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Fear of Flying? Economic Analyses of Airline Safety

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The safety of the commercial airline industry has attracted considerable attention in the wake of airline deregulation, amid growing concerns that the historical superiority of U.S. jet carriers' safety records may have been linked to economic regulation of the industry by the Civil Aeronautics Board. After all, economists argued that the suppression of price competition led airlines to focus on service competition, and public perceptions of service quality suggest that deregulation has led to substantial reductions in at least some dimensions. Perhaps less observable dimensions of product quality, like safety, have experienced equivalent or greater declines. If this were the case, traditional measures of welfare gains from deregulation could be greatly exaggerated.[1]

These worries have energized economic research on a broad range of questions relating to airline safety. Four questions have attracted the most attention from economists. First, has airline safety declined since deregulation? Research on this topic investigates whether heightened public concerns about air safety derive from objective increases in accident risks. Second, how has airline deregulation affected the safety of travellers overall? This literature explores indirect channels through which airline deregulation may have changed travel risks, including the substitution of commuter airlines for jet

[1]This assumes that safety was not *over*-provided prior to deregulation. Unfortunately, there have been no studies of the level of airline safety provided relative to an optimal level of safety, in either the regulated or the deregulated periods. Given a variety of pressures on airlines, many discussed below, excessive expenditures on safety (relative to social benefits) seem at least as likely as insufficient expenditures.

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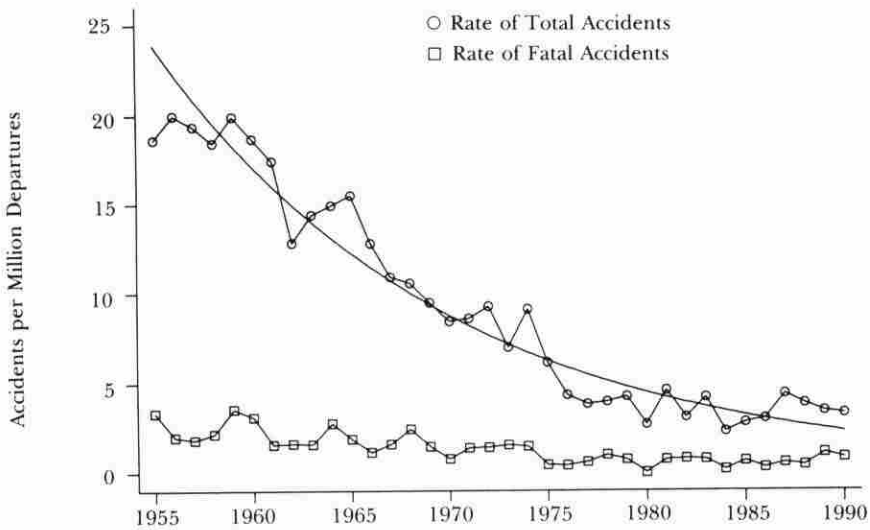
service and the replacement of highway driving by air travel. Third, what accounts for differences in safety performance across carriers? Work in this area analyzes heterogeneity in carriers' safety records as a means of learning about factors that influence safety performance. It extends the before-and-after deregulation research by examining through what links, if any, we might expect economic regulation to affect aggregate safety. Fourth, what are the market penalties for airline accidents? This research explores the effectiveness of market incentives in constraining the safety provision of firms. If consumers and insurance companies penalize airlines with worse safety records, carriers may be disinclined to reduce safety investment, even if regulatory changes would permit them to do so. I describe below our progress in answering these queries.

Has Airline Safety Performance Declined Since Deregulation?

Aggregate statistics on U.S. airline safety provide reassurance for travellers concerned that deregulation has led to increased risks in air travel. There are many potential measures of airline safety performance, including the absolute number of fatal and non-fatal accidents; fatal and total accidents per million departures; passenger fatalities per million passengers or per million passenger miles; passenger death risk per million departures; and "incidents" (such as near mid-air collisions or other hazards) per million departures. Virtually all of these measures suggest that the long-term trend toward increased airline safety has continued since economic deregulation of the airline industry in 1978. For example, Figure 1 plots the number of aircraft accidents per million departures for large U.S. scheduled air carriers over the period 1955–1990. Referred to as "Part 121" carriers, these jet airlines account for the bulk of U.S. commercial air travel. Both total and fatal accidents per million departures for these firms declined substantially over this period, although accident rates vary considerably from year to year.

Improvements in airline safety do not appear to have slowed appreciably since deregulation. Regression analysis of the log of accident rates on a time trend indicates that the coefficients on either a deregulation dummy variable or a variable measuring time since deregulation are insignificantly different from zero (Rose, 1989; updates through 1990 based on the author's calculations). There is some scope for caution, however. Total accident rates over the last four years (1987–1990) lie slightly above trend line shown on Figure 1. There is not enough data to determine whether recent increases reflect normal variation in observed accident rates over short-time horizons or an elevation of the true underlying risk, nor is it obvious that effects that do not materialize until ten years after deregulation should be attributed to it rather than to some other cause. Nevertheless, the possibility that regulatory effects may operate with long lags, through such mechanisms as reduced maintenance or increased aircraft

Figure 1
Actual and Predicted Accident Rates, 1955–1990



age, suggests continued scrutiny of aggregate safety performance over the next few years.

Passenger fatality rates also exhibit continued improvement after deregulation. For example, Barnett and Higgins (1989) calculate that the fatality risk for a passenger on a U.S. domestic jet airline flight declined from an average of 1 in 2.5 million flights over 1971–78 to 1 in 7.4 million flights over 1979–86. They argue, however, that the decline in risk would have been even greater, but for the entry of new jet carriers post-1978. As evidence, they separate the U.S. carriers into "established carriers" (trunk and local service airlines existing as of 1978) and new entrants (a group of 19 "jet children" of deregulation, most now out of business). For 1979–86, fatality risk for passengers on established carriers averaged 1 per 11.8 million flights. In contrast, the group of entrants Barnett and Higgins analyze had an aggregate fatality risk of 1 per 870,000 flights! This does not imply that the planes of the entrant carriers were continually dropping out of the sky, however: only 3 of the 19 carriers had *any* domestic passenger fatalities during the seven-year period, and these had just one accident each that led to a fatality. The high risk arises from the fact that the entrants carried relatively few passengers. The robustness of this conclusion and the safety records of entrants will be discussed further when we analyze differences in safety performance across carriers.

Analyses of the causes of airline accident rates can shed additional light on the effects of deregulation. If deregulation induced carriers to cut maintenance activities, for example, one might expect to observe more accidents due to

equipment failure. Accidents due to pilot error should increase if airlines compromised safety by hiring less experienced pilots, reducing training, or working pilots harder. If increased congestion combined with the staff reductions consequent to the 1981 air traffic controllers strike to degrade the air traffic control system, accidents resulting from air traffic control errors or interference by other aircraft should become more common.[2]

To test whether deregulation has had these effects, Oster and Zorn (1989) analyze National Transportation Safety Board (NTSB) Accident Briefs for scheduled domestic passenger service accidents over the 1971 through 1985 period. For each accident, they select as the "primary cause" the event or action that initiated the sequence of events culminating in the accident.[3] These causes are then grouped into categories that might be sensitive to deregulation-induced changes, including Pilot Error, Equipment Failure, Air Traffic Control Error, and Other Aircraft (General Aviation), and categories that are unlikely to be influenced by deregulation, including Weather, Seatbelt Not Fastened, and Other. Between the "regulated" (1970–78) and "deregulated" (1979–85) periods, total accidents per million departures for trunk and local service carriers declined by 54 percent. Accident rates due to pilot or controllers' errors, equipment failure, and other aircraft declined by this amount or more, topped by a 71 percent reduction in accidents initiated by equipment failures. This suggests a relative *decrease* in accidents due to causes under a carrier's control after deregulation.

Further evidence on the changes in maintenance practices and their effects on safety since deregulation is provided by Kennet's (1990) study of jet engine maintenance histories. Kennet analyzes complete aircraft engine histories for 42 Pratt and Whitney jet engines, operated by 7 different airlines. He finds that the length of time between maintenance shop visits has increased since deregulation, but that deregulation has had no effect on the probability of an engine shutdown. This may reflect a drive toward more efficient maintenance policies and practices in the wake of deregulation. The results suggest that these maintenance changes have not compromised air safety, which is consistent with Oster and Zorn's report of substantial relative declines in accidents initiated by equipment failure.

Has Airline Deregulation Reduced Travellers' Safety?

There are a number of channels through which deregulation may have influenced travellers' safety, independent of any direct effect on airline accident

[2] Increased congestion is not an inevitable consequence of deregulation, but results when increased traffic demand is not met with appropriate pricing of scarce capacity. See, for example, Arnott and Stiglitz (1988).

[3] Because their criterion differs from that used by the NTSB, their distribution of accidents by cause differs from the NTSB distribution. Broadly similar conclusions are reached by Morrison and Winston (1988), who analyze the distribution of fatal accidents using NTSB causes.

rates. First, the shift from jet airline to commuter airline service in many small communities may have increased risks for passengers on these routes. Second, increased reliance on hub-and-spoke networks may have increased the average number of stops or plane changes passengers must make. Since accident risks are roughly proportional to the number of takeoffs, this would tend to increase passengers' risks per complete trip, where a single trip includes all flights from origin to destination. Third, the introduction of price competition and service improvements may have induced travellers to substitute air travel for auto travel. Because the risk of a highway accident exceeds that for air travel over even moderate distances, this substitution would enhance travellers' safety. Recent research addresses each of these possible effects.

The Decline of Jet Service in Small Communities

Airline deregulation may have encouraged established jet carriers to abandon uneconomic service to small communities by eliminating explicit cross-subsidization and easing entry and exit restrictions. While most of these communities retain air service, it now typically is provided by commuter carriers. The higher accident rates of commuter airlines, relative to jet carriers, suggests that risks to travellers in these communities may have increased. For example, over 1979–1985, passenger fatalities were .30 per million passengers enplaned on trunk and local service airlines, but 1.27 per million passengers enplaned on commuter airlines—more than four times greater for commuters (Oster and Zorn, 1989).

These simple comparisons may substantially overstate the change in risk, however (Oster and Zorn, 1989). First, the largest commuter airlines are substantially safer than the smaller commuters, and these are the ones that typically have replaced jet carriers. The top 20 commuters, for instance, had passenger fatalities of .67 per million enplanements, roughly half the risk for commuters overall.[4] Second, service substantially improved on the routes where commuters replaced jets, with fewer intermediate stops and more weekly departures. In a sample of 60 city-pair markets where commuters replaced jets between 1978 and 1986, the average number of intermediate stops fell by half (Oster and Zorn, 1989). Re-stating accident rates in terms of fatalities per passenger *trip* (from origin to final destination) on these routes yields .48 deaths per million trips for jet carriers (.30 fatalities per million enplanements times 1.59 average take-offs) compared to a risk of .87 for the large commuters (.67 fatalities per million enplanements times 1.30 average take-offs). While the commuter risks are higher, the differences are less stark than implied by the initial comparison.

Finally, the average weekly departures in these 60 markets more than doubled after commuters took over service (from 2.88 to 6.29). The increased

[4]In this issue, Borenstein discusses the rise of "codesharing" arrangements between commuters and major carriers. While there have been no studies that look at commuter safety under codesharing, it seems likely that the increased scrutiny that codesharing imposes upon the commuters would lead to even better safety records than those implied by size alone.

frequency of service appears to be associated with increased ridership, at least part of which reflects a switch from cars to planes for some travellers. While there has been some debate over the correct method of calculating the auto fatality risk, as discussed below, reasonable calculations suggest an average fatality rate of at least 1.6 per million passenger trips in these markets.[5] Since this is substantially greater than the risk for the larger commuter airlines, the switch in mode of travel enhances overall safety.

Increases in the Average Number of Stops Per Trip

The second potential indirect effect of deregulation, possible increases in the number of stops or plane changes passengers must make en route to their final destination, has not been well-documented. While the development of hub-and-spoke networks may substitute one-stop or one-change service for nonstop service in outlying markets, it is likely to increase nonstop service availability for passengers travelling to and from the hub. The net impact on average stops cannot be predicted *a priori*.

Some evidence on this effect is provided by Borenstein (this issue). He finds an increase in the number of passenger trips that involve a change of plane, from 27.3 percent of trips in 1978 to 32.8 percent in 1990. If all remaining passengers flew nonstop, the average number of flights per trip would have increased by 4.3 percent over this period (from 1.273 to 1.328). While this increases air travel risks, the overall impact is not substantial. The average total (fatal and nonfatal) accident rate per million flights declined by 54 percent between the 10 years prior to deregulation and the 10 years after deregulation. Adjusting for a 4 percent increase in average flights per trip reduces the effective decline to 52 percent.

In fact, direct (no change of plane) service includes both nonstop and one- (or multi-) stop flights. Because there have been no studies of the change in the average number of stops for these passengers, we cannot determine the overall change in average departures per trip. However, failure to account for this seems unlikely to affect the conclusion materially.

Travel Shifts from Highways to Air

The lower average fares and the widespread adoption of discount fares and sophisticated price discrimination schemes that resulted from deregulation substantially increased air travel. Between 1975 and 1985, domestic passenger enplanements for the largest U.S. carriers grew at a rate of 6.6 percent per year and domestic revenue passenger-miles grew at 7.5 percent per year. Some of

[5]Evans, Frick, and Schwing (1990) estimate the 1987 average car driver fatality rate at 12.56 per billion vehicle miles. The rate is lower for a population of drivers with the age and sex profile of all airline passengers (by 24.1 percent) but higher for drivers on rural highways (by 32 percent on all rural federal aid highways). Accounting for these factors and an average trip length of 125 miles in these markets yields average driver fatalities of 1.6 per million passenger trips. This calculation excludes all injuries, which are substantially more numerous in auto travel than in air travel, and fatalities of those other than car drivers.

this increase represents new travel; that is, trips that otherwise would not have taken place. Some of the increase represents a shift from other modes of travel, such as automobile, rail, or bus.

This shift improves travellers' safety by replacing riskier private auto travel with lower risk air travel. The overall impact depends on how much traffic has shifted from highways to air and how much riskier highway travel would have been. We can say something about each of these questions, although existing studies have their limitations.

Two studies have used annual time series data to estimate the decline in auto travel that resulted from airline deregulation (McKenzie and Warner, 1988; Bylow and Savage, 1991). The more plausible of these estimated declines in annual intercity passenger car miles of 2.2 percent, an average of 9.5 billion vehicle miles per year over 1978–1988 (Bylow and Savage, 1991).[6] This implies an increase of 9.5 billion air passenger-miles if each car carried only a driver, or 19 billion air passenger-miles if two people occupied each car. These imply that 7 to 14 percent of the 140 billion increase in airline passenger-miles between 1975 and 1985 came from displaced auto travel.

Calculating the number of lives saved by this shift depends on choosing the correct highway accident rate. Using the fatality rate for federally funded highways implies an average reduction of 275 highway fatalities per year (Bylow and Savage, 1991). Evans, Frick, and Schwing (1990) argue that these rates overstate the highway risk for a typical airline passenger for three reasons: first, they include deaths of pedestrians and drivers of other vehicles; second, they assume that air travel displaces travel on average roads; and third, they assume that airline passengers are average risk drivers when on the road. Adjusting aggregate fatality rates for these factors yields auto fatality rates that are one-third to one-half the rate used by Bylow and Savage, depending on whether the travel is assumed to occur exclusively on rural interstates or on all federal aid highways.[7] These rates imply average reductions of 100 to 145 auto fatalities per year over 1978–1988. This contrasts to 5 to 10 expected fatalities

[6] This study estimates a model of passenger car miles that includes airline departures and prices as independent variables. The effects of deregulation on these variables are estimated in two reduced form equations, although it is not clear that price and departures are separately identified in this system. The results nevertheless seem more credible than the 4.4 percent, or 43 billion vehicle mile, decline in annual total passenger car mileage claimed by McKenzie and Warner (1988). This result is based on a dummy variable for airline deregulation (1975–1985) in a model of annual total passenger car miles.

[7] This calculation, available from the author, is based on 1988 highway fatality rates from the U.S. Department of Commerce *Statistical Abstract of the United States 1991*, table 1045, and scale factors reported by Evans, Frick, and Schwing (1990). It includes both driver and car occupant fatalities and accounts for the age and gender distribution of airline passengers. The 1988 re-scaled rates are 37.5 to 52.4 percent of the 1988 rate used by Bylow and Savage. Assuming the same proportional reductions for other years produces an average reduction in annual auto deaths of 102 to 143.

As Evans et al. point out, fatality rates would be even lower if these drivers were above average in their use of seat belts, below average in their use of alcohol, or drove heavier than average cars. Highway fatalities would be higher if the drivers switching from highways to air were younger (below 25) or older (65 and above) than the average airline passenger distribution would suggest, as would be the case if students and senior citizens were overrepresented among switchers.

in 9.5 to 19 billion passenger-miles of domestic air travel. Even with conservative estimates of the extent of modal shift and highway fatality rates, the overall number of lives saved by switching travel to the air is substantial: on the order of 90 to 140 or more lives per year.

What Accounts for Differences in Accident Rates Across Carriers?

Against the backdrop of substantial declines in aggregate accident rates over time lie wide variations in accident rates across individual carriers within any time period. Figures 2 and 3 illustrate this in histograms of total accident rates per million departures for a sample of major airlines over the 1971–75 and 1981–85 periods, respectively.[8] The wide variation in accident rates is not entirely surprising: given the infrequent nature of accidents, one additional accident in a five-year period can generate an enormous increase in a typical airline's accident rate per million departures. Do these statistics reflect expected random fluctuations around a common mean accident rate or more systematic differences in behavior and subsequent safety performance across airlines?

Economists have concentrated their efforts to model differences in carriers' safety records in three areas: the impact of airlines' financial condition on their safety performance; variations in safety performance between entrants and established carriers; and the determinants of higher accident rates for commuter carriers relative to jet airlines.

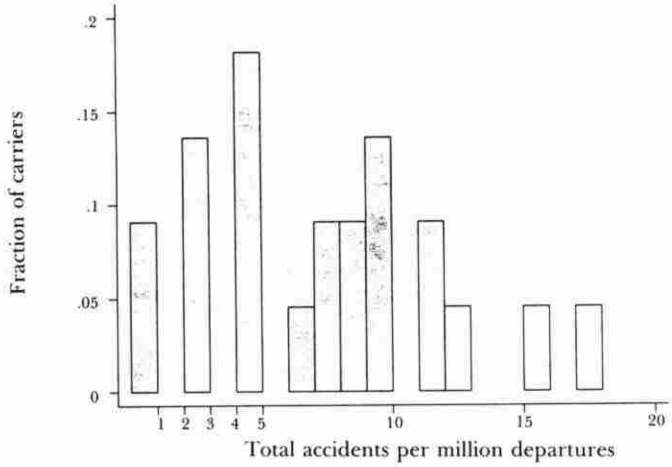
Financial Impacts on Airline Safety

The potential impact of financial pressures on the safety performance of airlines has provoked a long-standing debate in policy circles and attracted particular attention since deregulation. The argument that competition has reduced profit margins and forced carriers to "cut corners" on safety has been one of the key weapons in the arsenal of re-regulation advocates. A variety of economic models can generate predictions consistent with a link between financial pressure and reduced safety, including models of reputation formation under asymmetric information, liquidity constraints on investment behavior, and firm decision-making near bankruptcy. However, none of these models implies that such a link must exist, leaving the resolution of this debate to empirical tests.

Early studies, typically based on short time series and small cross-sections of carriers (or industry aggregate time series regressions), detected no significant relationship between financial variables such as profitability and airline accident rates. For example, Golbe (1986), who looked at cross-sections of 11

[8] These plots are based on data for a sample of 35 large airlines, as reported in Rose (1990). The 1981–85 plot omits World Airlines, which had two accidents and an accident rate of more than 51 per million departures. The next highest accident rate was 12.5 per million departures.

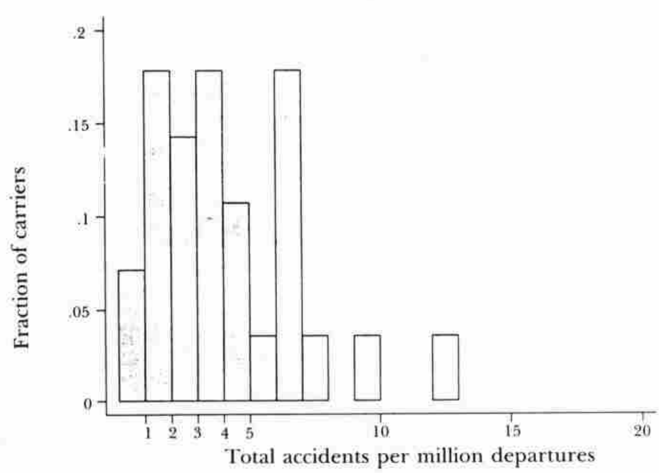
Figure 2
Distribution of Carrier Accident Rates, 1971–75



domestic trunks over the 1963–66 and 1967–70 periods, found an insignificant positive relation between profitability and accident rates. These studies share a common shortcoming, however: the infrequent nature of airline accidents combined with their small sample sizes may limit the power of statistical tests.

Analyses of more extensive data sets and alternative safety measures find evidence that lower profit margins are associated with worse safety performance, at least for some groups of carriers. Rose (1990) explored the determinants of airline safety performance for a panel of 35 U.S. part 121 air carriers over 1957–1986. For these primarily jet carriers, higher operating profits were

Figure 3
Distribution of Carrier Accident Rates, 1981–85



associated with lower accident rates in the following year. A 5 percentage point increase in the operating margin (for example, from 5 percent to 10 percent) implies about a 5 percent reduction in the total accident rate and more than a 15 percent reduction in the fatal accident rate, other things equal. This result for total accidents is replicated by Evans (1989) in a study of accident rates for nearly 100 carriers over 1970–87.

Even these average effects may mask important differences across carriers in their sensitivity of safety performance to profitability changes. Rose's data suggest that profitability effects may be strongest for the smaller and mid-size carriers, and may not be important for the very largest carriers studied. This pattern is particularly clear in the analysis of airline incidents, in which higher profits are associated with lower reported incidents for small- and mid-size carriers, but higher incident rates for the very largest carriers. A 5 percentage point increase in the operating margin implies about a 20 percent reduction in reported incidents for the smallest carriers in the sample and a 10 to 12 percent reduction for mid-size carriers.

The strength of the profitability-safety link for the small- and mid-size carriers may indicate greater flexibility in these firms' safety investment choices. A number of factors could make the safety investment levels of large firms less variable: public information about underlying safety levels may be better for the largest airlines (reducing information asymmetries), large airlines may have better access to capital markets or "deeper pockets" for internal financing, or FAA regulators may scrutinize these carriers more closely. This heterogeneity also may help to explain why the earlier studies, which tended to focus only on the very largest (trunk) carriers, failed to detect a link between profitability and safety performance.

A significant remaining gap in our analysis of financial influences on safety is an understanding of the profitability effects for the very smallest air carriers in the industry: commuter carriers. While recent studies include a much broader range of carriers than had previously been studied, they continue to be limited to jet carriers due to the lack of reliable financial data for commuter carriers. Anecdotal evidence suggests that commuters may be quite sensitive to financial pressures, and the arguments raised above for the smaller jet carriers seem to be at least as strong for commuters. Decisive conclusions about this segment of the industry must await further study.

New Entrant Safety Performance and the Role of Experience

A major concern after deregulation was the safety performance of new entrants into the airline industry. The conclusion of Barnett and Higgins (1989) discussed earlier—that entrant carriers were substantially more risky than established carriers in terms of passenger fatalities—heightens this concern. The empirical evidence on this issue is mixed, however. The relative riskiness of entrants appears sensitive to the measures of safety performance

employed in the study, and also may depend on the definition of entrant carriers and identities of the firms included in the sample.

The most thoroughly studied measure of safety performance for new entrants is total accidents per million aircraft departures. Virtually all analyses using this measure of safety indicate that entrants do not perform significantly worse than established carriers (Kanafani and Keeler, 1989; Oster and Zorn, 1989; Evans, 1989). Indeed, Evans (1989) concludes that entrants have *lower* accident rates than established carriers, other things equal. His analysis of 105 carriers over 1971–1987 suggests that post-deregulation entrants have accident rates that are roughly half those of established carriers, other things equal.[9] This result is not sensitive to whether the entrants are defined as completely new airlines or include carriers that previously provided intrastate or charter service. Evans speculates that this result may be due to more intense regulatory scrutiny of airlines newly certified in interstate service or their use of newer equipment.

The general conclusion that entrant safety performance does not significantly differ from that of established carriers holds across most measures of safety performance (Oster and Zorn, 1989; Kanafani and Keeler, 1989). The main exceptions to this sanguine view of new entrants are based on analyses of *fatal* accident rates. In addition to the Barnett and Higgins (1989) analysis discussed earlier, Oster and Zorn (1989) report that entrants (their "other jet carriers") had a substantially higher aggregate rate of fatal accidents per million departures over 1979–85 (.90 v. .22 for trunk and local service carriers). As in the Barnett and Higgins analysis, this poor group performance masks substantial heterogeneity across carriers, with most entrants massed at zero fatalities and a few extreme outliers pulling up the aggregate fatality rate.

Unfortunately, there have been no carrier-specific analyses of fatal accident rates to discern the sensitivity of the conclusions to this heterogeneity or to the definition of entrant airlines. For example, World Airlines, which had two accidents and a fatal accident rate of 51 per million departures over 1981–85, is included as an entrant in both studies of entrant fatality risk. While the airline was new to scheduled interstate service, it had been operating charter service prior to deregulation. Does World belong in the same group as either People Express, which entered airline service *de novo* after deregulation, or Pacific Southwest Airlines, which had provided scheduled service within California since 1948?

To understand which firms can be meaningfully grouped together, we must first understand the possible underlying causes of the entrant results,

[9] The relative accident rate for entrants in Evans's study should be calculated as exp(NEW − DEREG), where NEW is a dummy variable for new entrants (estimated at about −1.3) and DEREG is a dummy variable for established carriers post-1978 (estimated at about −.50). This calculation yields the value .44, implying that entrant accident rates are 44 percent of established carrier accident rates, other things equal. Note that this is not the calculation apparently reported by Evans.

which is difficult to do with either aggregate analyses or simple dummy variable regressions of carrier differences. However, few studies have attempted to move beyond these approaches. Oster and Zorn (1989) report that entrants as a group have a higher total accident rate attributable to pilot error (.60 per million departures, compared to .16 for trunks). This might be consistent with entrants' pilots being on average less experienced or less well-trained, either overall or relative to their new positions. Rose (1990) provides evidence of some learning-by-doing effects on safety performance. For total accident rates, airline operating experience has at most a weak negative effect, which vanishes in specifications that control for a carrier's average accident rate. For both fatal accidents and total incidents, however, experience exerts a strong, statistically significant negative effect: more experienced airlines have fewer fatal accidents and fewer incidents, other things equal. Although these estimates are not based solely on entrant performance, the results are broadly consistent with studies that find no significant entrant effect for total accident rates, but worse entrant performance on fatal accidents. This could be consistent with the ability of more experienced carriers to limit the severity of otherwise unavoidable accidents, reducing or eliminating fatalities. Additional investigation is required to develop a better understanding of this relationship and of other sources of the apparent differences in safety performance between entrants and established carriers.

Commuter Carrier Safety Performance

Commuter airlines, as a group, have substantially higher accident and fatality rates than do jet carriers. The implications of this observation, however, depend critically upon the source of these differences. For example, if commuter airlines invest less in safety, other things equal, then more rigorous FAA regulation of their safety practices would tend to improve their safety records. Such regulation will have little effect if the disparities arise from inherent differences in equipment reliability (perhaps because smaller, propeller aircraft are more prone to failure, even when optimally maintained) or airport facilities (perhaps because commuters are more likely to serve airports that lack advanced navigational aids or offer more hazardous operating conditions). Similarly, if most of the performance differences are attributable to route rather than carrier conditions, then substituting one type of carrier for another *on a given route* is unlikely to have much impact on safety.

Discerning the relative importance of carrier and route conditions on commuter safety records would be difficult under any circumstances. This task is further impeded by the dearth of reliable, detailed firm-level data for this segment of the industry. Nevertheless, there is suggestive evidence that carrier investment has a substantial impact on safety performance in this sector.

First, commuters that were part of the Allegheny (USAir) commuter system had an overall safety record that matched the jet carrier safety record over the

1970–80 period, despite substantially higher accident rates for the commuter industry as a whole (Meyer and Oster, 1987). This is unlikely to be solely attributable to differences in the routes and equipment of these firms.

Second, the FAA substantially tightened commuter safety regulations in 1978, increasing pilot qualification, crew training, and maintenance requirements (particularly for larger commuter aircraft), and specifying minimum equipment lists for commuter flights for the first time. This appears to have had a dramatic impact on aggregate commuter safety. The commuter passenger fatality rate per million enplanements declined by more than half between 1970–78 and 1979–85, with the bulk of the decline occurring in accidents caused by equipment failure, pilot error, and weather (the latter possibly influenced by both enhanced pilot certification and training requirements and equipment rules governing instrument flight rule operations; Oster and Zorn, 1989). Since commuter regulations remain less stringent than those for jet carriers, additional improvements in safety are likely to be possible. Of course, whether the benefits of these additional safety measures would outweigh the costs is less clear, depending on whether commuter carriers currently underprovide safety.

What are the Market Penalties for Airline Accidents?

For air travellers, safety is an important aspect of product quality. Unlike other characteristics of product quality—such as schedule convenience, crowding, and on-board service—consumers have difficulty observing the level of safety provided by a carrier when they make their travel decisions. As in other markets where consumers cannot observe or evaluate product characteristics, there is reason to suspect that the market may supply less safety than consumers would demand if fully informed. Concern with potential market failure has led to a complex web of government regulation that specify minimum safety input and performance standards for air carriers. There are alternative (or complementary) mechanisms for insuring adequate safety provision, however. Both the system of tort liability and consumer reliance on airline or aircraft reputation may provide sufficient incentives to maintain safety performance. Economists have focused on the latter for at least two reasons.

First, aircraft manufacturers and airlines purchase virtually complete indemnity against crash liabilities. Major airlines, for example, typically purchase policies with first and last dollar coverage for accidents, including only nominal deductibles for hull (aircraft) losses and policy limits well in excess of expected settlements for even major catastrophes. With complete insurance, insurers must play the role of regulators for this mechanism to function. There is reason to think this may not be sufficient: insurance companies do not directly monitor firms and insurance premiums appear only partially responsive to accident

histories (Chalk, 1986, 1987; Mitchell and Maloney, 1989; and conversations with industry executives).

Second, most airline executives cite the need to preserve and enhance their reputation as their primary concern in maintaining safety standards. If such reputations are effective checks on behavior, we should observe market penalties for firms that deviate from their established reputations. This notion has given rise to a substantial amount of economics literature that evaluates market responses to air carrier accidents.

We can analyze market responses to airline accidents from two perspectives. First, does the market penalize aircraft models involved in an accident: what is the effect of an accident on the profits of the aircraft's manufacturer, the profits of airlines that operate a substantial number of that aircraft type, and the traffic patterns of passengers who previously flew on that aircraft type? Questions of this sort will be most appropriate when flaws in the aircraft itself are suspected to have contributed to a particular accident. Second, does the market penalize airlines that are involved in accidents: how does an accident affect an airline's profits and traffic flows, and the profits and traffic flows of its competitors?

In this literature, profit effects typically are measured using an event study methodology, which estimates the change in the equity share price of a firm following an accident. This yields an estimate of the expected change in the present discounted value of future profits resulting from the accident. Traffic responses have been analyzed both by examining changes in "before and after" market shares and by measuring the deviation from predicted demand using econometric models of airline demand functions. The samples are restricted to fatal accidents, and most studies exclude flights that carry only cargo or crew. These criteria select the worst and more highly publicized accidents for analysis.

Aircraft Reputation

Studies of aircraft reputation effects focus primarily on two DC-10 crashes: the crash of an American Airlines flight at Chicago on May 25, 1979, which is the worst domestic U.S. airline accident (273 fatalities), and the United Airlines Sioux City crash on July 19, 1989 (Barnett and LoFaso, 1983; Chalk, 1986; Karels, 1989; Barnett, Menighetti, and Prete, 1990). Both of these accidents raised concerns about potential DC-10 manufacturing or design problems. One study (Chalk, 1987) also examines accident effects on aircraft manufacturers' profits across a broader sample of "suspect" crashes.[10] What do these analyses reveal?

[10]Chance and Ferris (1987) find no effect on the manufacturer for a sample of 46 accidents over the 1962–1985 period. Their sample does not, however, distinguish cases where it was believed that the aircraft itself may have been at fault from those where it did not appear to be.

First, there is some evidence of a market penalty for aircraft manufacturers, based on the 1979 DC-10 crash. McDonnell Douglas, the manufacturer of the DC-10, lost roughly 10 percent of its equity market value, or approximately $100 million, in the first four days after the accident. The firm's shares declined by an additional 10 percent when the FAA announced its unprecedented decertification of the DC-10, an action that grounded the entire DC-10 fleet indefinitely. These market value declines are substantially larger than any direct costs imposed by the accident, and would be consistent with lower expected sales of McDonnell Douglas aircraft as a result of the accident. Estimates of the final effect of the accident on McDonnell Douglas returns are quite dependent on the time period studied, however. As new information suggested that improper maintenance practices were the likely cause of the accident, part or all of the initial share price declines were reversed (Chalk, 1986; Karels, 1989).

There is some evidence that the 1979 DC-10 crash adversely affected airlines that owned substantial numbers of these aircraft, although there have been no general studies of this effect. Karels (1989) finds share price declines for both American Airlines (the operator involved in the crash) and a portfolio of other airlines operating DC-10s in the aftermath of the 1979 accident. The first response to the crash was a 2 percent decline in share values, although this could not be statistically distinguished from zero. The decertification announcement led to a 5.3 percent decline for American and a 2.9 percent decline for the other DC-10 airlines. A portfolio of non-DC-10 airlines was unaffected.

Responses to the 1979 DC-10 crash are not representative of the impact of other accidents, however. In direct contrast to the 1979 experience, McDonnell Douglas appears to have been unaffected by the 1989 Sioux City accident. Despite early reports that the design of the DC-10 hydraulic system was a major factor in the crash, returns on McDonnell Douglas stock were commensurate with market returns over the days following the accident. On July 20, the first trading day after the late July 19 crash, McDonnell Douglas shares declined 0.9 percent, compared to a 0.7 percent for the market as a whole. McDonnell Douglas share prices rose over the next week. While Chalk's (1987) study suggests modest manufacturer losses for a broader sample of 19 accidents to which aircraft failures contributed, these may be strongly affected by including the 1979 DC-10 crash in the sample. Chalk finds an average share price decline of roughly 4 percent over the five business days following an accident, corresponding to an average loss of $21 million in market value. The data indicate no statistically significant share price effects for accidents involving Boeing or Lockheed aircraft, however, and the estimated average McDonnell Douglas decline is likely to be quite skewed by the massive declines associated with the 1979 crash.

Studies of passenger avoidance of aircraft involved in fatal accidents complement the market event studies. These provide evidence of little or no permanent passenger reaction to the DC-10 crashes. Barnett and LoFaso's

(1983) study of DC-10 market shares six months before and six months after the 1979 crash revealed no systematic changes in travellers' behavior on a sample of 18 routes.[11] In their study of travel agency ticketing data, Barnett, Menighetti, and Prete (1990) find evidence of very short-term DC-10 avoidance following the 1989 Sioux City crash. In their sample of 14 routes, one in three passengers who booked travel within the first two weeks after the crash avoided choosing DC-10 flights, relative to pre-crash behavior. This behavior quickly dissipated, however, with booking shares returning to within 10 percent of pre-crash levels by 8 weeks after the crash. (The study did not examine booking patterns beyond 8 weeks post-crash.) Moreover, despite the development of sophisticated pricing and inventory management systems by 1989, airlines did not appear to lower prices on DC-10 flights in response to initial traffic declines.

This literature, *in toto*, provides little support for the claim that "market forces can compel producers to invest in safety" (Chalk, 1986). The strongest evidence of market responses is associated with the 1979 American Airlines DC-10 crash; evidence of market responses to other accidents is weak to non-existent. In addition, the market in 1979 may have been responding more to specific FAA interventions than to general reputation effects. FAA airworthiness directives can require airlines and manufacturers to invest substantial amounts in inspections and repairs, replacements, or re-designs of aircraft components. The FAA's 1979 decision to revoke the DC-10's certificate grounded the existing fleet of DC-10s indefinitely (inducing direct losses for DC-10 operators) and raised the possibility that McDonnell Douglas would be required to make extensive modifications as a prerequisite to selling any additional aircraft (and re-certifying the existing fleet). While market reputation effects and direct FAA interventions both may induce manufacturers to invest in aircraft safety, the policy implications of these two mechanisms are quite different. The existing empirical evidence does not distinguish the relative effects of these two factors.

Airline Reputation

A number of studies have investigated market responses to accidents at the airline level: does an accident reduce the airline's expected profitability? Two of the more interesting and careful of these analyses are Borenstein and Zimmerman's (1988) study, which couples an investigation of profit effects with traffic responses, and Mitchell and Maloney's (1989) study, which pairs an examination of profit effects for different classes of accidents with a study of

[11]While Barnett and LoFaso control for some airline route characteristics, they do not have data on average fares. It is possible that airlines with DC-10 service lowered fares to retain market shares. However, the study of the 1989 DC-10 crash suggests that this explanation is unlikely to account for their result.

changes in insurance premiums. Both find evidence of modest profitability declines in response to fatal accidents.

Borenstein and Zimmerman analyze responses to 74 fatal accidents over 1962–85. For the 62 accidents that occurred while passengers were on board the aircraft, they find an average decline in equity value of roughly 1.3 percent on the first trading day following the accident, and 1.5 percent over the first two days following the accident. This translates into an average $12 million loss in 1990 dollars. (All dollar values reported in this section have been escalated to 1990 dollars using the Consumer Price Index.) Mitchell and Maloney divide their sample of 56 accidents over 1964–87 into 34 "pilot error" crashes and 22 "carrier not-at-fault" crashes. For the pilot error sample, they find a one-day decline of roughly 1.6 percent and a two-day decline of roughly 2.3 percent.[12] This corresponds to an average loss in equity value of $22 to $31 million in 1990 dollars.

Because airlines typically carry quite complete hull and passenger liability insurance, most of the equity decline appears to arise from prospective losses, rather than actual cash outlays, resulting from the current accident. Two possible sources of prospective losses are increased insurance premiums and reduced demand due to reputation effects. Mitchell and Maloney estimate that the additional liability insurance cost over a five-year period following an at-fault accident is roughly 90 percent of the one-year premium before a crash. A substantial part of this may reflect the loss of a "profit commission," often 15 to 20 percent of the company's current year insurance premium, which is forfeited in the event of a major accident. While the data suggest higher premiums in years subsequent to the accident, this "surcharge" is small and statistically insignificant after the third year. The total present discounted value of insurance increases over 5 years average about $10 million in 1990 dollars.[13] This can account for one-third to one-half of their estimated decline in equity value, and appears to be smaller than average insurance settlements. A rough estimate based on average settlements of $500,000 per death and the sample average of 57 deaths per accident suggests payouts of nearly $30 million for passenger liability alone.

Borenstein and Zimmerman investigate the impact of accidents on demand for an airline's services. They find virtually no effect of an accident on demand during the regulated period of their sample (1960–77). After deregulation, there may be a short-term demand response to an accident. In their sample of 13 accidents over 1978–85, estimates of the cumulative loss in demand average

[12]The point estimate declines for the carrier not-at-fault sample are about half as large and are quite imprecisely estimated. This may suggest, as Mitchell and Maloney concluded, that the market does not penalize airlines for accidents not caused by pilot error. From a different perspective, however, a pooling test across the two samples would not reject the hypothesis that both sets of results are drawn from the same distribution.

[13]One should view these estimates with some caution, as the hull insurance increases in particular are quite sensitive to model specification.

10 percent to 15 percent of one month's traffic volume, although these are at best of marginal statistical significance. Consistent with the implications of the DC-10 traffic response studies, this decline is quite short-lived: most of the effect appears to be experienced in the first two months following a crash. While relatively small and short-term, these demand declines imply large revenue losses, averaging over $100 million in 1990 dollars. This suggests considerable market penalties for airlines involved in fatal accidents.

The strength of this conclusion is, however, limited by a number of factors. First, these results are based on a relatively small sample and the uncertainty around the estimate is substantial. Second, the estimated revenue losses greatly exceeds the estimated declines in equity value, and the difference is unlikely to be accounted for by cost reductions associated with serving fewer passengers in the very short-term. Third, revenue losses appear to be uncorrelated with the change in equity value in the sample.

Finally, there is relatively little evidence that accidents have a significant effect on the demand or profits of an airline's competitors. Over the entire deregulation period, Borenstein and Zimmerman's estimate of the demand change for *other* airlines following an accident is negative, but very small and imprecisely estimated. The eight largest accidents (100 or more fatalities) may have induced a small (1 percent) one-month increase in demand for other airlines, but the stock price of these airlines was unaffected. This suggests that most passengers who choose not to fly an airline recently involved in an accident decline to fly *any* airline. The plausibility of this implication remains an open question. Further investigation, using the years of post-deregulation data now available, appears necessary to resolve some of these questions concerning demand effects.

While the literature suggests the possibility of some market penalties for airlines that experience passenger fatalities, these methodologies may be inherently incapable of providing definitive tests of the strength of reputation effects. Airline accidents, while newsworthy, may not be very informative. The expected (or optimal) level of airline safety is unlikely to involve zero accident risk, and while an accident today predicts a somewhat higher probability of an accident tomorrow, the serial correlation is relatively small.[14] Given this, the occurrence of an accident may not cause consumers to revise their safety expectations for a firm (Borenstein and Zimmerman, 1988). If an accident does not lead consumers to revise their priors about an aircraft's or airline's safety, consumers should not penalize the firm involved in the accident. Minimal consumer responses therefore may be consistent with both highly efficient reputation mechanisms (for example, where firms that deviate from expected safety levels would be severely punished and therefore are deterred from ever

[14]A regression of current fatal accident rates on the prior year's rate, controlling for carrier average accident rates, yields a coefficient of .10 (t-statistic of 2.8) for the 35 airlines in Rose's (1990) sample.

Table 1
Front Page Stories for 6 Sources of Mortality Risk, New York Times, 10/1/88 – 9/30/89

Risk Source	*Number of Stories*	*Stories per 1,000 U.S. deaths*
Cancer	7	.04
Suicide	1	.03
Automobiles	4	.08
Homicide	35	1.7
AIDS	35	2.3
Commercial Jets	51	138.2

Source: Barnett (1990), Table 4.

"cheating") and ineffective reputation mechanisms (for example, where consumers are unaware of the aircraft type used on particular flights, have difficulty assessing safety records and so are slow to update their priors in response to accidents, or are slow to respond to differences in perceived accident risks across aircraft or airlines). The existing analyses do not enable us to distinguish these two extremes.

Conclusion

Economists have learned a substantial amount about airline safety, even though many questions remain unanswered. In fact, one might wonder about the motivation for devoting so much energy to studying such a low risk activity. Airline safety analyses appear to have garnered a disproportionate share of major journal pages in recent years, relative to more significant risks. While our professional fascination may be inspired in part by the amount of time we spend in the air, we are not alone in this interest. Airline accidents attract far more public attention than most other sources of fatality risk, including such popular concerns as cancer, homicide, and AIDS. A recent analysis of *New York Times* front page coverage, reproduced in Table 1, revealed: "The *Times* had more page-one stories about the dangers of flying than about any of ... five other [prominent] threats to life, and on a per-death basis, it had orders of magnitude more" (Barnett, 1990). This national preoccupation with airline safety may provide the ultimate explanation for the high safety standards maintained by U.S. carriers and the immense improvements in air safety over time.

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