or after deregulation. Corsi and Fanara found that the year of firm establishment, post-deregulation, predicted crash rate in a multivariate model (Corsi and Fanara Jr. 1989). This would suggest that firm experience plays a role in safety as well, probably because it takes time to develop a safety culture and safety management practices.

Firm size

Corsi and Fanara's study of 2,000 safety audits found that, using multiple regression, firm size correlated negatively to crash rates, with larger firms having lower rates (Corsi and Fanara Jr. 1988). However, Even and Mcpherson noted that the relationship between firm size and employee turnover weakens when accounting for such factors as the nature of pension coverage (Even and Macpherson 1996a). This finding suggests that research must carefully assess the possibility of interactions between firm size and other firm characteristics such as industry segment, union presence, and others.

Mixon and Upadyyaya used agency theory and its moral hazard mechanism to suggest that managers of large firms with greater separation of ownership and control are more likely to pursue better labor relations and improved safety levels. However, the authors recognized that firm size is not always the best measure of remote ownership (Mixon and Upadhyaya 1995). An improved design might have compared publicly traded firms and firms owned by holding companies with privately-held firms. While firm size was a significant predictor of a proxy for safety (damage expenses), firm size may not have a linear effect, the authors found.

Industry segment

There has been considerable attention paid to the similarities and differences which can exist between different sectors of the trucking industry and to the need to better understand the nature of industry segmentation (Belzer 1994b, 1994a, 1995b, 1995a, 2000; Blevins and Chow 1988; Burks 1999). Yet despite the work of Moses and Savage, research still has not distinguished conclusively among differential rates and causes of crashes in different sectors of the trucking industry. The firm-level factors that can enable the stratification of findings or a focus on a particular segment include for-hire or private fleet; load mix (primary commodities hauled); trailer mix (primary and secondary trailer types); truckload, LTL, or both; and average length of haul. Such firm characteristics are readily available in industry directories as well as from other sources.

Research on the effects of competition, discussed above, actually may tell the story of industry segment differences. Horrace and Keane show that the most competitive trucking industry sectors – produce, intermodal, and refrigerated sectors – have the worst safety performance (Horrace and Keane

2004; Horrace, Keane, and Braaten 2002). This is consistent with Belzer's research, cited above related to the carhaul and intercity bus industries.

Summary

Moses and Savage note that "even among ostensibly similar firms there may be 'safe' firms and 'not-so-safe' firms" (Moses and Savage 1994). The design of the federal SAFESTAT system rested upon a similar assumption in order to develop a national "safety fitness" program for the nation's commercial trucking fleet. The Progressive Compliance Program, a component paired with SAFESTAT, was designed to identify "'sick' (i.e. unsafe) carriers and provide different treatments based on that diagnosis to nurse these 'sick' carriers back to health" (John A. Volpe National Transportation Systems Center 1998). Despite the advances in research on firm characteristics outlined above, the definition of a "sick firm" remains unresolved. Furthermore, given the paucity of longitudinal firm-level research, the question remains: are firms with high levels of crashes at the present time unsafe or merely "unlucky?" Could a significant year-to-year random variation in firm crash levels explain purported trends? Finally, do some firm characteristics have a differential effect across several years, such as whether a firm purchases a new fleet all at once (and experiences the effects of fleet aging later) or replaces a portion of the fleet each year (thus masking the effect of vehicle age and safety features)?

Sound research requires a full examination of firm-level characteristics, along with the specific compensation level and method effects. We must combine examination of existing records with prospective research, beginning with some baseline year, to fully understand this problem.

Empirical Evidence for the Effect of Methods and Level of Compensation in the Trucking Industry: Driver-Level Research

The unavailability of driver-level demographic data has contributed to limitations to the empirical research in this area. Researchers, as a result, have used either survey data gathered separately or have approached private firms in order to have access to their human resources data. The limitations of both approaches are readily apparent. Most survey data are not representative of the population. Truck stop surveys, for example, may cause oversampling of truckload for-hire carriers, over-the-road drivers, and drivers who use truck stops for some other reason. In carrier-level findings, the results exclusively apply to the population of drivers belonging to the firm and it becomes difficult to make inferences to the truck driver population. Finally, data limitations on the causes of the crashes observed rarely provide a data element that easily distinguishes truck-at-fault from truck-not-at-fault crashes.

Despite these limitations, some researchers have studied the effects of compensation on driver crashes and productivity. In one of the early and definitive studies, Krass (1993) studied the economic environment of trucking firms in order to explain truck-at-fault crashes in California from 1976-1987.

He used an ordinary least squares econometric model, relying on real wage rates as an indicator, and found that safety declined after deregulation, and that this decline was specifically attributable to the lower wage rates in the industry. The results were highly significant, with an R^2 greater than 95% (Kraas 1993). Deregulation reduced safety outcomes because of structural changes in the trucking industry attributable to a market failure for trucking services; lower rates for trucking services did not incorporate higher costs of increased safety risk and roadside inspections became less effective. Lower rates earned by carriers probably led carriers to skimp on safety and drivers to violate hours-of-service regulations at more than double the previous rate.

The reduced effectiveness of roadside inspections is consistent with results found in subsequent research. This finding is especially consistent with and helps to explain recent findings by Belzer and by National Transportation Safety Board (NTSB) investigations that safety in the interstate and international motorcoach bus industry has become a critical problem for "curbside" and charter bus operators.[7] Part of this problem is due to the "needle in a haystack" or "whack-a-mole" problem faced by enforcement officers attempting to use roadside inspections and carrier compliance reviews in an industry characterized by very small firms with shifting ownership and management structures—carriers never granted interstate and international operating authority or "reincarnated" after having been placed out of service by FMCSA (Belzer 2009a).

Beilock, Capelle and Page studied the effect of various driver-reported firm characteristics on safety-related behavior of drivers and on firm crashes. The data set comes from a survey of 1,762 truck drivers in the Florida peninsula. They viewed speeding as providing an intrinsic pleasure-seeking ability for some drivers, as well as being a way of maximizing leisure time (given the predominant per-mile form of payment). The authors found that tight schedules, high company-demanded productivity, and the incentives of the per-mile pay method were associated with speeding. The authors also estimated a logit model with a binary dependent variable indicating if a crash had occurred in the past n years (hence drivers with less than "n" years of experience were excluded from the sample). They hypothesized that crash likelihood would be a function of carrier characteristics, driver characteristics, and equipment features. They found that miles driven in the 12 months before a crash and method of compensation (hourly vs. per-mile) were insignificant (Beilock, Capelle Jr., and Page 1989). However, since firm characteristics were based on current employer, and crash experience was based on the drivers' overall experience over the past year, high industry turnover could have prevented an accurate estimate of these effects.

[7] See especially the NTSB investigation of the Victoria, Texas fatal bus crash. http://dms.ntsb.gov/pubdms/search/projList.cfm?ntsbnum=HWY08mh011. See also their investigations of the Sherman, Texas bus crash (fatal to seventeen people) and other crash investigations: http://www.ntsb.gov/investigations/reports_highway.html

Another study examined the effects of a multicomponent incentive system on the performance, safety, and satisfaction of 22 drivers working for a private carrier. This case study claimed to find that the introduction of performance-based pay incentives led to sustained productivity increases over a long period, without accompanying increases in crashes or turnover or decreases in workers' satisfaction (LaMere et al. 1996). However, given the random nature of truck crashes, the small sample may explain the lack of a statistically significant increase in crashes. Even though the multiple baseline design creates some econometric problems in attributing causality to the intervention, the results reported are strong enough to suggest that the incentive pay was an important factor in increased productivity. All drivers in the study were paid by the hour and the incentives included a distance-driven bonus. As a result, the carrier did not pass on earnings risk to drivers by implementing the incentive pay system. In addition, the study provided very limited information about driver characteristics (e.g., experience and tenure) and driver exposure. This information may help to further explain the changes (or lack thereof) in productivity and crashes.

In 1991, the US General Accounting Office (GAO) published the report "Freight Trucking: Promising Approach for Predicting Carriers' Safety Risks." The report documented the development of a model system of economic factors and safety. Even though the GAO models driver quality as a function of macroeconomic conditions of firms, driver compensation is the underlying mechanism that makes this hypothesis operative. As firms face economic hardship, they are unable to pay high compensation levels, and therefore the quality of their work force decreases (General Accounting Office - U.S. Congress 1991). Similarly, the GAO hypothesizes that in the presence of unfavorable firm financial conditions, drivers who are paid on a "rate basis … can work at the same pace and face income erosion or they can drive harder … to maintain their incomes" (General Accounting Office - U.S. Congress 1991). The GAO finds that as pay increases, the odds of engaging in a moving violation decreases. However, for owner operators the odds of conviction decrease as pay increases and then increase, forming a U-shaped curve (General Accounting Office - U.S. Congress 1991).

Elements of GAO's model were tested empirically using survey data from the Regular Common Carriers Conference (RCCC) survey. The authors found that compensation method was not a significant factor in determining the probability of crash involvement for truck drivers who had experienced a crash in the past 10 years (Beilock, Capelle Jr., and Page 1989). However, this study had a selection bias because only drivers who had crashes were included in the sample, making inferences about the driving population questionable. In a subsequent study, Beilock found that compensation method (by the load, per mile, per hour or fixed salary) was not significantly correlated with a driver's schedule tightness, but this study did not observe hours of service and speed, and other factors (Beilock 1995).

These studies had significant flaws, however. There was little variation in method of compensation in the sample (virtually all of the drivers were paid by the mile), so the lack of significant results would be spurious. Second, a reasonable assumption in the analysis is that no extended breaks were taken before the interview because of the location of where the interviews were taking place (Florida Peninsula, outbound). As a result, only cargo-loading (and not weather or traffic, or cargo unloading) could actually explain any variations in the schedules under different methods of pay. Furthermore, pay also can affect the intensity of driving (speed), an effect not accounted for in this study. Braver *et al.* did find that lower per-mile compensation levels were associated with higher propensity to violate hours of service regulations, but they made no explicit link to crashes (Braver et al. 1992). Hertz explicitly mentions compensation method as a probable cause for the hours of service violations found in her study. Per mile and per load compensation provide drivers "with direct economic incentives to drive longer hours" (Hertz 1991).

A comprehensive study in Australia concluded that overall earnings had significant negative influence on the number of driver convictions for moving violations. The same study found strong evidence suggesting that owner-operator compensation and company freight rates have a significant negative influence on the propensity to speed (Hensher et al. 1991). In another Australian study, using a set of structural equations, Golob and Hensher found that rates of compensation significantly influence the propensity to speed, take "stay-awake pills" (amphetamines), and to self-impose schedules; these endogenous variables all contribute to safety problems for truck drivers (Golob and Hensher 1994, 1995).

In addition to the violation of hours-of-service regulations, other factors such as sleepiness, fatigue and speeding play an important role in driver crashes. For example, a report on the causes and effects of sleepiness and fatigue for motor carrier drivers in New York State concluded that pay method was associated with driving more than 10 consecutive hours and taking fewer than 8 hours off-duty (McCartt, Ann T., Hammer, and Fuller 1997a).[8] Hensher found strong evidence suggesting that owner operator compensation and company freight rates have a significant influence on the propensity to speed. The authors contend that "he negative relationship is stronger for owner drivers as might be expected" (Hensher et al. 1991).

Besides being an important crash risk factor, speeding also correlates with crash severity (Wasielewski 1984). Beilock suggested truck drivers speed because of (a) pleasure or thrill, (b) they overestimate their abilities, and (c) because of economic pressures, though without empirical evidence the "pleasure" hypothesis remains conjectural. Assuming individuals are risk averse, or at least risk neutral, there should be some payoff from increasing the level of crash risk (Golob and Hensher 1995) associated with speeding (Beilock,

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[8] No multivariate analysis was included in the paper. It is unclear if the association found between pay method and violations would hold after controlling for other relevant factors.

Capelle Jr., and Page 1989). Finally, research shows that overall earnings also have a negative influence on average speeds (Hensher et al. 1991).

Other Issues in the Relationship between Driver Compensation and Safety

Piece-rate compensation is a common form of performance-based pay widely used in trucking. However, incentive mechanisms go well beyond piece rates. Many firms have readily identified this and now offer pay bonuses for maintaining a satisfactory safety record, having low fuel consumption, and other characteristics of interest. It therefore is important to stress that the incentive literature is replete with papers documenting varying degrees of effectiveness of safety pay bonuses.

Wilde, considered to be the author of the risk homeostasis theory (a fundamental concept in risk behavior analysis), has studied safety incentives for the trucking industry (Wilde 1995). He claims that safety incentives are "generally more effective than engineering improvement, personnel selection, and other types of intervention, including disciplinary action". This theory would suggest that individual compensation tied to specific safety outcomes might be the key to reducing crashes. His study provides solid evidence of the success of safety incentives in other industries (mostly manufacturing), though many of the studies assessing the effectiveness of safety incentives tend to suffer from the econometric complications stemming from the longitudinal character of the data. The author explicitly states, however, that he knows of no controlled experiments addressing the safety and incentives issue (Wilde 1995).

Another study found a significant relation between the introduction of safety incentives (e.g., surcharge and rebate system due to crash frequency) and the reduction in the number of crashes (Kotz and Schaefer 1993). It is unclear, however, if these differences observed are due to changes in manager or worker behavior. Furthermore, there are other methodological questions of concern (e.g., omitted variables correlated with predictors and the panel nature of the data).

Besides the fundamental need to determine more precisely the association between driver pay and driver safety, we have identified three areas related to driver compensation and driver safety that warrant further detailed study: (a) the interaction between compensation method and level, (b) the role of pensions, and (c) the role of internal labor markets.

Regarding the interaction between compensation method and level, we presented research suggesting that piece rates shift earnings risks to drivers. Said differently, piece rates provide drivers with some degree of autonomy to determine effort and intensity levels. It is reasonable to expect, therefore, that the intensity and effort incentives afforded by piece rates vary according to the different piece rate levels. For example, a driver paid low piece rates may have a higher incentive to speed than a driver paid high piece rates. In order to reach an earnings target, the driver on low piece rates might find it necessary to drive more miles overall. In fact, some researchers have recently argued that workers do exhibit a target level of earnings; as a result, workers earning below the earnings target gain more satisfaction from additional pay than do those earning above the target level (Drakopoulos and Theodossiou 1998). Incentives may have a similarly varying effect at different piece-rate levels.

In contrast, the effects of incentives afforded by time rates are harder to determine. On the one hand, a driver can speed in order to complete a task and have more leisure time (or work more and earn extra pay). On the other hand, a driver can drive or work slower than normal (i.e., shirk) and make extra hourly pay, even though his time-on-task is monitored frequently. We have found no other research about the potential interaction between compensation method and compensation level.

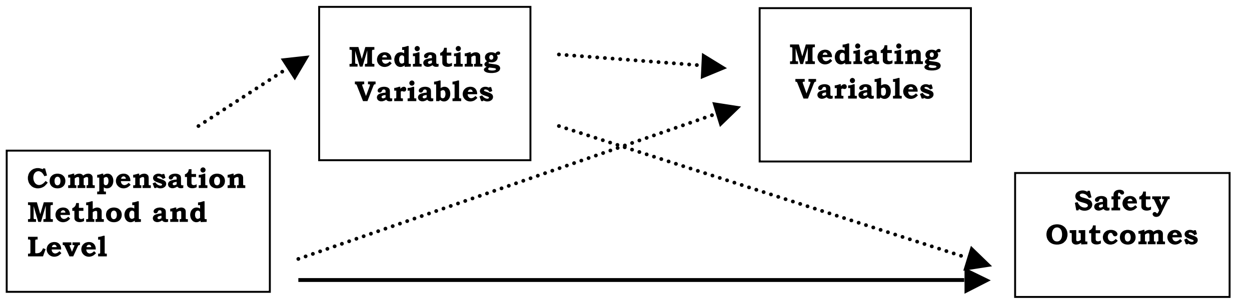
Only Southern et al., in their survey of personnel managers, included pensions as a compensation category. They find that vacation time and sick time, pension fund contributions, and safety bonuses were not ranked as high as pay as the most important factor in drivers' choice of motor carriers for employment (Southern, Rakowski, and Godwin 1989). A model that departs from using only the traditional piece or hourly rate and includes pensions and other bonuses may therefore be useful in painting a more accurate picture of overall truck driver compensation levels. We found no other study in the trucking industry that included the role of pensions on worker mobility and worker satisfaction.

Internal labor markets are difficult to proxy with these data except by looking at pay raises and retention as proxies for career ladders. Since drivers' occupations are on the surface (and at our level of data analysis) homogeneous, we are limited to this approach to internal labor markets.

Indirect Links between Driver Compensation and Driver Safety

Does the literature look at potential indirect effects? An examination of available research shows sorting and effort-eliciting incentives for different levels and methods of compensation. For example, through sorting, higher compensation levels would attract a more qualified labor pool, which, in turn, will exhibit safe behavior. Figure 1 shows the paths of direct and indirect effects of compensation method and level on safety. This section evaluates mediating variables that have been associated with both compensation and safety for truck drivers, such as age, job satisfaction, turnover, and propensity to engage in risky behavior (e.g., drive long hours, use illegal substances, and speed), among others. These indirect links appear as dotted lines in Figure 1.

Figure 1. Direct and Indirect Effects — Compensation Method and Level



Indirect Effects, Compensation Level and Method

An important mediating variable is the link that exists between compensation level and both job satisfaction and organizational commitment. Previous research suggests that level of pay affects attitudes and perceptions that affect behavior, including the propensity to have crashes. Results of a controlled experiment suggest that neither the payment system nor the incentive level directly affect pay satisfaction beyond their impacts on absolute level of pay (Berger and Schwab 1980). As expected, other researchers have established a link between job satisfaction (i.e., satisfaction with the employer) and driver turnover (Richard, LeMay, and Taylor 1995).

Some researchers have found important differences in job satisfaction between and within the truckload and the less-than-truckload segments of the industry. Researchers divided TL drivers into short haul and long haul occupations, and the differences reported correspond to the different job characteristics. For example, long haul truckload drivers reported more negative attitudes concerning issues such as benefits, income, and advancement opportunities than did short haul drivers (McElroy et al. 1993). Such results support other research showing substantial pay differentials between regional and long-haul drivers; long-haul TL drivers are among the lowest-paid U.S. workers (Belzer 2000). This might also be further evidence of the importance of career ladders in some segments of the trucking industry, as discussed previously.

Employee turnover becomes an issue because of low job satisfaction, but it also is instrumental in determining the sorting effects caused by variations in compensation levels. In fact, the sorting effect of efficiency wages or wage tilting may be an indirect path that could result in increased safety. Some researchers have found evidence that firms' wage levels are associated positively with the previous experience of new hires, the tenure of employees with the firm, managers' perceptions of employee productivity, and managers' perceptions of the ease of hiring qualified workers. Wage levels were negatively associated with job vacancy rates and training time (Holzer 1990).

In a meta-analytic study, Cotton and Tuttle found that higher pay and some socio-demographic variables were associated with lower turnover likelihood. Demographic variables include age, tenure and number of dependents (Cotton and Tuttle 1986). This finding is important because a firm's compensation policies might attract certain types of individuals who might be more or less prone to quitting the job early. Cotton and Tuttle's review notes that 4 out of 5 papers assessing the link between individual performance and turnover found that the relationship was negative and significant. LeMay *et al.* found similar results in a truck driver study (LeMay, Taylor, and Turner 1993). In another trucking study, the driver's sense of trust in the company predicted actual turnover best. In the same study, trust, optimism and job satisfaction had weak relationships with employee attitudes (Kalnbach and Lantz 1997). Studies in other industries have shown that those who perceive their jobs as stressful and those who have limited family responsibilities for children tend to be prime candidates for turnover (Keller 1984).

Similar analyses have shown similar results for compensation method. For example, one study used an experimental design to measure the differences in employee satisfaction with pay for workers under time rates compared with those under incentive payment systems. Results indicated that neither the payment system nor incentive levels directly affect pay satisfaction beyond their impacts on absolute level of pay (Berger and Schwab 1980).

The likelihood of using illegal drugs on the job also is an indirect effect of compensation level. In the single study of this type for truck drivers, Hensher *et al.* found that the pay level for owner operators is negatively associated with the propensity to use illegal drugs. The higher the pay the less likely the owner operator will use performance-enhancing drugs, particularly amphetamines (Hensher et al. 1991; Hensher, Daniels, and Battellino 1992).

Indirect Effects, Driver Safety

If driver compensation influences the age distribution of the driver pool, and the age of drivers correlates strongly with safe or unsafe behavior, then one could argue that driver compensation and safety are linked via an age-mediating variable. We describe in this section the "intermediate factors," such as age and tenure, and their association with driver safety.

Age

Considerable literature exists that links driver age with crash rates. For example, younger and less experienced drivers have higher crash involvement. The fatal crash involvement rates for drivers of large trucks decrease with increasing driver age (National Highway Traffic Safety Administration - U.S. Department of Transportation 1982). Younger drivers have six times the frequency of crash involvement in comparison to the overall driver involvement rate (Campbell 1991). In addition, research has shown that young truck drivers, compared with older drivers, have significantly more traffic violations, with a higher proportion of unsafe speed, reckless or careless driving, and failure-to-yield violations (Blower 1996). In addition, Braver *et al.* found that being a violator of hours-of-service regulations was significantly associated with being a young driver, having a tendency to speed or drive longer when given unrealistic schedules, and not knowing the hours-of-service rules (Braver et al. 1992).

Work experience

Research attempting to distinguish between age and experience has not been very convincing. With respect to employee safety, worker experience shows the same effect as the driver age variable, probably due to the high collinearity between the two (Bloom and Milkovich 1995). Ayres attempts to distinguish between the two concepts econometrically, and concludes that experience and age make separate significant contributions to injury risk with age as the most important predictor and experience the second most important out of ten factors identified. Surprisingly, when both factors are in the same equation the presence of each factor enhances the predictive power, but age takes on a negative sign. Ayres explains this by claiming that this picks up a tendency for more experienced drivers to acquire an “optimism bias” that, since it is unwarranted, makes the driver feel overconfident and increases risk (Ayres 1996). While this may be true, econometric problems suggest this hypothesis requires considerable more validation. Clearly, age and experience alone have a positive affect on safety and incorrect statistical specification may have introduced this paradoxical outcome. However, Lin, Jovanis and Yang studied the experience of one large interstate carrier and found that while driving time on the trip prior to a crash was the strongest predictor of a crash, drivers with more than 10 years of experience had the lowest crash risk, although the relationship was not linear between one and ten years of experience (Lin, Jovanis, and Ynag 1993).

Fatigue

Despite its intuitive appeal, literature has shown no conclusive empirical evidence linking driver compensation method and the onset of fatigue. Clearly, more research is necessary in this area. An NTSB study of the factors that affect fatigue in heavy truck crashes did observe pay structure (but not pay level) as a variable affecting the onset of fatigue (National Transportation Safety Board - U.S. Department of Transportation 1995). However, the aim of the study was to examine the factors that affect driver fatigue, and not the statistical incidence of it. This study introduced definite statistical biases because it observed single-vehicle heavy truck crashes in which the driver survived, and thus overestimated the incidence of fatigue substantially. Nevertheless, it is safe to say that the report “raises questions about the influence of pay policies on truck driver fatigue … and raises questions about a link between method of compensation and fatigue-related accidents” (National Transportation Safety Board - U.S. Department of Transportation 1995).

Hensher's study in Australia tested the hypothesis linking driver fatigue to the underlying economic conditions in the long distance trucking industry. However, the experimental design did not allow the observation of fatigue *per se*. Rather, Hensher assumed fatigue could not be observable directly. Instead, Hensher used proxies for fatigue, such as the number of moving violation convictions and number of crashes (Hensher et al. 1991), and questions remain whether such proxies embody the phenomenon of interest. Even within the industry, differences remain between drivers' and companies' perceptions regarding the causes of fatigue, and strategies that should be used to manage it (Arnold, Pauline K. and Hartley 1997; Arnold, Pauline K. et al. 1997).

The link between fatigue and driver safety, however, seems to be more robust (Saccomanno, Frank F, Yu, and Shortreed 1995; Arnold, Pauline K. and Hartley 1997; Chatterjee et al. 1994; Feyer et al. 1993; Golob and Hensher 1995; Wylie et al. 1996). Studies have shown increases in driving errors and decreases in driver alertness due to fatigue (National Highway Traffic Safety Administration 1982). A preliminary statistical link is established between truck driver fatigue and crash rates, as a contributing factor (Saccomanno, Frank F, Yu, and Shortreed 1995). Despite experimental design limitations, an NTSB study found that fatigue and fatigue-drug interactions were involved in more fatalities than alcohol and drug abuse alone (National Transportation Safety Board - U.S. Department of Transportation 1990).

Turnover

High labor turnover rates have been linked to crash rates. For example, the Bureau of Labor Statistics found that workers were approximately three times more likely to be injured during the first month of employment than during their ninth month of employment. In addition, it found that workers under 25 years of age were 10 to 20 times more likely to sustain work injury than older workers (Bureau of Labor Statistics - U.S. Department of Labor 1982). Several studies in the trucking industry have found a consistent positive correlation between turnover and crash rates (Corsi and Fanara Jr. 1988; LeMay, Taylor, and Turner 1993; Taylor and J & H Marsh & McLennan 1997). The implications of these studies for future research on driver compensation are important. Again, a correlation between driver turnover and accident rates (at the firm level) is established, though the causal mechanisms remain unclear. This correlation may be spurious, due to driver age, for example. Younger drivers change jobs more frequently and have higher accident rates, therefore accounting for the correlation.

In other firm-level studies, high turnover rates have been positively correlated with injury rates and injury costs (Rinefort Jr. and Van Fleet 1998). Again, in most instances these associations tell little about causation, though plausible mechanisms outlining causality between turnover and crashes can be devised easily.

Safety Climate

The safety culture of an organization is considered a subset of organizational climate such as work practices, work style, training and industrial hygiene. A poor safety climate is considered an antecedent of safety outcomes such as crashes and unsafe behaviors. In a recent study of the relationship between culture, turnover and driver safety, Taylor and McLennan find a statistically significant correlation between intent-to-quit and the safety culture of the organization (Taylor and J & H Marsh & McLennan 1997).[9] Another study found a high correlation between traditional safety indices, such as lost time and crash rates, and safety climate (Coyle, Sleeman, and Adams 1995).

At the individual level, driver stress affects performance significantly (Matthews 1996), as does work pressure (Belzer 2009b). As with fatigue, however, there appears to be no conclusive evidence linking compensation with either safety culture or stress. It is intuitive to think that the performance pressures induced by piece-rate systems, for example, have an effect on the individual's perception of stress and an organization's safety climate. It may be likely that a sorting mechanism underlies these phenomena. It may be simply that data are lacking to test one way or the other. Individuals more able to handle the stress of piece rate compensation schemes may opt for them while others would find jobs that have different compensation systems (Rubin and Perloff 1993), but the fact that the pay system for virtually every over-the-road trucking job is piece-rate (either by the mile or a percentage of revenue) means that few alternatives exist for those with the truck-driver skill set, and testing for significant differences in the real world is almost impossible. Research does link work stress with turnover (Keller 1984) and it is not difficult to imagine that wage systems in trucking (including piece-work rates such as mileage pay or percentage pay, or no explicit pay at all for non-driving time) would be associated with work stress.

Driver Safety and Driver Crashes

Asalor et al. identify five primary root causes of crashes at the level of an individual (Asalor, Onibere, and Ovuworie 1994):

1. environmental (e.g., the road and its surroundings);
2. vehicle (e.g., equipment failure);
3. driver;
4. pedestrian and other non-motorized users; and
5. "pure circumstance."

Pure circumstance consists of being on the road at the wrong time and, say, being struck by a passing vehicle. This is different from pure randomness,

[9] See also TRB safety synthesis on the role of safety culture (Short et al. 2007).

however. If crash involvement for any given driver is purely random or circumstantial, however, then crash involvement should not be an issue when studying driver compensation policies. In fact, observing crash data that contains a strong "pure circumstance" component to it introduces a standard error bias.

Pure circumstance is a subset of pure randomness. Someone can get into a crash for a number of reasons, such as environmental, vehicle and driver factors. There is randomness in all of these. The fact that a driver's tire blew out because of a nail or the fact that he or she encountered black ice in his or her lane has some randomness to it. Included in that randomness is "pure circumstance" – the fact that the driver was at the wrong place at the wrong time. A specific instance of pure circumstance comes from the fact that other vehicles can hit you. Speaking personally, even though I did not encounter black ice in my lane but my neighbor did, this occurrence resulted in a crash between both of us. If pure circumstance is an important factor in crashes, then observing multi-vehicle crashes may not be as efficient as observing single-vehicle crashes for detecting the causes of the crash. This is because in multi-vehicle crashes, some of the crashes are due to the pure circumstance of being next to a vehicle that crashed into you. Instead, single vehicle crashes will exhibit less (but still some) pure circumstance crashes than multi-vehicle crashes, and as such there is less noise impeding the extracting of the causal factors in single vehicle crashes. However, an individual driver's ability to avoid "pure circumstances" in which crashes occur – his ability to avoid risky situations in which his vehicle is more likely to be struck by another vehicle or an incautious driver – probably is a measure of his ability to drive more safely in the same traffic pattern as others who have higher crash probabilities.

Pure circumstance must not exist in single vehicle crashes, except insofar as an object falls from the sky and strikes the vehicle. A vehicle in a multi-vehicle crash, however, may be there due to pure circumstance or due to any of the first four categories listed. If pure circumstance were a factor, then single vehicle crashes would be significantly different from multi-vehicle crashes. The implication for future research is that additional information about the crash (i.e., number of vehicles involved) might be desirable in order to improve the explanatory and predictive power of the models.

Arguably some degree of human capital or incentive difference explains these drivers' safety records. Indeed, the studies by Belzer et al. all show that individual characteristics of drivers associated with their compensation rates predict greater propensity to avoid risk and thus greater safety on the job (Belzer, Rodriguez, and Sedo 2002; Rodriguez et al. 2003; Rodriguez, Targa, and Belzer 2006).

In addition to the use of subsets of crashes at the individual level, researchers have used moving violation convictions as proxies for driver safety behavior. The stochastic nature of crashes highlights the difficulty in predicting them. As a result, researchers have consistently used driving convictions as variables that are less vulnerable to randomness (Beilock, Capelle Jr., and Page 1989; Peck, McBirde, and Coppin 1971). Most researchers have found that they generally can use moving violations to predict future crashes. These results lead to the conclusion that drivers exhibit bad behavior, as measured by moving violations, consistently over time (Ferreira 1972; Mitter and Vilardo 1984). This conclusion does not support the common belief that we can model poor driver behavior as random walk (Poisson distribution or Poisson-related model). The relevant variables probably have some of the same behavioral elements involved in moving violations and are more stable and sensitive measures of individual differences of driver behavior. Miller and Schuster, however, found a positive relationship between previous violations and future (or current) moving violation convictions but not with crashes (Miller and Schuster 1983). Arguably "there is sufficient initial evidence to examine the issue further, together with the relationship between employee status and crashes" (Pearson and Ogden 1991).

Market Factors

In his extensive report on truck crash causation, Quinlan concludes that Australia's truck safety problems stem from competitive industry forces, and particularly on pressures created by shippers who demand rapid and timely service for a low price. This has created a "sweatshop" sort of environment in Australia that is responsible for an alarming truck safety problem, including long hours, high levels of chronic fatigue, and amphetamine abuse. Regulations aimed at individual drivers are relatively ineffective because they do not address underlying economic performance pressures on the industry. Self-regulation in the absence of a market model, while laudable, also does not work because it does not address the problems created by competitive market forces. His inquiry recommends the establishment of an industry-wide "Code of Practice" which would include coordination among regulatory agencies, compulsory licensing of all participants in the logistics industry, the replacement of logbooks with "Safe Driving Plans" signed and filed by motor carriers and drivers, and minimum pay and conditions standards for all drivers - a "safety rate" applicable to both employee and owner-operator drivers and carriers (Quinlan 2001). Quinlan's concept of a safety rate also has become accepted as a matter of national policy in Australia (Quinlan, Wright, and National Transport Commission 2008; Skulley 2009), although implementation remains unclear and bogged down in process.

In his elaborate Trucking Industry Benchmarking Program, Belzer uses cost-effective on-line data collection methods in an effort to collect data on both direct and indirect operational factors, with which he hopes to predict motor carrier safety. Based on the premise that cutthroat carriers cut corners to attract business by having low operating costs, and assuming that this corner cutting behavior includes practices that likely put the carrier at risk, Belzer proposes to determine the extent to which marginal pricing in trucking, in the absence of effective financial responsibility laws, might cause large and safe carriers to subsidize unsafe carriers against their will, thereby creating a market externality imposed on those carriers and the motoring public. Economic theory suggests that carriers with few assets may be "damage proof" because they can insure the value of their investment at a rate far lower than that which the market would charge if insurance companies were allowed to charge market rates for motor carrier insurance, representing their estimate of carries' true risk. If the cost of one fatal crash averages approximately US$3.5 million and federal regulations only require that carriers maintain $750,000 in per-crash liability insurance—state laws allow carriers to insure themselves at a prescribed minimum liability of $1 million or less—then it is quite possible that this subsidy helps to drive down shipping rates as well as motor carrier profits and driver pay rates. Belzer argues that self-regulation is possible only if public policy forbids these subsidies and if motor carriers benchmark their operational characteristics and practices (including compensation factors) against each other (see http://www.ilir.umich.edu/TIBP/) as well as Transportation Research Board presentations at http://www.ndsu.edu/ndsu/trb/).

Research recently published demonstrates clearly the relationship between market forces and motor carrier safety. Analyzing data collected from J.B. Hunt, a large truckload carrier that elected to solve its driver supply problem by raising wages substantially all at once, Belzer, Rodriguez, and Sedo show that this carrier cut its turnover rate as well as its overall crash rate in half in less than one year by paying an efficiency wage (Belzer, Rodriguez, and Sedo 2002; Rodriguez et al. 2003; Rodriguez, Targa, and Belzer 2006). Indeed, the firm reduced its monthly rate of major crashes four-fold, for unscheduled over-the-road freight drivers. A duration model, predicting the probability that each individual driver will have a crash in each succeeding month[10] showed that at the mean, for each ten percent in base mileage wage, the carrier reduced the probability of crash for the average driver by 34 percent. In addition, since some drivers received wage increases during this strategic change in compensation policy, a ten percent increase in drivers' base wages produced a six percent lower probability of crash. Clearly the policy had the desired effect.

IV. Conclusions

Economics – the competitive forces resulting from markets – strongly influence the structure of industry as well as the structure of the labor markets on which industries rely. This is a fundamental driving force in market economies, where private companies compete for business and by selling goods and services to customers subject to their preferences. Transportation is a

[10] Duration models are a method of conducting survival analysis, appropriate to the particular variables incorporated within a model. See methods section below for detail and explanations.

commodity within these markets because one unit of transportation is the same as the next, subject to quality constraints with imperfect information.

Transportation service failures take the form of delays due to many factors, including weather and equipment breakdown. Catastrophic failures, in the form of vehicular crashes, are low probability high impact events the predictability of which continues to stump analysts who know how to predict crashes based on mechanical failures or precautionary failures, including human error. The probabilistic prediction of commercial transportation failures, however, has eluded analysts who continue to restrict their focus to the equipment or human factors without looking systematically at the economic environment in which the commercial activity – and the failure – occurs.

Most critically, analysts fail to take into consideration that unlike personal travel, commercial vehicle transportation – whether by marine, air, rail, or highway – constitutes a derived demand industry that responds to the laws of economics as surely as it responds to law and regulation. In other words, while truck drivers respond to laws and regulations governing their operations, such laws vary by time and place, while economic laws do not vary. Truckers and trucking companies respond to the market demands of their customers, and compete based on satisfying those customers' demands for both price and service. Governments regulate truckers' equipment, practices and behaviors to create boundaries around that competition, but they can do so imperfectly. Since markets are systems of reciprocal demands set in a social context, the context itself requires systematic regulation that acknowledges the markets that frame the system. In other words, we must embed systematic truck safety regulation in the context of market systems.

Trucking is a labor-intensive industry, so we cannot effectively regulate trucking industry safety without addressing the fact that truck driver compensation is a major factor underlying the price of service that underlies this market. If freight transportation is a derived demand industry and if price and service are the dominant factors motivating competitive carriers, then we must deal with compensation factors if we are going to have any effect on motor carrier safety.

These studies show that higher driver pay is associated with safer operations. Clearly the more drivers are paid, and the more they are paid for their non-driving time, the less likely they are to have crashes. Part of this effect is due to labor market sorting: carriers that pay more money can afford to be more choosy, which allows them to select drivers with superior unobserved (to us) human capital characteristics. Part of this effect also is due to incentives: drivers who earn more money are motivated to protect their records and, if they have them, their retirement plans. Carriers that pay drivers more money do so because the value of their service is higher to the customer, and the generally higher value is associated with greater service demands and necessarily higher value of the freight.

These studies also show that market competition, an extremely powerful force in a world of unregulated economic competition, has put supply chain power in the hands of the shippers and consignees who determine rates and conditions under which freight services are allocated. The development of the supply chain approach to freight transport has placed the consumer in the most powerful position, as the consumer drives transactions in a world governed by welfare economics. The shippers and consignees are the consumers within the supply chain and represent end consumers.

The question is whether all the costs of transport are incorporated within the supply chain. Does the market governing supply chain externalize costs to society, creating inefficient market signals within supply chain transactions? Evidence presented here suggests that not only does the market incent inefficient use of freight transport resources, creating sprawl and environmental consequences, but it incents safety and health consequences the cost of which are borne by commercial motor vehicle drivers as well as the motoring public. These consequences represent a market failure that calls for regulatory solutions designed to incorporate all costs and benefits into an efficient market. An efficient market can therefore not only increase macroeconomic efficiency but spin off the equity that is the promise of the utilitarian ideal.

V. Policy Implications

Engage the U.S. Department of Labor as well as FMCSA

- Get government regulators out of their silos. FMCSA and the Department of Labor should cooperate to regulate the economic conditions that lead to safety problems. The DOL has the authority to regulate compensation and should do so.

The FMCSA should not have sole responsibility for CMV safety. While safety regulation is an important DOT function, safety is everybody's business. Once we recognize that safety problems have economic origins, and that these economic origins stem substantially from the effects of competition on the labor market, it becomes apparent that the Department of Labor needs to share responsibility. The silos of the Federal Government do not help to solve problems when they create artificial barriers for public policy.

FMCSA believes it does not have the authority to regulate compensation, even though it has commissioned research showing that competitive forces, including compensation and industry segment (a proxy for the price carriers charge to cargo owners, which eventually leads to driver compensation levels), play a major role in safety performance. The Department of Labor likewise believes it must take a hands-off attitude toward trucking, which originally was regulated by a Congressional agency – the Interstate Commerce Commission –

that has not existed for more than fifteen years. This analysis shows that we will not make lasting progress in safety without reconciling this turf question.

Regulations enforcing the FLSA should require explicit pay for implicit as well as explicit work. While it's fine to say that drivers must at least earn the minimum wage, many earn less than the minimum wage for all time employed, and most earn nothing explicitly for the hours they spend doing non-driving labor. Research cited here suggests that the average intercity driver probably works about 25% more hours than he logs, because he simply does not log unpaid non-driving labor time, and surveys show that on average 25% of drivers' work time involves non-driving labor. If carriers and cargo owners had to pay drivers for all of their time, the amount of time spent in doing non-driving labor would decline accordingly; cargo owners would no longer benefit from the moral hazard of playing with somebody else's time – or money. This moral hazard causes economic deadweight loss for society, as cargo owners and their agents demand more freight services – including service that they value at a very low rate – than the market would bear absent this moral hazard.

Carriers must charge, and cargo owners must pay, for all services they receive. It should be illegal to decline to collect such fees, or to refuse to pay documented charges. These fees include various "ancillary" charges such as waiting time (waiting to get loaded or unloaded), inside delivery, stacking and restacking freight inside food warehouses, and "demurrage" (excessive delay time). Shippers can order a truck early because they have the leverage to require it and receivers can refuse to unload a truck when it arrives because they aren't ready for the freight (or because the driver missed the time window). This causes drivers to engage in risky behavior to make appointments and they will not log unpaid time, extending their workday and workweek by working "off the clock", again demonstrating the interaction between competitive forces and safety and health risk.

In sum, while "safety culture" of the firm is something that FMCSA can address, and it can issue regulations on equipment and driver training, behavior, and qualifications, if economic forces require that safety culture be superimposed on a no-holds-barred competitive environment, the regulator will be fighting a continuous rear-guard battle against the iron law of competition. If the fundamental exigencies of markets work at all, then cargo owners' need for lowest price will lead to a race to the bottom and safety will suffer. Because economic forces are involved, economic solutions must be considered.

<u>Implement chain of responsibility regulations</u>

- Implement Chain of Responsibility regulations like those enacted by the Australian Parliament to create a level playing field in a deregulated environment.

Mitigation of the negative effects of competition requires that everyone in the supply chain – everyone in the chain of custody – take joint responsibility for safety outcomes. If cargo owners share the responsibility for the safe transportation of goods and people, they will have an incentive to work together with brokers and transportation providers to insist on socially responsible contracting practices, including a willingness to pay reasonable rates for the service. Following an inquiry on truck safety that determined that economic forces underlie commercial motor vehicle safety (Quinlan 2001), Australia implemented a "chain of responsibility" policy, in cooperation with the trucking industry and all levels of government (2004)[11]. On the principle that all participants in the chain of custody need to participate in developing and implementing a safety culture, government safety officials have cooperated with the industry to develop a safety accreditation scheme designed to engage the industry in continuous improvement with respect to safety (Baas and Taramoeroa 2008).

In Australia the government has gone so far as to announce a "safe rates" policy setting a minimum compensation package for truckers (Quinlan, Wright, and National Transport Commission 2008), which was passed the House on March 12, 2012 and the Senate on March 20, 2012.[12] Fair Work Australia has set up an industrial tribunal that begins work July 1 to establish a minimum national compensation scale for all truckers. It has widespread political as well as scientific support.

Carriers, drivers, third-party logistics providers, brokers, and cargo owners must be responsible for the supply chain in its entirety. The fragmentation of economic and legal responsibility for freight transport imposes hidden costs on the transportation system by imposing hidden costs on society. These costs appear in the form of safety and health burdens absorbed disproportionately by CMV drivers for whom the excessive work hours and safety and health burdens impose risks, and for motorists and others on the public roadway as well as health burdens suffered by the public generally by excessive low-cost trucking. It leads to widespread subcontracting as well, which shifts risk burdens to those least able to support them, shifting risk from the service providers to society, with attendant efficiency losses.

Currently the largest carriers, with the greatest visibility and assets to protect, tend to be the deep pockets that attract lawsuits. Our legal standards, which tends to hold parties responsible for damages according to the depth of their pockets, creates some inefficient incentives. The FMCSA only requires that carriers carry insurance for up to $750,000 per incident, even though single incidents can cost millions of dollars, and this unrealistically low level subsidizes unsafe carriers that can charge rates reflective of their inadequate

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[11] http://www.ntc.gov.au/newsdetail.aspx?newsid=149;
http://www.ntc.gov.au/viewpage.aspx?documentid=01419 (accessed on July 9, 2012).

[12] http://www.ministers.deewr.gov.au/shorten/safer-roads-all-australians (accessed on July 9, 2012). To locate the full Hansard, search http://www.aph.gov.au/hansard.

coverage while society bears the cost of this risk. In addition, motor carrier risk is hard to assess, and though the chance of a major loss is small, the cost could be great. Because low probability, high impact events are so hard to rate they can be hard to insure, and these carriers may be able to obtain insurance from assigned risk pools that, at least in some states, may charge below-market rates. Large motor carriers, on the other hand, which are substantially self-insured, pay the full cost of insuring against losses and may pay a premium over less safe carriers.

Australian policy makers have found that although "chain of responsibility" is hard to define and implement, it has been an effective way to get everyone's attention. In some cases where a willful pattern of violations has been identified, such as a case in New South Wales involving systematic overloading of trucks by grain shippers, criminal charges have been made, and industry-wide compliance occurred quickly.[13]

Subcontracting

- Tighten regulations on subcontracting that balances the power between contractors and trucking companies, as Australians have done. Court rulings 40 years ago usurped legislative authority, disallowing traditional cooperation among owner-drivers to negotiate with carriers. This would give owner-drivers a fair shake.

Widespread subcontracting, and arguably misclassification of workers as contractors in an attempt to evade employment and labor law as well as escape other burdens of having employees, has undermined public policy relative to employment and undermined true small business truckers as well. Independent businesses owners do not have to pay themselves a minimum wage, much less a living wage, removing the floor from the labor market entirely. When employees with no bargaining power are classified as business owners, they make a mockery of small business. As discussed in Belzer and Swan (2011), an intensive study of owner-drivers showed that the average owner-driver of one truck in interstate commerce, which he drives himself, earns only $21,267 in wages and profits combined. Since we know from other surveys that these drivers work at least 3,000 hours per year, their average earnings are slightly greater than $7 per hour. Since the median is almost identical to the mean, half earn less than that. Again, with pay a strong predictor of safety, economic pressures may account for most of their safety risk, and their risk as well as the risk to other highway users is substantial.

[13] Philip Halton, Assistant Director, National Transport Policy, Licensing, Registration & Freight. Roads and Traffic Authority of New South Wales. Personal communication and talk at the University of Michigan Transportation Research Institute conference in June 2009. Haltom presentation on "Compliance Issues (P10-1187)" also given at Transportation Research Board Annual Meeting on Sunday, January 10, 2010, in the session: "OECD-JTRC International Study on Truck Transport Safety, Productivity, and Sustainability: Final Results".

Subcontracting (or worker misclassification) has increased in recent years, with thousands of workers essentially buying their jobs. They own the equipment and the risk but motor carriers, under whose authority they operate, control them just like employees, with many working under conditions that resemble debt peonage. Many of these subcontract to other drivers who, though they do not own the equipment they drive, also become subcontractors. This individualization of work, now also widespread in the construction industry (especially residential), completely changes the employment dynamic, making labor and employment law enforcement, including regulations protecting worker safety and health as well as tax collection, virtually unenforceable. This creates a dangerous climate for safety and puts both the drivers and the public at great risk.

While these are just three recommendations that arise from this research stream, these three changes would have a profound impact on the economics of safety and health in the U.S. commercial carrier industry. Implications for trucking are obvious, but the same kinds of reform would result in safer airlines and commercial motor coach bus industries as well.

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