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FEAR OF FLYING? ECONOMIC ANALYSES OF AIRLINE SAFETY

by

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ABSTRACT

The safety of the commercial airline industry has attracted considerable public attention and debate since economic deregulation of the industry in 1978. These concerns have energized economic research on three aspects of airline safety. First, has the level of 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, what accounts for differences in safety performance across carriers? This literature analyzes heterogeneity in carriers' safety records as a means of learning about factors that influence safety performance. Third, how do markets respond to airline accidents? This work explores the effectiveness of market incentives in constraining the safety provision of firms. This paper describes our progress in answering each of these queries.

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The safety of the commercial airline industry has been of long-standing interest to policy-makers and the general public. This issue attracted particular attention in the wake of airline deregulation, amid growing concerns that the historical superiority of U.S. jet carriers' safety records may have been inextricably 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 substantial reductions in at least some dimensions. Perhaps less observable dimensions of product quality, such as safety, have experienced equivalent or greater declines. If this were the case, traditional measures of welfare gains from deregulation could be greatly exaggerated.

These worries have energized economic research on a broad range of issues relating to airline safety. Three 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, what accounts for differences in safety performance across carriers? This literature 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. Third, how do markets respond to airline accidents? This work 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.

1. Has airline safety declined since deregulation?

Aggregate statistics on U.S. airline safety provide reassurance for travellers concerned that deregulation increased the risks of air travel. Virtually all measures of accident or fatality risk suggest that the long-term trend toward increased airline safety has continued since economic deregulation of the airline industry in 1978. This is illustrated in figure 1, which plots the number of aircraft accidents per million departures for large U.S. scheduled air carriers over the period 1955-1990.[1] Both total and fatal accidents per million departures declined substantially, although there is considerable variation in accident rates from year to year.

There is little evidence that improvements in airline safety have slowed appreciably since deregulation. Observed accident rates since 1978 conform closely to those predicted by a trend estimated over the 1955-1977 data, as illustrated in figure 2. More formally, regression analysis of the log of accident rates

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[1] Referred to as "Part 121" carriers, these are carriers that operate aircraft with capacity in excess of 60 seats. These carriers currently operate primarily jet aircraft fleets.

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.[2] Figure 2 does, however, suggest some scope for caution. Accident rates over the last four years (1987-1990) lie slightly above trend. There is not enough data to determine whether this reflects 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 regulatory changes rather than to some other cause. Nevertheless, these data may suggest 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 fatality risks for passengers on U.S. domestic jet airline flights 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,

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[2] Rose (1989) presents results for 1955-1986 data; my updates based on the 1955-1990 data yield similarly insignificant results. This conclusion is reinforced by an analysis of the time fixed effects (1958-1986) from the model of airline specific accident counts in Rose (1990).

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 <u>any</u> domestic passenger fatalities during the 7 year period, and these had just one fatal accident each. 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 reductions in air traffic control (ATC) staff after the 1981 controllers strike, degraded the air traffic control system, accidents resulting from ATC errors or interference by other aircraft should become more common.

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, such as 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%. Accident rates due to equipment failure, pilot error, ATC error, and other aircraft declined by this amount or more, topped by a 71% reduction in accidents initiated by equipment failures. This suggests a relative <u>decrease</u> 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

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[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.

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 result that engine shutdown probabilities have been unaffected suggests that these maintenance changes have not compromised air safety, consistent with Oster and Zorn's report of substantial relative declines in accidents initiated by equipment failure.

Indirect effects of deregulation on travellers' safety

There are a number of indirect channels through which deregulation may have influenced safety. 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 take-offs, this would tend to increase passengers' risks per trip (origin-destination). Third, the introduction of price competition and service improvements may induce travellers to substitute air travel for auto travel. Since the risk of a highway accident substantially exceeds that for air travel over even moderate distances, this substitution would enhance travellers' safety.

Substitution of commuter service: By eliminating explicit cross-subsidization and easing entry and exit restrictions, airline deregulation may have encouraged established jet carriers to abandon uneconomic service to small communities. While most of these communities retain air service, it now typically is provided by commuter carriers. Because commuter airlines have higher accident rates than jet airlines, risks to travellers in these communities may have increased. For example, over 1979-1985, passenger fatalities were .38 per million passengers enplaned on trunk airlines, but 1.27 per million passengers enplaned on commuter airlines-- more than three 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 much 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 (from .59 to .30; see Oster and Zorn, 1989). Re-scaling the fatality risk to reflect total risk per passenger trip on these routes yields a risk of .60 per million trips for jet carriers (.38

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[4] There have been no studies that look at commuter safety under codesharing arrangements with major carriers (see Borenstein, 1991, for a discussion of codesharing). Given the increased scrutiny that codesharing imposes upon the commuters, it is likely that their safety record is even better than implied by size alone.

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 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. Oster and Zorn (1989) estimate the auto fatality rates in these markets to lie between 1.9 and 2.3 per million passenger trips. Since this is substantially greater than the risk for the larger commuter airlines, the modal switch enhances overall safety for these travellers.

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 (1991). He finds an increase in the number of passenger trips that involve a change of plane, from 27.3% of trips in 1978 to 32.8% in 1990. If all remaining passengers flew nonstop, the average number of flights per trip would have increased by 4.3% 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% between the 10 years prior to deregulation and the 10 years after deregulation. Adjusting for a 4% increase in average flights per trip reduces the effective decline to 52%.

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. Based on the results for the change of plane statistics, however, failure to account for this seems unlikely to alter the basic conclusion.

<u>Shifting traffic from highways to air</u>: 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% per year and domestic revenue passenger-miles (RPMs) grew at 7.5% per year. Some of 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.

It is difficult to determine the precise extent to which travellers have shifted from automobile travel to air travel as a result of airline deregulation. Using annual aggregate data on passenger car miles travelled and a dummy variable for airline deregulation, McKenzie and Warner (1988) estimate a decline of nearly 4% in passenger car miles as a result of airline deregulation, or an average reduction of 43 billion car miles annually during the 1979-85 period. They conclude that this reduction in auto miles corresponds to roughly 1700 fewer auto fatalities per year. If the average auto occupancy rate for intercity traffic is 2.0, a shift of 43 billion car miles to air travel would imply an increase of 86 billion passenger miles for airlines. The number of air fatalities associated with this amount of air travel averages about 41. A shift of this magnitude from highway to air would have an enormous net savings in lives: more than 1650 per year. Is this a credible estimate?

Airline RPMs increased by roughly 70 billion between 1975 and 1980, or 140 billion between 1975 and 1985. If the estimated shift in highway travel is correct, the bulk of the increase in air RPMs comes from displaced auto trips. This seems implausibly large. Unfortunately, we do not have better estimates of the true magnitude of the modal shift. Even if the effect is only one-fifth as large as McKenzie and Warner estimate, however, more than 300 lives would be saved each year by the shift to air travel--more than the total U.S. airline passenger fatalities in any of the last 10 years.

2. 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 3 and 4 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.[5] The wide variation in individual accident rates is not entirely surprising: given the discrete and 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. This raises the question: 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

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[5] 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.

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 airlines' safety performance 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 financial link to safety, including models of reputation formation under asymmetric information, liquidity constraints on investment behavior, and firm decision-making near bankruptcy. None of these models implies that such a link must exist, however, leaving the resolution of this debate to empirical tests.

Early studies, typically based on short time series for 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 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 their 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 part 121 U.S. carriers over 1957-1986. In the full sample, higher operating profits were associated with lower accident rates in the following year. A 5 percentage point increase in the operating margin (e.g. from 5% to 10%) implies about a 5% reduction in the total accident rate and more than a 15% 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.

These average effects may themselves mask important differences across carriers in the sensitivity of safety performance to profitability changes. Rose's data suggest that profitability effects may be strongest for the smaller and mid-size carriers in the sample, 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% reduction in reported incidents for the smallest carriers in the sample and a 10% - 12% 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, and FAA regulators may more closely scrutinize these carriers. 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" (Part 121) carriers due to the lack of reliable financial data for commuter (Part 135) carriers. Anecdotal evidence suggests that commuters may be quite sensitive to financial pressures, and the arguments raised above for the smaller jet carriers would seem to apply even more strongly to commuters. Decisive conclusions about this segment of the industry must await further data and study, however.

<u>New entrant safety performance and the role of experience</u>

A major concern after deregulation was the safety performance of new entrants into the airline industry. Barnett and Higgins' (1989) conclusion 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 somewhat 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 (e.g., Kanafani and Keeler, 1989; Oster and Zorn, 1989; and Evans, 1989). Kanafani and Keeler (1989), for example, find that identifying a carrier as an entrant does not add significant explanatory power to a regression model of total accident rates over 1982-85, perhaps in part because of the enormous variability in accident rates across the 25 entrants in their sample. Evans (1989) argues that entrants appear to have <u>lower</u> 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.[6] 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 argues that this result may reflect more intense regulatory scrutiny of airlines newly certified in interstate service.

The general conclusion that entrant safety performance does not significantly differ from that of established carriers holds across a wide variety of safety measures. Oster and Zorn (1989) find no significant differences between trunks and "other jet carriers" for five of six aggregate safety measures over 1979-85, including passenger fatalities and passenger injuries per million enplanements, and total accidents, serious injury accidents, and minor accidents per million aircraft departures. Their group of "others" corresponds to the broadest definition of entrants used in the literature. Kanafani and Keeler (1989) report no significant difference in FAA inspection ratings for new entrants under the National Air Transportation Inspection program and some evidence that new entrants have lower near mid air collision reporting rates than do established carriers (though the latter may reflect differences in reporting incidence rather than

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[6] 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% of established carrier accident rates, other things equal. Note that this is not the calculation apparently reported by Evans.

differences in occurrence rates).

The dominant 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 noted earlier, this poor aggregate 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 studies of entrant fatality risk. While the airline was new to scheduled interstate service, it had been operating charter service prior to deregulation. Should World be grouped either with People Express, which entered airline service <u>de novo</u> after deregulation, or with Pacific Southwest Airlines, which had provided California intrastate service since 1948? In most studies, "entrants" are defined to include all of these types of carriers.

To understand which firms can be meaningfully grouped together, we must first understand the possible underlying causes of the entrant results. This is difficult to do with either aggregate analyses or simple dummy variable regressions of carrier differences. Unfortunately, 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 general 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. Additional investigation is required to develop a better understanding of other sources of the apparent differences in safety performance between entrants and established carriers.

Commuter carriers

Commuter airlines, as a group, have substantially higher accident and fatality rates than do jet carriers. The implications of this observation 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.[7] Such regulation will have little effect if the disparities arise from inherent differences in equipment reliability (e.g., smaller, propeller aircraft are more prone to failure, even when optimally equipped and maintained) or airport facilities (e.g., 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 <u>on a given route</u> 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

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[7] Whether this is socially optimal depends on whether commuters currently underprovide safety.

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, in 1978 the FAA substantially tightened commuter safety regulations, increasing pilot qualification, crew training, and maintenance requirements (particularly for larger commuter aircraft), and specifying for the first time minimum equipment lists for commuter flights. 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 presumably influenced by both enhanced pilot certification and training requirements and equipment rules governing instrument flight rule operations; see Oster and Zorn, 1989). Since commuter regulations remain less stringent than those for jet carriers, additional improvements in safety are likely to be possible-- although whether these would be welfare enhancing remains unknown.

3. <u>How do markets respond to airline accidents?</u>

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 air carrier safety levels 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 regulations that specify minimum safety input and performance standards for air carriers. Airlines' and aircraft manufacturers' reputations may provide an alternative (or complementary) mechanism for insuring adequate safety provision. If these 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 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 types 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? These questions will be most appropriate when an airline's actions or inaction are suspected to have contributed to the accident.

In this literature, profit effects typically are measured using an event study methodology, which measures 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 cargo and crew only (re-positioning) flights. These criteria select the worse and more highly publicized accidents for analysis.

Aircraft reputation

Studies of aircraft reputation effects have focused on two DC-10 crashes: the American Airlines Chicago crash 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.[8] What do these analyses reveal?

The 1979 DC-10 crash provides some evidence of a market penalty for aircraft manufacturers. 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.[9] 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.[10]

These declines are not representative of responses to other accidents, however. In 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

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[8] Chance and Ferris (1987) find no effect on the manufacturer for a sample of 46 accidents over the 1962-1985 period. Their sample is not, however, stratified by likely cause of the accident.

[9] The accident occurred after the market close on Friday, May 25, of Memorial Day weekend. The share price response therefore is measured from the Friday close to the Tuesday close. See Chalk (1986).

[10] As new information suggested that improper maintenance practices were the likely cause of the accident, at least part of the initial share price declines were reversed. The exact estimates of the net effect on McDonnell Douglas appear highly dependent on the time period over which stock returns are evaluated. Chalk (1986) reports statistically significant net declines of 14 to 22 percent through various dates in July 1979. Karels' (1989) attempts to reproduce these results yielded estimates of +1 through -21 percent net returns, all statistically insignificant.

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.[11] Chalk's (1987) evidence on manufacturer losses for a sample of 19 accidents to which aircraft failures contributed suggests modest profit losses, but these estimates may be strongly affected by the inclusion of the 1979 DC-10 crash in the sample. Chalk finds an average share price decline of roughly 4% over the five business days following an accident, corresponding to an average loss of $21 million in market value. His 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.

Profit declines for aircraft manufacturers do not appear to result from passenger avoidance of aircraft involved in fatal accidents. Barnett and Lofaso's (1983) study of DC-10 market shares 6 months before and 6 months after the 1979 crash revealed no systematic changes in travellers' behavior on a sample of 18 routes.[12] In a study of travel agency ticketing data, Barnett,

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[11] The accident occurred after the market closed on July 19; July 20 therefore is the first post-crash return day. McDonnell Douglas shares lost nearly 7% on July 19, probably due to its announcement on that day of unexpectedly large second quarter losses. On July 20, McDonnell Douglas shares declined 0.9%, compared to a 0.7% for the market as a whole. McDonnell Douglas share prices rose over the next week.

[12] 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

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, 1 in 3 passengers who booked travel within the first 2 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% of pre-crash levels by 8 weeks after the crash.[13] 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.

Finally, 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% decline in share values, although this could not be statistically distinguished from zero. The decertification announcement led to a 5.3% decline for American and a 2.9% decline for the other DC-10 airlines. A portfolio of non-DC-10 airlines was unaffected.

How should we interpret these studies? It seems premature

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market shares. The study of the 1989 DC-10 crash suggests that this explanation is unlikely to account for their result.

[13] The study did not examine booking patterns beyond 8 weeks post-crash.

to cite these as confirmation of a "reputation effect," at least in the sense that "market forces can compel producers to invest in safety, even if consumers are ignorant of all the technical details of the product" (Chalk, 1986).[14] 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 1979, however, the market 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 decisively indicate which mechanism is more important.

<u>Airline reputation</u>

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[14] One should remember that while air passengers may not be well informed about technical characteristics, they are only indirect consumers of aircraft services. The direct customers of aircraft manufacturers are airlines, which tend to be highly knowledgeable and sophisticated buyers.

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 insurance premia changes. 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% on the first trading day following the accident, and 1.5% over the first two days following the accident. This translates into an average $12 million loss in 1990 dollars.[15] 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% and a two-day decline of roughly 2.3%.[16] This corresponds to an

[15] All dollar values reported in this section have been escalated to 1990 dollars using the CPI.

[16] 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 conclude, 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

average loss in equity value of $22 to $31 million in 1990 dollars. Because airlines typically carry quite complete hull (aircraft) and 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 premia 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 pre-crash. The total present discounted value of insurance increases average about $10 million in 1990 dollars.[17] This accounts for one-third to one-half of their estimated decline in equity value.

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 total loss in demand over a four-month period average 10% to 15% of one-month's traffic volume, although these estimates are at best of marginal statistical significance. Consistent with the implications of

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results are drawn from the same distribution.

[17] Their results for hull insurance increases are quite sensitive to the specification of the model. An estimate of hull insurance increases is included in the total dollar value of insurance increases, however.

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.

It is difficult to interpret these results. The demand changes during the deregulation era, while relatively small and short-term, imply large revenue losses. For the sample of 13 accidents, the average implied revenue loss is over $100 million in 1990 dollars.[18] 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 are estimated very imprecisely. Second, the estimated revenue losses substantially exceed 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 this 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 point estimate of the demand change for other airlines following an accident is negative, but very small and imprecisely estimated. The 8 largest accidents (100 or more fatalities) may have induced a small (1%) one-month increase in demand for other airlines, but the stock price of these airlines was unaffected. This suggests

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[18] The uncertainty around this estimate is, however, enormous.

that most passengers who would have flown an airline recently involved in an accident instead choose not to fly, which may not be entirely plausible. Further investigation, using the additional years of post-deregulation data now available, appears necessary to address these concerns and resolve the question of 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 aircraft or airline 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. Given this, the occurrence of an accident may not cause consumers to revise their safety expectations for a firm. 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 to an accident therefore may be consistent with both highly efficient reputation mechanisms (e.g., where firms that deviate from expected safety levels would be severely punished and therefore are deterred from ever "cheating") and ineffective reputation mechanisms (e.g., 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 economically 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 that "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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Table 1

Front Page Stories for Six 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	.02
Suicide	1	.03
Automobiles	4	.08
Homicide	35	1.7
AIDS	35	2.3
Commercial Jets	51	138.2

Source: Barnett (1990), Table 4.

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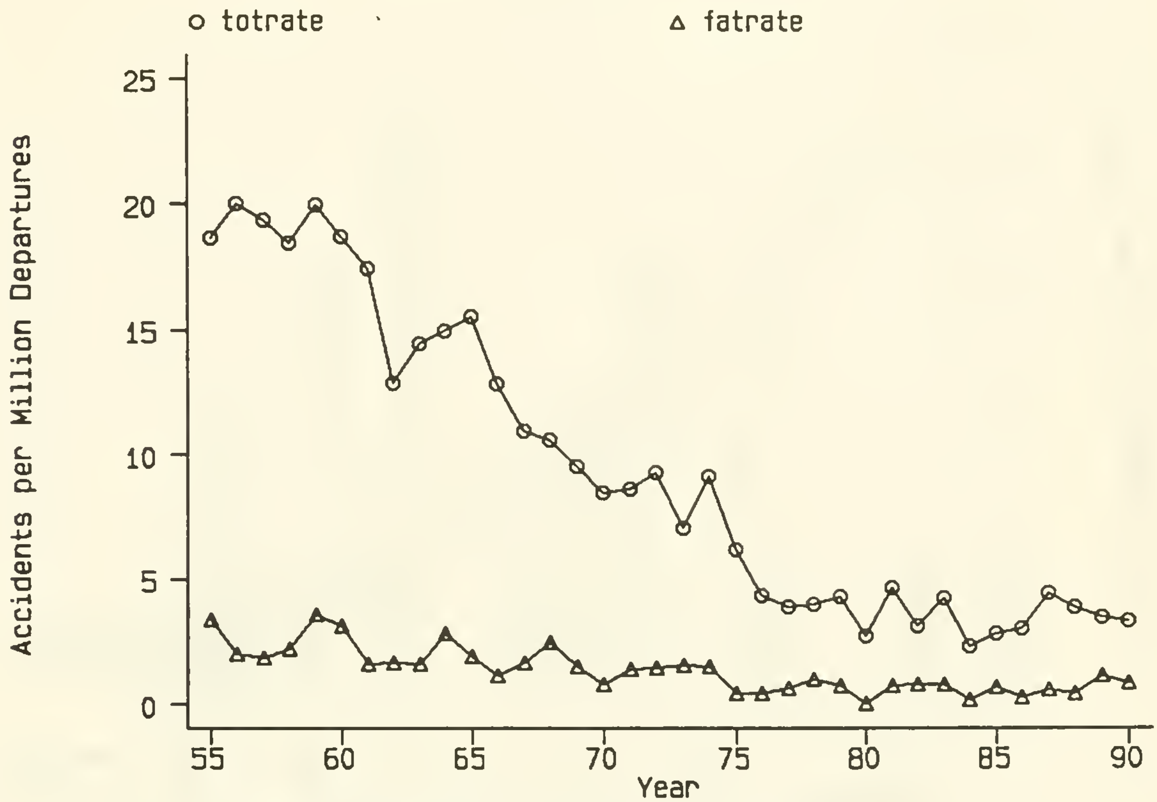
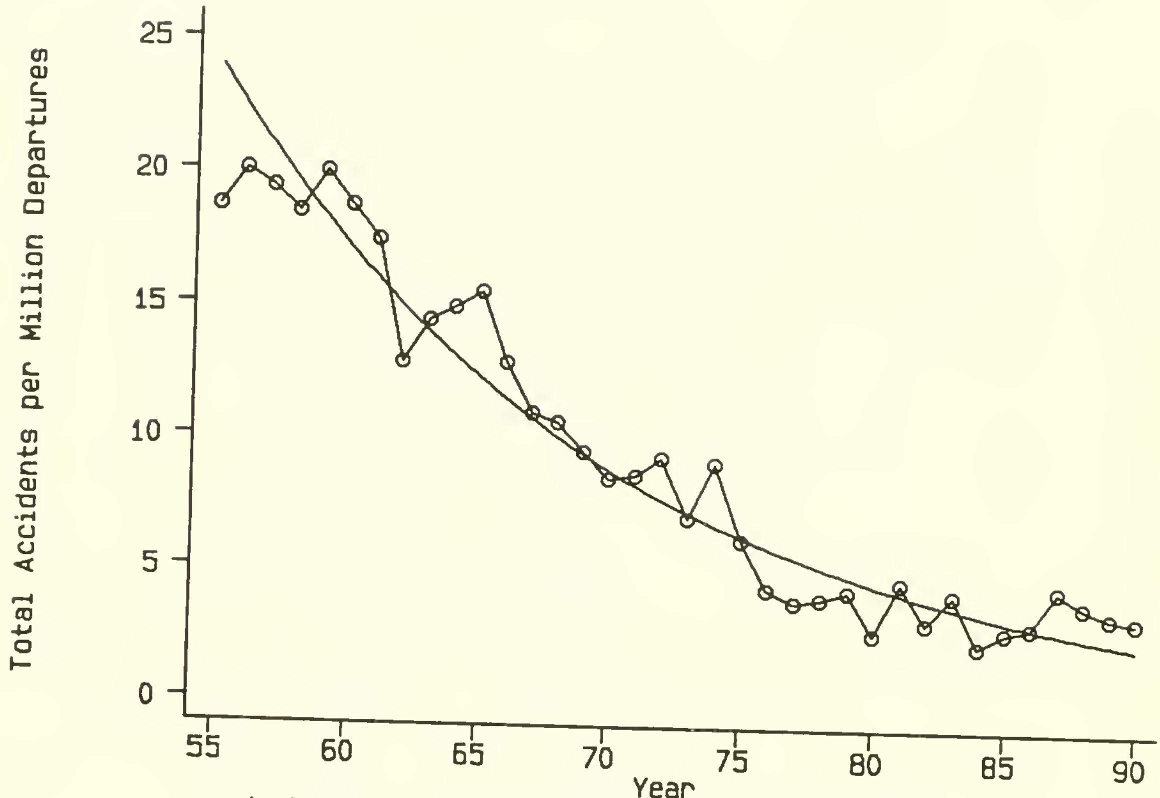
Figure 1



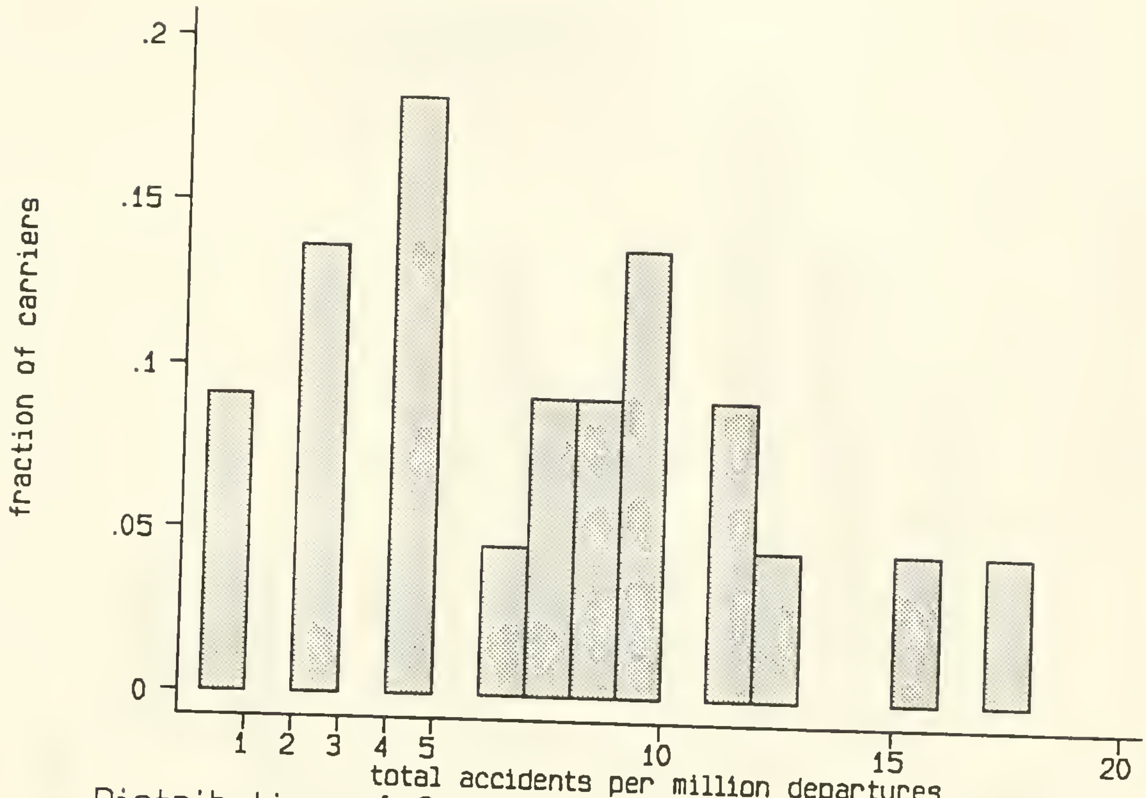
Aggregate Accident Rates

Figure 2



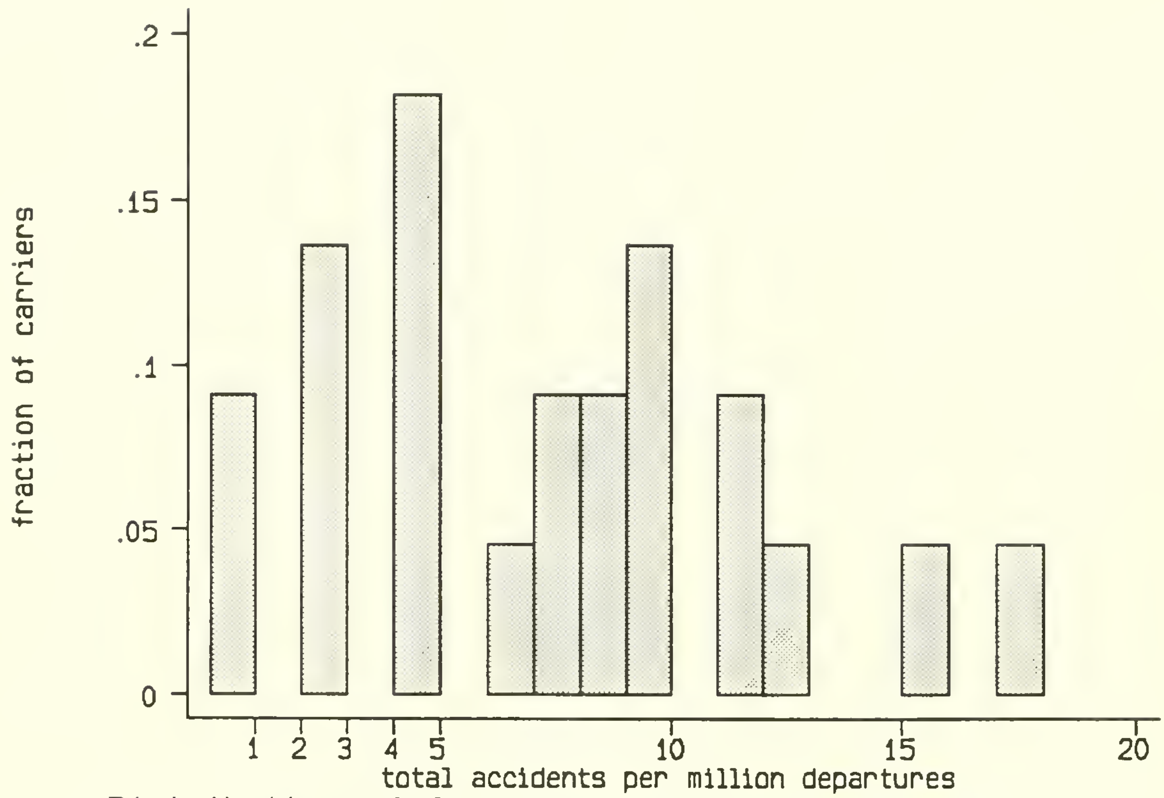
Actual v. Predicted Accident Rates

Figure 3



Distribution of Carrier Accident Rates, 1971-75

Figure 4



Distribution of Carrier Accident Rates, 1981-85