Reflections on the Economics of Transportation Safety

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Abstract

This is the introductory chapter to the special issue on the economics of transportation safety. It provides some context for the papers that are included in this volume. It does so by explaining the fundamental economics of safety, and by identifying the major trends in the literature. The paper concludes that transportation safety provides a wide variety of interesting topics for investigation by economists, and that there are plenty of unanswered questions for the next generation of the profession to tackle.

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This introduction has a dual purpose. The first is to provide some context for the papers that are included in the volume. The second is to convince readers that transportation safety provides a wide variety of interesting topics for investigation by economists, and that there are plenty of unanswered questions for the next generation of the profession to tackle.

Traditionally the field has been dominated by engineers, psychologists, medical doctors, and those who study organizational behavior. A relatively small band of economists have contributed to the debate. This volume brings together the work of many of them. While the number of economists active in the field may be small, many of the most fundamental questions in safety are ideally suited to the skills and mindset of economists. These questions include: How safe is "safe enough?" Can safety provision be left to the private marketplace? What is the role of public regulation in the provision of safety? And, are existing regulations effective and worthwhile? I cannot guarantee that this volume adequately answers these questions, but the economists' approach helps to clarify the questions and frame the answers.

When I was asked to edit this volume, I had a number of objectives. I wanted to include review papers and text-book style treatments of the core literature in addition to papers presenting new research findings. I wanted to do so because the existing literature is widely scattered among many journals. In addition, the existing mainstream textbooks on transportation economics devote little, if any, space to safety-related matters. Consequently, I asked all of the authors, even those who are primarily presenting new research, to provide a much longer than usual literature review section

1. Transportation Safety is an Important Issue

Perhaps it is unnecessary to have to convince the reader of the importance of transportation safety. In a review of the safety of various transportation modes in the decade from 2000 to 2009, the paper in this volume by Ian Savage (2013) indicates that about 43,000 Americans die each year in transportation incidents. These deaths represent almost four out of every ten "unintentional injury" deaths in the United States. Unintentional injury deaths are those deaths that do not result from old age, disease, homicide or suicide. Transportation is the largest cause of such deaths. Indeed, it is greater than the sum of the next two leading causes of such deaths (which are falls and poisonings).

In addition to fatalities, there are countless non-fatal injuries, property is damaged and destroyed, delays are imposed on other users while incidents are attended to and cleaned up, and the environment is damaged by any consequent release of hazardous cargoes. There are also administrative costs associated with legal proceedings and insurance adjudication. Blincoe *et al*. (2002) calculated that the annual cost to society of highway crashes in the United States in the year 2000 was $306 billion (updated from 2000 to 2012 dollars). This is equivalent to about 2.3% of gross domestic product, or about $1,100 dollars annually for every man, woman and child.

2. The Fundamental Economics of Safety

In terms of traditional economic models, safety is most likely an important part of both the demand and supply functions. The possibility of loss, injury and death presumably enters travel demand and mode choice decisions, albeit that the profession is still hard pressed to quantify the exact magnitude of the relationship. Analysis of the demand relationships is complicated because, unlike price or travel time, the traveler is generally thought of as having an imperfect knowledge of the risks that they face. Asymmetric information and the consequent market failures are endemic in safety determination. Even when there is no formal market interaction going on, such as when people are driving their own vehicles, it is likely that economic agents are poorly informed about the inherent risks, and often have cognitive limitations in processing whatever information they do have.

Safety also pays a large (if somewhat ill-defined) part of the costs of transportation. The cost of automobiles is inflated by the inclusion of many types of safety-related design features. Commercial transportation providers invest in higher quality equipment and staff training to reduce the probability of mishaps. As discussed in the previous section, when mishaps do occur there are also costs imposed on the parties involved in the mishap and also externalities imposed on bystanders. The underlying legal regime determines how much of the externality is internalized by the party that "caused" the incident.

An unusual feature of safety is that economic agents - be they individual users or firms - in deciding on their course of action have to consider both ex-ante costs that lessen the probability and/or severity of an incident (what we might term "prevention costs") and ex-post costs that are incurred only when and if an incident happens. Incidents are probabilistic in nature and occur at undefined points in the future. Consequently economic agents are trading off certain costs in the present against averting or mitigating uncertain cost consequences in the future. It is easy to see how myopia (or putting it more charitably a steep discount rate) could lead to decisions that the agent, and others, may regret in the long run.

At some level, safety can be regarded as "quality" attribute of transportation, and economists can ask the usual question concerning "how much quality should be provided?" The classic theoretical industrial organization literature on product quality from the 1970s and 1980s informs our thinking about automobile product safety features and decisions by airlines and trucking firms on the level of safety to provide. Recognizing that safety is valued by consumers yet costly to provide, economists would have no problem in concluding that the "optimal" level of safety is most likely not perfect safety (presuming that it was even technically possible). This type of thinking clearly creates tension between economists and those who feel that it is somewhat "immoral" to decide not to spend money to avert some low probability risk. This tension is inherent in many papers in this volume, but is particularly evident in the paper by Andrew Evans (2013) in his discussion of the economics of advanced train control systems.

Perhaps living up to the public perception of economics as the "dismal science," the profession inherently argues that society is always trading off risks to life and limb against money. While society spends untold amounts to rescue known seafarers who find themselves in peril, most of the decisions are more mundane and unexciting and deal with evaluating small

changes to already small risks effecting future potential victims whose identity is not known. Economists are therefore very comfortable with the concept of a "value of a statistical life" (also known as the "value of preventing a fatality") for use in monetizing the safety benefits in such calculations. This concept is present, either explicitly or implicitly, in every paper in this volume.

A few paragraphs ago I wrote that at some level safety might be regarded as a product quality attribute. While analytically there may be great similarities, there is a big difference between safety and other transportation quality attributes. For other attributes, some sort of market failure might mean that railroad commuters may have stand rather than get a seat, bus passengers may have to wait an extra five minutes in the rain, or drivers may get stuck in traffic for 15 minutes. A failure in safety provision results in funerals, shattered lives and shattered families. The stakes are so much higher, and so are the rewards from engaging in research on this topic.

3. Accidental and Deliberate Acts

A word on terminology is necessary at this point. I, like many analysts, prefer to avoid using the word "accidents." This is often hard to do because in some modes the term has a specific definitional meaning. The reason for avoiding the term is that relatively few incidents can be described as occurring due to pure fate or an "act of God." In most cases there has been a deliberate prior decision to act with a certain level of care and attention and/or a decision on investments to mitigate the risks imposed by the weather and the physical environment. For nearly all incidents, a different set of prior actions or a greater expenditure could have averted or mitigated the incident.

In the highway modes, the preferred word of the past couple of decades seems to be "crashes," albeit that some incidents such as fires may not accord with the common understanding of the meaning of the word. For other modes, the term "incidents" has the dual benefit to being both non-pejorative and also general enough to cover the range of different types of mishaps that can occur.

However, in a certain sense, we are dealing with "unintentional deaths" in that transportation casualty statistics usually exclude cases of deliberate acts such as homicide, suicide, terrorism and sabotage. Yet, as has become apparent in the past couple of decades, transportation has been a popular target for terrorists, and transportation vehicles have become weapons of terrorism. With the exception of the paper on aviation by Clinton Oster, John Strong and Kurt Zorn (Oster *et al*., 2013), these risks are not discussed in this volume. In the decade since the terrorist attacks using civilian aircraft in the United States on September 11, 2001, other modes have also been targeted. Passenger trains have been bombed in Spain, Britain and India, and there has been a resurgence of piracy on the high seas. While one might have imagined that the skills of researchers in transportation safety would have been transferable to the analysis of the terrorist risks, there would appear to have been very little crossover.

While consideration of terrorist risks is largely absent, suicidal acts do receive some attention in these pages. Suicides by pedestrians stepping in front of trains (and sometimes by car drivers stopping on highway-rail grade crossings) are a significant issue. While definitive data in the United States was not available prior to July 2011, other evidence suggests perhaps half of all fatal train-pedestrian incidents are suicides. While the percentage of total suicides by means of a train is probably about 1% in the United States, the proportion is much higher in Europe at 5% to 7% (Silla and Luoma, 2012). While formal highway fatality data usually also exclude known suicides, it is likely that a proportion of the incidents that are included are actually also suicides. Pompili *et al*. (2012) in a review of the literature places the proportion at 2% to 3%, with suspicions that it might be higher. The paper by Gail Blattenberger, Richard Fowles and Peter Loeb (Blattenberger *et al*., 2013) finds that when a comparison is made across states in the USA, those states with higher suicide rates (by all methods) tend to have higher highway crash rates. While the nature of the causal links may be debatable, and indeed it is likely that both are symptoms of other social and geographic variables, it is undeniable that a non-trivial proportion of highway crashes are either documented or undocumented suicides.

4. Private Driving on the Highway

Savage's paper points out that despite the widespread press reporting of dramatic train collisions and aircraft crashes, almost all transportation fatalities occur on the highways (Savage, 2013). The figure in the United States is in excess of 95%. Most of these incidents receive very little press attention as the number of fatalities in each incident is low, and they occur with sufficient frequency that they cease to be newsworthy.

Even when fatalities are expressed as a rate relative to the amount of travel, highway risks are an order of magnitude greater than those of other modes. Consequently the greatest payoff from academic research is likely to occur in the highway field. It is therefore not surprising that the vast majority of the papers in this volume (10 of the 12) deal, at least in part, with highway risks. This is also reflected in the academic literature in general where the journal *Accident Analysis and Prevention* publishes hundreds of papers each year on highway safety, and there are countless more in professional engineering journals dealing with highway design and automotive engineering. In contrast papers on safety in other modes are much smaller in number and widely dispersed among many journals.

Only about 13% of highway fatalities involve a commercial vehicle such as a taxicab, bus or large truck. The other 87% occur when private users are in single vehicle incidents or collide with each other. In this section, I will discuss the economics of private highway use. I will reflect on the safety of commercial vehicles in the next section, as the economics of safety of these firms has great similarities to that of commercial carriers in other modes such as aviation, maritime and rail.

To motivate the discussion of the economics of private highway travel safety, I would like to highlight five stylized facts from the United States:

a) A surprisingly large proportion of highway fatalities, more than half, occur in incidents that only involve one vehicle such as when a vehicle rolls over or leaves the highway without being involved in a prior collision with another vehicle.

b) The other 45% of fatal highway crashes involve two or more highway users (including pedestrians) colliding with each other.

c) About 30% of vehicle-occupant fatalities in all incidents involving automobiles and light trucks are passengers in the vehicle rather than the driver.

d) A third of fatal crashes involve at least one party that had consumed alcohol beyond the legal limit.

e) In many cases the driver is a victim of his or her inexperience, youthful exuberance, gender (men in general and those under the age of 24 in particular have considerably elevated risks), or human frailties such as inattention, cognitive overload and poor judgment.

The first two statements appear to auger well for economists. On a superficial level, single-vehicle crashes would appear to be a classic economic tradeoff where the driver is solely responsible for the crash occurring (even if part of that responsibility is appropriately responding to weather conditions) and presumably bears most of the consequences. Multi-vehicle (or vehicle-pedestrian) collisions would seem to be even more fertile ground for economists. Shavell (2004) provides a comprehensive treatment of the game-theoretic incentives that both parties to such crashes have to provide due care and attention under different legal liability regimes. The fact that the party that suffers the most harm in these "bilateral crashes" might not be the party that "caused" the crash has also given rise to the holding of insurance, and economists have been heavily involved in the design and operation of insurance markets.

The final three statements do not play to the comparative advantage of economists. While economists do have expertise in principal-agent problems, the interpersonal dynamics of how adult passengers can influence the risk taking behavior of the driver of their vehicle tends to be beyond our sphere of competence. The pervasive involvement of alcohol would seem to suggest that an economic analysis of many traffic crashes could require specification of a two-stage decision. The first stage is the decision to consume alcohol in excess. The second is the risk-taking decisions made by the impaired person when driving. The final statement highlights the fact that many of the fundamental causes of traffic crashes are due to human performance factors. Economists tend to have limited insights into such matters.

That said, economists have been effective in analyzing choices that drivers can make to mitigate the inherent risks. Drivers can elect to equip their vehicles with a greater number of safety features that help prevent crashes from occurring, or mitigate the consequences if a crash does occur. In making the decision to purchase such safety features, one might imagine that drivers (and their families) might vary based on differences in personal risk aversion, their budget constraints, and their perceptions (accurate or not) of the risk reduction afforded by specific devices and vehicle characteristics.

An active literature has analyzed the consequences and desirability of mandated changes in safety equipment and highway design that are common to all road users. Mandating the installation of safety devices or design features usually raises the price of new vehicles. Some devices, such as seatbelts, also require the user to devote time to the activation of the device and/or some discomfort or disutility from using them. While the cost of the devices is usually fairly easily calculated, the benefits of reduced risk are more difficult to discern and are often quite controversial.

Even if the benefits in terms of a reduced number of crashes can be discerned, there is still the problem of how these benefits should be compared with the, primarily financial, costs of vehicle or highway infrastructure improvements. While some of the benefits, such as reduced property damage are measured in financial terms, most are not. The most prominent benefits come from a reduction in the number of fatalities and injuries. Some of benefits from injury reduction can be expressed in financial terms such as the reduced need for medical attention and a reduction in the loss of productivity of workers who are off work while they recuperate. However, starting in the 1960s there was a feeling that direct costs and productivity loses understated the benefits of preventing fatalities and injuries. Moreover, it would seem that individuals were making choices based on much higher inherent valuations of their own lives.

The paper by Michael Jones-Lee and Michael Spackman (Jones-Lee and Spackman, 2013) describes the developments over the following decades in the United Kingdom to determine, using stated preference techniques, transportation users' mean (or median) valuation of averting the death of an anonymous random member of society. This is known as the "value of preventing a fatality" (VPF) in the United Kingdom, and the "value of a statistical life" (VOSL) in many other parts of the world. The figures obtained are in the multiple millions of dollars implying that there is a considerable valuation of the "pain and suffering" in excess of the purely out-of-pocket financial consequences suffered by the victim's family and society in general. So far there has been less investigation of the valuation of injuries, despite that fact that non-fatal injuries are much more common and some of the most severe injuries might be regarded as "worse than death" by many people.

While there might be opportunities to measure VPF/VOSL from some revealed choices (such as the willingness for some drivers to purchase additional safety features for their automobile), much of the literature in the transportation field has been derived from stated preference surveys and experiments. The literature continues to expand. The paper by Knut Veisten *et al*. (2013) describes an experiment where drivers choose between routes that have different inherent risks. The authors are able to infer a willingness of pay for safety. Perhaps the greatest unease concerns whether people's stated preferences elicited in surveys and experiments accord with their "revealed preference" when confronted with actual choices. The paper by Henrik Andersson (2013) takes a set of survey respondents and compares their stated preferences and their revealed preferences (as represented by their use of safety devices).

Of course, the tradeoff between financial expenditures and life saving is common to many other fields, such as food safety and medical care. But transportation economists have been at the forefront of valuing life saving. I would argue that this is due to the prevalence of the

risks on the highways (which were much higher in the 1960s when this line of research started than they are today), and the generally public good nature of highway safety provision. There is no direct market, and hence no market price, for highway geometry improvements and law enforcement activities, and many vehicle safety devices are mandated by law rather than offered as an optional add on to drivers.

The valuation of lives saved and injuries averted goes hand-in-hand with the deployment of benefit-cost analysis. Again this has been an area of economics in which transportation economist have played a leading role. In many counties, the valuation of injuries and deaths avoided, and its close cousin the valuation of travel time savings, have become a standard part of the evaluation tool used for assessing highway improvements. That said the laundry list of potential safety-related projects is long, and welfare economics is fraught with the possibilities that incorrect choices might be made in prioritizing projects. The types of failures of rationality that can occur are described in the paper by Rune Elvik (2013). Even beyond issues of rationality, the paper by Robert Noland (2013) discusses that benefit-cost analysis has to struggle with issues of poor information on the engineering relationships between highway design and safety outcomes, and tough trade-offs such as when there is a tension between improving safety and restricting mobility or the ease of mobility.

Economics has a more direct effect on highway safety by attempting to improve driver behavior by ensuring that drivers internalize the consequences of acting in a careless manner. Most drivers hold insurance against legal claims and personal loss. Indeed in many jurisdictions the holding of insurance (of at least a minimum coverage against third party claims) is required. The paper by Georges Dionne, Pierre-Carl Michaud and Jean Pinquet (Dionne *et al*., 2013) reviews the literature on how insurance premiums can be set to encourage drivers to take care and penalize those who do not. In setting premiums, insurance companies are not perfectly informed about how much care an individual driver takes. Consequently, it is likely that the premium schedule does not fully provide the correct incentives. Insurance companies can look to a driver's record of claims to provide some information, but claims are relatively rare events. Therefore, insurance companies also look to a driver's record in terms of police citations for infractions of driving rules.

Given that the enforcement of traffic laws, and responding to crashes, represents a considerable proportion of the activities of most police departments, one would imagine that the economics of policing would be a fertile area for research. Economists have been able to determine, to some extent, whether changes in traffic laws have measurable effects on crash rates. The changes over time, and across jurisdictions, in the legal drinking age and the legally-allowable blood–alcohol content, speed limits, and also laws concerning the wearing of seatbelts have provided ample opportunity for applied economists (see Zaal, 1994, for an early literature review, and Tay, 2005, for a recent research paper.) However, it is difficult to observe the resources devoted and the veracity that police departments enforce traffic laws. Consequently, questions about the economically optimal level of policing of traffic infractions are open for further research.

Despite these somewhat negative statements about how little we know about many aspects of highway safety, it is undeniable that safety has improved considerably in recent

decades in most developed countries. The improvement in crash and fatality rates per vehicle mile has been sufficiently large that the absolute number of crashes and casualties has also declined despite population growth and increased car ownership. There are many reasons for the improvement. The paper by Clinton Oster and John Strong (Oster and Strong, 2013) discusses how the baby boom generation has aged out of their early reckless years into middle age, there have been engineering advances in cars and highways, there has been a continuing trend for people to move from rural to urban areas where crashes tend to be less severe, and countless other possible explanations.

A useful device to categorize the myriad possible reasons is Haddon's (1972) three-by-three crash causation and severity matrix. On one edge of the matrix are the categories of the driver, the vehicle and the highway. The other edge has the categories of factors that occur before the crash, during the crash and after the crash. Prior to the crash are factors such as driver licensing and training, and the design of the vehicle and the roadway. During the crash, the severity of the outcomes can be mitigated by the driver having previously decided to wear a safety belt, design features of the vehicle and also highway design features such as guard rails and the cushioning of bridge abutments. An often overlooked factor is events that occur after the crash. It could be argued that a considerable reduction in the rate of fatalities and serious injuries has resulted from faster and better-equipped emergency medical response. Physicians often talk of the "golden first hour" that exists for attending to and transporting to hospital seriously injured people.

There have been improvements in most cells of the Haddon matrix in the past forty years. There has been a considerable literature by economists trying to identify which of the various possible explanations for the safety improvements have been the most important. Economists have a comparative advantage in this endeavor due to their econometric skills. Much of the literature concerns the United States because authors can take advantage of variation across states as well as across time. Often traffic laws are introduced at different times in different states, and states vary in the demographics of their population. The biggest problem that an econometrician faces is deciding which explanatory variables from a lengthy list of possible variables should be in the regression. The paper by Gail Blattenberger, Richard Fowles and Peter Loeb (Blattenberger *et al*, 2013) uses Bayesian methods on a pooled dataset across states and time to conclude that the leading explanations are that advances in automotive technology (measured by the median car model year) reduces the fatality rate, while the spread of cell phones, and the extent of poverty in a state raises the rate.

Econometricians can also analyze cross-sectional data on individual crashes to determine which factors seem to explain crash occurrence. I would say that economists have tended to have less interest in such disaggregated analyses because the results often point to localized engineering fixes such as changes in highway geometry and intersection configuration. The paper by Kibrom Araya Abay (2013) uses innovative econometric techniques to look at collisions between automobiles and pedestrians, a risk that should not be underestimated. In addition he focuses on predicting the severity of incidents that occur, rather than their frequency. This is an important consideration as most other papers in this volume deal with the probability of occurrence rather than severity. Of course, one can understand why most analyses are confined to fatal crashes.

We have good, reliable and comprehensive data on fatal crashes, whereas there is widespread under-reporting of non-fatal injury and property damage crashes.

5. Crashes Involving Commercial Carriers

Crashes involving commercial carriers on the highways and in other modes account for just 15% of transportation fatalities in the United States. Amazingly, only 15% of the 15% (that is to say 2% of total transportation fatalities) are people involved in the production or consumption of transportation as employees or passengers. The majority of the commercial transportation related fatalities are pedestrians and automobile occupants who are involved in collisions with trucks and buses, and highway-rail crossing users and pedestrian trespassers who are struck by trains (Savage, 2013)

The implication for economists is that two extensive field of safety research - industrial organization analysis of firms' commercial safety choices and labor economics' examination of workplace safety - bear on only a small minority of total fatalities. Despite the relatively small number of victims, fatal incidents in the commercial sector tend to have political ramifications. In part this is because incidents in which more than a handful of people die occur almost exclusively in the commercial sector, and these incidents receive a disproportionate amount of press coverage and public policy scrutiny. Moreover transportation is a highly unionized sector, and labor unions are vocal in campaigning for safe working conditions for their members.

5.1 Industrial Organization Aspects

The first question an industrial organization economist would ask is "how much safety would a profit maximizing firm provide?" and follow that up with a second question regarding how this equilibrium might differ from a first-best outcome. If one starts from the proposition that safety can be regarded as a "quality" product attribute, then one can turn to a sizeable theoretical literature from the late 1970s and early 1980s to aid in our understanding of the basic economics of safety. Classic theoretical papers include Spence (1975) on monopoly, Shaked and Sutton (1982) for duopoly, and Dixit and Stiglitz (1977) for monopolistic competition.

The transportation safety literature is almost devoid of any empirical papers that have attempted to estimate such equilibria. The sole exception, to my knowledge, is a paper by Evans and Morrison (1997) who analyzed the safety choices made by a monopoly (at least within its own mode) passenger railway in Britain.

The literature is presumably so small because of three major complications. The first is that as soon as one moves away from monopoly, there will be strategic interaction between firms in deciding on the level of safety to offer consumers. Game-theoretic considerations soon make identifying any unique equilibrium elusive. The second is that the parameters of the demand response to the safety level(s) on offer are hard to measure. The best that one can do is use the stated-preference evidence from the VPF/VOSL literature to attempt to infer demand elasticities. In reality, such calculations are moot, because classic benchmark models require consumers to be perfectly informed about the product and its attributes. Because crashes occur rarely,

consumers are most likely under-informed about safety. Asymmetric information will be rife in safety markets. Consequently the reality is that models of market failure will be much more applicable. Indeed the theoretical literature on product quality in the 1970s and 1980s soon turned to the issues of consumers learning about what levels of quality are on offer, and how firms obtain (and perhaps destroy) reputations for providing high quality products (Savage, 1999, 2001).

The third complication is that one cannot even assume that firms are aware of their own production function for safety. Aviation professionals have taken a leading role in a growing literature on how safety is produced. This literature suggests that the relationship between safety-related inputs (such as maintenance activities or staff training) and safety outcomes is not well-defined or easily characterized. Safety outcomes depend not only on these direct inputs to safety but also on the layers of "defenses" that companies build into their systems to protect against naturally occurring human and environmental errors (Maurino *et al.*, 1995). It also depends on the "safety culture" that senior management creates throughout the whole organization. The work of James Reason and his collaborators argues that most incidents in high technology systems do not occur as a result of one failure, but are caused by a whole chain of events. Even if one link in the chain can be broken the hazardous circumstance may not result in an incident. Furthermore every "defense" against incidents usually has some, known or unknown, flaw. One could think of this as a hole in a slice of Swiss cheese. For an incident to occur all of the holes in the multiple slices of cheese, that represent the multiple defenses, must be lined up. The implication is that the production of safety is somewhat of a black box. Firms can only make decisions on the inputs to safety, and the number of defenses put in place (i.e., the number of slices of cheese), but the resulting safety level is somewhat unpredictable.

It is not surprising, therefore, that the empirical literature has changed the question from "how much safety should be provided" to "how have certain market failures affected the level of safety that is provided." One particular aspect has received a lot of attention. When consumers are poorly informed, there is the potential for firms to earn short term rents by reducing the level of safety on offer. This behavior is rather attractive to firms because the savings in (for example) maintenance expenditures occurs in the present, while the adverse effects of a crash or a consumer backlash only occurs in a probabilistic fashion in the future. A dominant focus of the literature has been that firms close to bankruptcy might act in this fashion because there is an upside possibility that by saving costs they might survive long enough for better times to come along. Moreover they suffer no downside risk from a crash because they would be out of business anyway.

There is more than enough anecdotal evidence of firms behaving in this fashion in almost all modes to give credence to such fears. Empirical economists became interested in this issue in the years following economic deregulation because competitive pressures forced inefficient firms from the market, and the popular concern was that these firms would sacrifice safety in their final periods of operation. Because there never seems to be a shortage of transportation firms suffering financial hard times, there has been an ongoing literature analyzing the links between profitability (defined in various ways) and safety performance (also defined in various ways). Much of the literature concerns the aviation industry where there is plentiful financial data available.

Another stream of the literature has attempted to quantify whether adverse demand effects after a crash might lead to a sufficient backlash from consumers and investors that firms are dissuaded from acting in a myopic fashion. Most of the literature has also been in the aviation industry where crashes are few but widely publicized, and there is good data on revenues and stock prices. My reading of this literature is that, in general, the "market discipline" argument is not totally persuasive, albeit that one can easily point to well-known companies who have suffered, sometimes irrevocably, after safety problems are revealed. Of course, the public concern is that these market corrections are inherently ex-post and occur after lives have been lost.

I think there are many unanswered question as to how and why firms might gain a "notorious" reputation for poor safety. How many crashes are necessary before the public infers that something other than "bad luck" is at play? Do these crashes have to occur within a certain time period? Are there other types of "news" that are equally or more damaging to a reputation than actual crashes? And, is it possible to recover from a poor reputation?

The flip side of these questions is also very interesting. How can a firm signal to its potential customers that it provides a high level of safety? Because crashes occur rarely even for poor firms, the absence of crashes does not necessarily indicate that a firm is of high quality. Advertising the superior quality of your staff and equipment is somewhat problematic in that a firm may not wish to highlight what is essentially a negative aspect of its product. In addition "talk is cheap" and consumers may well ask whether the firm's statements are credible.

This brings us to the crux of the industrial organization economists' questions. Will there be a diversity of safety levels on offer to consumers? Of course, this presupposes that consumers have a diversity of taste for safety. It is easy to imagine that this diversity exists in the freight sector. Goods vary in their resilience to damage in a crash, and the amount of environmental damage that might result. One could imagine that shippers of some commodities will seek out high-safety firms, whereas shippers of other commodities will be happy with higher-risk firms that offer a discounted price (Savage, 2011). Moreover, shippers may be quite familiar with the safety levels on offer by individual firms because they are constantly having to deal with minor claims for loss and damage due to spoilage, rough handling and theft. One might imagine that such a vertically differentiated market is most likely to exist in the truckload trucking industry. Perhaps it might also exist in the bulk maritime industry.

Diversity is much less likely in the freight railroad, liner shipping, and the less-than-truckload trucking industry. A common infrastructure (in the railroad industry) and economies of scope mean that firms can only provide a "one size fits all" level of safety. Undoubtedly some shippers receive a higher level of safety (at a higher price) than they would prefer, and others receive a lower than desired level of safety but at a lower price than they would be willing to pay.

One might imagine that a similar dynamic might be at play in the passenger sector. In the charter and private-hire part of the market there may be some matching of very safety conscious consumers with high-quality firms, and discount price and low safety firms with consumers who

have a lesser taste for safety. Yet in the common carrier part of the market, by necessity there would need to be a "one size fits all." A functioning vertically-differentiated market presupposes three things. The first is that there is a diversity of consumer tastes for personal safety. Evidence from the empirical VPF/VOSL literature certainly points to a range of response from those interviewed. Some of the variation can be explained by characteristics such as age (with an inverted U shape with middle age people having a higher valuation that the young or old), and income (with valuation increasing but at a less than proportional rate with income). Some people seem to be more carefree and risk taking than others. That said, I have yet to see a literature that quantifies the distribution of these tastes in terms of transportation demand.

The second presumption is that consumers can identify those firms that offer a safety level that matches their personal tastes. In some limited circumstances this may occur. I would imagine that frequent consumers in the charter bus or aviation markets may be informed consumers. I am aware of some aviation charter markets where consumers employ consultants to undertake safety audits of potential contractors. But in most mainstream markets I think that poor information means that there ends up being very little competition on the basis of safety. Most common carriers in a particular mode end up offering indistinguishable levels of safety from their rivals. A firm cannot deviate upward from the pack because they are unable to credibly convince consumers that higher safety is offered in return for the higher price.

The third presumption is rather troubling. Diversity in the demand for safety levels may result not only from variation in personal tastes but also from ability to pay. Given that some level of mobility is a necessity, and might even be regarded as a right, vertical differentiation is likely to result in the lowest safety-level firms being patronized by the most impecunious in society. Of course, this is a phenomenon that exists in many aspects of life and not just transportation safety. It is possible that some people would choose to patronize these low-safety firms even if they were fully informed about the risks. If these risks are large enough it is possible that society may foreclose on these options using minimum safety regulations, even if it means that certain segments of society lose out on a certain level of mobility.

The previous paragraph has described one possible reason for government intervention. The plausible risk of myopic behavior, and the difficulty that ordinary consumers have in determining ex-ante those firms with poor safety practices, provide additional reasons. Transportation has been subject to safety regulations for a long time, and it seems to endure. Even at the highpoint of liberalization of economic regulations in the 1970s and 1980s, the proponents were quick to add that "safety will not be deregulated."

Government action usually entails defining a minimum acceptable standard, and coupling it with an inspection regime to monitor and enforce the standard. Of course, the public is only really interested in minimum safety *performance*, but it is tough to legislate and enforce safety outputs. Consequently, the government usually specifies minimum levels of safety *inputs* such as mechanical specifications or staff qualifications and training. Because the regulations focus on inputs rather than outputs, the effect of any regulatory action is rather unclear either at the time that the regulation is proposed or even in retrospect.

With the uncertain link to safety outcomes, it is easy to see why some regulatory initiatives might be ill-conceived, or perhaps would not pass a benefit-cost analysis test. The papers by Jones-Lee and Spackman (Jones-Lee and Spackman, 2013) and by Evans (Evans, 2013) reflect on attempts by public agencies in Britain to use economic principles in regulating risks on mainline railways and subways. Jones-Lee and Spackman report on studies that indicate that the VPF was not found to be higher when the risks involve multiple-fatality events or frightening methods of death such as the victim being trapped in a burning subway train. Nonetheless it does appear that commercial modes are held to a much higher standard than is the case for private highway travel. Often reference is made to the psychology literature of the 1970s that showed that risks that are "involuntary" or "uncontrollable" are tolerated much less than risks that people freely choose to engage in or can control the outcome if something untoward occurs (Fischhoff *et al*., 1978).

In the paper by Evans (2013) reference is made to the discussions in the 1990s in Britain to possibly install an "Automatic Train Protection" system. A similar system known "Positive Train Control" was mandated by the United States Congress in 2008. In both countries it is likely that the implementation would fail a cost-benefit test by a wide margin based on conventional values of injuries and deaths. In some cases, regulations have been hastily implemented because politicians need to be seen to "have done something" after a particularly newsworthy incident. It is often difficult to argue against such actions because the possible positive effects on safety are usually apparent, yet the magnitudes of the effects are hard to quantify.

Part of the problem is that traditional regulation has focused on things that inspectors can measure and assess for compliance with the rules. An alternative approach is to use "performance standards" which designate minimum acceptable crash rates. This approach has several advantages. First, carriers are allowed to use entrepreneurial skill to produce the desired level of safety at minimum cost. Second, new technology can be introduced quite quickly, unhindered by the need to change the regulations. Third there is less susceptibility to politicking by avaricious parties who wish to use regulation of safety inputs to preserve old working practices, exclude new entrants, or promote the use of their own specific safety-related product. There have been some limited moves toward performance standards and this will provide a fruitful area of research for the coming years.

Another alternative strategy to correct market failures might be to provide up-to-date safety information directly to passengers and shippers. In theory such information could attack the root cause of asymmetric information, a major safety market failure. Whether wide dissemination of this information will help customers make better choices and dissuade carriers from indulging in myopic behavior is an open question, however. The traditional concern is that the public is unable to draw proper inferences from data on events that occur with a low probability. A more serious concern is that providing historical crash data does nothing to ameliorate the problem of current myopic carriers. Unscrupulous carriers who wish to cheat will, by definition, deviate from their past performance. Consequently, it is often argued that the public should be provided with information on carriers' safety inputs such as the average experience of staff and the age and condition of equipment. In this way customers can make predictions of future safety performance. This information is currently not widely available or

disseminated. Some also argue that this data may be misleading because even safety professionals cannot definitively relate input measures to the expected effect on safety. Nevertheless, the information age provides the opportunity for disseminating safety information directly to the public. Future research will show whether any such experiments are successful and whether a more-informed public obviates the need for some safety regulations.

The commercial transportation section of this volume is much briefer than I would have liked. In part this is understandable in that the relative size of the death toll has attracted much more professional attention to private motoring. The two papers that are included have similarities in that they provide a time series analyses. Andrew Evans (2013) looks at risks associated with railroads and Clinton Oster, John Strong and Kurt Zorn (Oster *et al*., 2013) look at aviation risks. A number of things are apparent to me from these papers. The first is that "safety" is not one-dimensional in either mode. Railroads have separate, and somewhat unrelated, safety issues concerning collisions, derailments, fires, rail-highway grade crossings, trespassers and suicidal people. Aviation safety is composed of weather-related issues, mechanical and design issues, human factors, hijackings and bombings. The second is that technological advances have had huge impacts, especially in aviation. The rudimentary technology that existed well into the 1960s is almost inconceivable to a modern day traveler. Undoubtedly engineers have had, and will have, a much greater effect on transportation safety than economists. Finally it is clear in both papers that government action is interwoven into all aspects of safety provision, even in the primarily private sector aviation industry.

5.2 Labor Economics Aspects

A career in transportation usually means using heavy machinery and working outdoors often in places far removed from immediate medical care. It is perhaps not surprising that the fatality risk in trucking is twice that of working in construction, and the fatality risks in the much safer aviation and railroad industries are still twice those of working in manufacturing. Given that labor unions are still strong in many modes, the elevated workplace risks mean that safety-related matters are the subject of intense collective bargaining.

For me the most interesting labor issue occurs in transportation modes where there appears to be a vertically differentiated safety market. An example would be the truckload trucking industry. Presumably there must be a dynamic process whereby the managers and workers with the greatest safety skills get matched with the high-quality firms. This process must occur because it is the talents and skills of these employees that are crucial to these firms actually being able to deliver a high-quality product. Human factors have a role, to some extent or other, in most safety-related incidents. Consequently, other things being equal, the safest firms are those who employ the most safety-conscious workers.

Such a diversity of labor outcomes presumes that some workers have a greater aptitude for safety operation (for example, they may be a "natural" pilot), others decide to invest in their skills, and others just act in a more conservative and cautious manner. Firms with the best safety records are able to achieve this feat by attracting the safest workers to come and work for them. Presumably these workers will also enjoy premium wages or get other benefits from being in a work environment with like-minded people.

Of course, one of the ways that workers obtain skills is on-the-job experience which leads to the common phenomena that new entrants to the labor market are recruited into the lowest-quality segment of the industry. Then those workers who gain experience and/or discover that they have particular aptitudes can graduate to higher-quality firms who also pay more. This also means that there is a self-regulating process that keeps firms that are at the bottom of the food chain stuck in that position. Any skilled workers that would be vital to the firm improving its reputation would not choose to work for that firm, and those who are already employed there would move to other firms that are a better match for their talents. It is a very interesting process, and one that I feel has not been well researched,

5.3 Law and Economics Aspects

Almost all (85%) of fatalities in commercial transportation incidents are parties other than employees or passengers. In addition, environmental damage can result from releases of hazardous materials following a crash. The sheer magnitude of these effects suggests that the profession would be well advised to devote plenty of attention to the interaction of commercial carriers with third parties.

It should be said that not all of the other affected parties are innocent bystanders. Private highway users may be at fault in some collisions with trucks, some highway users drive around lowered gates at railroad grade crossings, and some people trespass on the railroad tracks. The issues of the legal responsibilities of both parties in bilateral crashes, and their optimal duty of care, are of considerable interest to lawyers and economists. There is the potential for market failures when court decisions are made in situations where corporations are pitted against individual citizens.

Even in the case of the release of hazardous materials, when the issue of liability is reasonably clear cut, there are plenty of controversies that would interest an economist. Examples include whether the liability should lie with the carrier or with the freight shipper, the optimal provision and location of appropriately-equipped emergency responders, and decisions on whether some commodities should take circuitous routings around populous areas. The edited volume by Moses and Lindstrom (1993) indicates the range of interesting topics and the potential for additional work.

6 Concluding Comments

These introductory comments are intended to be more extensive than just a summary of the papers in this volume, but less extensive than a comprehensive treatise on the economics of transportation safety. Primarily it has been a personal reflection on the issues I have found to be important, and some thoughts on the strengths and weaknesses of the existing literature. While economists are generally loathed to want to encourage new entrants to come and compete, I hope that I have demonstrated that there are plenty of interesting topics that remain largely unexplored and are waiting for talented researchers to tackle.

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