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DETERMINANTS OF AIRCRAFT ACCIDENTS AND POLICY IMPLICATIONS FOR AIR SAFETY (*)

WAYNE K. TALLEY**
PHILIP A. BOSSERT Jr.

ABSTRACT: It has been argued that economic deregulation of the U.S. airline industry has reduced the profitability of the industry which, in turn, has resulted in cutbacks in such safety expenditures as maintenance (and thus a less safe airline industry). The results of this paper based upon an analysis of aircraft-accident time series data support this argument only in part. The empirical results indicate that a worsening of the financial condition of airlines (as under deregulation) will result in a decrease in the relative maintenance expenditure of airlines; however, relative maintenance expenditure was not found to be a significant determinant of aircraft accidents. A highly significant negative relationship was found between aircraft accident and pilot expertise. Policy recommendations for air safety include hiring additional FAA controllers and placing even tighter stringent rating-requirements on airline pilots.

INTRODUCTION

It is generally argued that economic deregulation of the U.S. airline industry has caused a deterioration in air travel safety. In his book on airline safety, John Nance (1986) argues that deregulation (following the passage of the Airline Deregulation Act of 1978) has put pressure on management to cut

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(**) *Wayne K. Talley and Philip A. Bossert, Jr. are affiliated with the Department of Economics, Old Dominion University, Norfolk and United States Air Force, McGuire Air Force Base, New Jersey, respectively.* The views expressed in this paper are those of the authors and are not intended to present official views of the United States Air Force. The authors are grateful to Richard Phillips and Eric Anderson for helpful comments.

costs at the expense of safety. In this framework, deregulation via its negative effect on profitability is expected to correlate with deterioration in air travel safety. However, descriptive statistics on aircraft accidents under deregulation do not suggest a deterioration. For the deregulation period, 1978-1984, aircraft accidents for scheduled U.S. certified route airline service had a range of 12 to 25 accidents per year; for a regulation time period of 1959-1977, the range was 21 to 93 accidents per year, with the number of accidents being 93 in 1959.

The purpose of this paper is to investigate the determinants of U.S. aircraft accidents during a regulated and deregulated time period. In an empirical analysis, we investigate those factors that have had a significant impact on aircraft accidents as well as how sensitive aircraft accidents are to a change in a given factor. Furthermore, policy implications with respect to aircraft accidents in a deregulated environment will be stated.

In the next section below, a simultaneous-equation aircraft-accident model is specified. Variables are defined and *apriori* signs are hypothesized. The following section discusses the data to be used in the empirical analysis. Then, empirical results from estimation of the simultaneous-equation model are presented. In the final section, conclusions and policy implications are presented.

THE MODEL

In order to analyze determinants of U.S. aircraft accidents (AA), we posit an aircraft-accident function of the following form:

$$AA_t = f(AS_t, ME_t, PE_t, FAA_t, DEG_t, TEC_t, PAT_t) \qquad [1]$$

Where,

AA_t = aircraft accidents of scheduled certified route air carriers (or airlines) at time period t (1).

(1) An aircraft accident as defined by the National Transportation Safety Board is "an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight until such time as all persons have disembarked, and in which any person suffers death or serious injury as a result of being in or upon the aircraft or by direct contact with the aircraft or anything attached thereto, or in which the aircraft receives substantial damage".

AS_t = level of air service of scheduled U.S. certified route carriers at time period t.

ME_t = relative maintenance expenditure (or the ratio of maintenance expenditure to total operating cost) of scheduled U.S. certified route air carriers at time period t.

PE_t = pilot expertise of U.S. commercial air pilots at time period t (2).

FAA_t = size of the federal-government air safety (i.e., FAA) program at time period t.

DEG_t = a binary variable representing the airline-deregulated time period t.

TEC_t = a time trend variable representing time period t.

PAT_t = a binary variable representing post-PATCO strike time period t.

In the empirical literature of passenger transportation safety, the selected proxy measures of safety vary. Both rate and non-rate measures have been used. In an analysis of highway safety, Peltzman (1975), Crandall and Graham (1984) and Lave (1985) use the fatality rate (or fatalities per vehicle mile); Loeb and Gilad (1984) and Loeb (1985) use fatalities, accidents and the fatality rate as proxies for highway safety. In an analysis of airline safety, Golbe (1986) chose aircraft accidents rather than the fatality rate as a proxy for airline safety.

In this paper, we chose to investigate determinants of aircraft accidents rather than determinants of aircraft accident (or fatality) rates. The rationale for this decision is as follows. First, the objective of airlines is to limit aircraft accidents and not necessarily the aircraft accident rate. For instance, the aircraft accident rate (or number of aircraft accidents per aircraft mile) may decline even though aircraft accidents are rising, i.e., aircraft miles flown may increase at a faster rate than the increase in aircraft accidents. Second, there is a drawback to a rate measure in and of itself. For instance, the aircraft accident rate may vary even though the number of aircraft accidents remain constant. If so, determinants in an aircraft accident rate function would be deter-

(2) Data on the experience of pilots involved in accidents are not available. However, pilot experience and pilot expertise are expected to be positively correlated. The pilot expertise of U.S. commercial air pilots rather than just the pilot expertise of air pilots providing scheduled U.S. certified route air carrier service is considered, since the pilot expertise of pilots providing any tipe of U.S. commercial air service can affect the number of aircraft accidents incurred by scheduled U.S. certified route air carriers. This follows since all types of commercial air service generally use the same airports and the same airway capacity.

minants of the reciprocal of the level of service variable (such as aircraft miles flown). Third, the level of service measure used in construction of the aircraft accident rate variable may be a determinant of aircraft accidents. Specifically, the level of airline service provided may measure air travel intensity (i.e., utilization of airway capacity) and air travel intensity, in turn, is expected to affect aircraft accidents.

The level of air service (AS) provided by air carriers (or airlines) may be measured by the number of revenue passenger enplanements (RP), number of aircraft miles flown (AM), number of aircraft hours flown (AH), or the number or aircraft departures (AD). As a measure of air travel intensity, the level of air service is expected to have a positive impact on the number of aircraft accidents, i.e., as the use of a given airway capacity increases, the likelihood of aircraft accidents increases.

A negative relationship is expected between aircraft accidents and relative maintenance expenditure (ME). If the pilot expertise (PE) of air pilots increases, we would expect a decrease in aircraft accidents. As the size of the government air-safety program (the number of FAA employees) increases, the number of aircraft accidents is expected to decrease. FAA employees include air traffic controllers (FAC) and aviation safety inspectors (FAI). The variables FAC and FAI are used to measure the intensity of regulatory oversight; they do not necessarily capture the effects of labor-saving technological change.

In order to account for a change in the operating environment of the airline industry (i.e., from an economically regulated to an economically deregulated environment), the binary variable (DEG) is utilized. The variable is assigned a zero value when the industry is under economic regulation and a one when the industry is deregulated. The general perception is that deregulation has resulted in an increase in aircraft accidents. If so, the *a priori* sign of DEG will be positive. However, based upon our previous discussion, annual aircraft accidents have generally been less under deregulation than under regulation, thus implying a negative *a priori* sign for DEG.

The time trend variable (TEC) is included in aircraft-accident function [1] as a proxy for technological change (e.g., the switch to jet aircraft). Failure to include a proxy for technological change would likely bias the estimated coefficients of the included variables. Since technological change in air passenger service has tended to promote air safety, a negative relationship is expected between aircraft accidents and technological change (TEC).

In August, 1981, President Reagan fired 11,400 air traffic controllers for participating in an illegal strike led by the now defunct Professional Air Traffic Controllers Organization (PATCO). In order to consider the impact of the post-PATCO strike environment on aircraft accidents, the binary variable (PAT) is utilized. The variable is assigned zero value for time periods prior to the strike and a one for time period after and including the strike. Since the strike would be expected to have an adverse impact on aircraft accidents, the *a priori* sign for PAT is positive.

Our aircraft-accident function [1] is similar to that of Golbe's (1986) in that both consider the level of airline service as an explanatory variable. However, unlike Golbe's aircraft-accident function, our function also considers pilot expertise, the size of the federal government (or public sector) air safety program and deregulation of the airline industry.

It has generally been argued (especially by the media) that the reduction in airline profitability (under deregulation) will, in turn, result in air carriers cutting back on such safety expenditures as maintenance, thus resulting in a greater number of aircraft accidents (3). This argument suggests a multi-equation model for investigating aircraft accidents, i.e., an aircraft-accident function and an airline-maintenance expenditure function. The profitability (of financial condition) of airlines is expected to be a determinant of airline maintenance expenditures and airline maintenance expenditures are expected to be a determinant of aircraft accidents. The number of aircraft accidents is expected to have a positive impact on the maintenance expenditures of air carriers. Fearful of further accidents and the perception of the traveling public that air travel is unsafe (and therefore the potential loss of passengers), air carriers are thus expected to increase their maintenance expenditures in response to an increase in aircraft accidents. Thus, with aircraft accidents appearing in the airline-maintenance expenditure function, our two-equation model becomes a two-equation simultaneous model, i.e., maintenance expenditures appear as a determinant in the aircraft-accident function and aircraft accidents, in turn, appear as a determinant in the airline-maintenance expenditure function.

The general form of the airline relative-maintenance expenditure function may be expressed as follows:

$$ME_t = g(AA_t, OR_t, AS_t, FAI_t, DEG_t, TEC_t) \qquad [2]$$

(3) It should be noted that air carrier maintenance expenditures do not include some safety-related expenditures (e.g., crew training). Further, technological change over time may mean that maintenance inputs can decline without decreasing the output of safety.

Where, OR_t represents the operating ratio (or the ratio of total operating cost to total operating revenue) of scheduled U.S. certified route air carriers at time period t. The operating ratio has often been used by regulatory agencies such as the Interstate Commerce Commission as a measure of the financial condition and profitability of transport carriers. For relative-maintenance expenditure function [2], a positive relationship is expected between relative maintenance expenditure and aircraft accidents; a negative relationship is expected between relative maintenance expenditure and the operating ratio of an air carrier. As the level of air service increases (holding the number of aircraft constant), the relative maintenance expenditure of air carriers is expected to increase. This follows since as the utilization of aircraft increases, the aircraft will require greater maintenance.

Since the FAA inspects aircraft and specifies certain aircraft maintenance guidelines, an increase in the number of FAA inspectors (FAI) is expected to result in an increase in the relative maintenance expenditure by air carriers. If relative maintenance expenditure by air carriers is expected to be less in an economically deregulated environment, the sign of the coefficient on the binary variable (DEG) is expected to be negative in relative-maintenance expenditure function [2]. Since variable TEC is a proxy for such technological change as the switch to jet aircraft and since newer aircraft are expected to require less maintenance than older aircraft, a negative relationship is expected between relative maintenance expenditure and the time trend variable TEC.

DATA

Annual data for the years 1959-1984 are used to estimate the parameters of functions [1] and [2]. Data for the variables AA, RP, OR and ME were taken from the FAA Statistical Handbook of Aviation (years 1960-1985). The variable AA represents U.S. aircraft accidents (as defined previously) of scheduled U.S. certified route air carriers. The variable RP represents the number of revenue passenger enplanements (measured in 1000s) for scheduled U.S. certified route air carriers. The variable OR represents the operating ratio of scheduled U.S. certified route air carriers. The variable ME represents the ratio of maintenance expenditure to total operating expenditures for scheduled U.S. certified route air carriers.

Data for the variables AM, AH and AD were obtained from the National Transportation Safety Board, i.e., the Board's *Accidents, Accident Rates,* *Certified Route Air Carrier - All Scheduled Service* (years 1960-1985). The variable AM represents the number of aircraft miles flown (measured in 1,000,000s) of scheduled U.S. certified route air carriers. The variable AH represents the number of aircraft hours flown (measured in 100,000s) of scheduled U.S. certified route air carriers. The variable AD represents the number of departures (measured in 100,000s) of scheduled U.S. certified route air carriers.

Data for the variables PE, FAC and FAI were obtained from the FAA's Public Affairs Office in Washington, D.C. The variable PE represents pilot expertise of U.S. commercial air pilots. A measure of PE was obtained by dividing the number of U.S. air transport pilot ratings (ATPs) by the number of U.S. commercial (including ATPs) air pilot ratings. An ATP is the highest civilian air pilot rating attainable and is a required rating of air pilot captains (or first officers) of U.S. commercial air carriers; second officers are not required to hold an ATP but are encouraged to obtain one. It is assumed that the greater the number of ATP rated pilots that serve as air pilots of commercial air service, less the likelihood of aircraft accidents being incurred by scheduled U.S. certified route air carriers (4). The variable FAC represents the number (measured in 10,000s) of FAA air-traffic controllers; the variable FAI represents the number (measured in 1,000s) of FAA aviation safety inspectors.

The DEG variable was assigned a one for the year 1978 (when the airline industry was deregulated) and for the time periods thereafter; for the previous time periods, DEG was assigned a zero. The PAT variable was assigned a one for the year 1981 (the year of the PATCO strike) and for the time periods thereafter; for the previous time periods, PAT was assigned a zero. The time trend variable TEC was assigned a one for the first year (i.e., 1959) of the data set and higher consecutive integer values for the remaining years (i.e., through 1984) of the data set.

EMPIRICAL ANALYSIS

Utilizing the above data, we proceed to obtain two-stage least squares (2SLS) parameter estimates of aircraft-accident function [1] and relative-

(4) The actual percentage of scheduled U.S. certified route air carrier pilots processing ATPs is unavailable. The Future Airline Pilots Association of America (FAPA), the only organization found to have such data, began keeping these data in 1984.

maintenance expenditure function [2]. Linear and log-linear functional specifications were considered. Based upon the traditional criteria of adjusted R^2, t-tests, signs of coefficients consistent with *a priori* expectations, and the apparent avoidance of serial correlation, log-linear estimations of these functions were selected and are presented in Table 1 and 2.

TABLE 1

Log-Linear Aircraft-Accident Equation: 2SLS Parameter Estimates

Explanatory Variable	*Equation (1-1)*	*Equation (1-2)*	*Equation (1-3)*
Log AM	-0.266		
	(-1.439)		
Log ME	-0.0003	0.111	-0.242
	(-0.001)	(0.381)	(-0.537)
Log PE	-1.629***	-1.125***	-1.280***
	(-5.740)	(-3.678)	(-3.262)
Log FAC	-0.857***	-0.712**	-0.638**
	(-3.711)	(-2.709)	(-2.199)
DEG	-0.002**	-0.003**	-0.004***
	(2.489)	(-2.722)	(-2.959)
TEC		-0.025*	-0.031*
		(-1.771)	(-2.069)
Intercept	3.694**	2.410***	3.132***
	(2.215)	(3.082)	(3.136)
Adjusted R^2	0.936	0.941	0.937
DW	2.001	2.179	2.075

*** One percent level of significance.
** Five percent level of significance.
* Ten percent level of significance.
t statistics are presented in parentheses;
DW represents the Durbin-Watson statistic.

TABLE 2

Log-Linear Relative-Maintenance-Expenditure Equation: 2SLS Parameter Estimates

Explanatory Variable	*Equation (2-1)*	*Equation (2-2)*	*Equation (2-3)*
Log AA	0.402***	0.404***	0.356***
	(5.267)	(5.463)	(4.260)
Log OR	-1.773**	-1.763**	-1.926**
	(-2.102)	(-2.135)	(-2.264)
Log FAI	0.539**	0.557**	0.310
	(2.195)	(2.399)	(1.134)
DEG	0.0002		
	(0.266)		
Intercept	0.795**	0.777**	1.088**
	(2.107)	(2.137)	(2.562)
Adjusted R^2	0.714	0.725	0.688
DW	1.168	1.192	1.132

*** One percent level of significance.
** Five percent level of significance.
* Ten percent level of significance.
t statistics are presented in parentheses; DW represents the Durbin-Watson statistic.

In the 2SLS estimation of aircraft-accident function [1], a multicollinearity problem was encountered. Specifically, the correlation coefficient for DEG and PAT was 0.99; the correlation coefficient for log AM and TEC was 0.83; the correlation coefficient for log AM and log FAI was 0.84; and the correlation coefficient for the log ME and TEC was -0.76. The variable PAT was dropped from all estimations of function [1]. Further, the variables log AM and TEC were not considered in the same estimation. Also, the variables log AM and log FAI were not considered in the same estimation. Equation (1-1) in Table 1 represents 2SLS log-linear parameter estimates of function [1], with the variables PAT and TEC being deleted prior to estimation. For equation (1-

1), the coefficient on aircraft miles flown (AM) is negative (i.e., of the wrong sign) and insignificant. Negative 2SLS parameter estimates were also found for each of the other measures (i.e., RP, AH and AD) of the level of air service; these parameter estimates were also insignificant.

The sign of the parameter estimate of ME in equation (1-1) is negative as expected. However, the parameter estimate is insignificant. Thus, we do not have evidence to support the argument that a decrease in the relative maintenance expenditure of air carriers is expected to result in a greater number of aircraft accidents (5). The coefficient on the explanatory variable, pilot expertise, has the correct sign and is significant at the one percent level.

In equation (1-1), the number of FAA air traffic controllers (FAC) has the correct sign and is significant at the one percent level. The deregulation binary variable (DEG) is negative and significant at the five percent level. Since a one is assigned to the variable during economic deregulation and a zero during the economic regulation period, the negative coefficient thus indicates that fewer aircraft accidents are expected under deregulation, after controlling for the level of air service, relative maintenance expenditure, pilot expertise, and the number of FAA air traffic controllers. Further, it may be argued that air carriers have a greater incentive ex ante in an economically deregulated environment (as opposed to an economically regulated environment) to provide safety, because the magnitude of loss (as related to profit and market shares) ex post from unsafe practices is likely to be greater in the former environment than in the latter environment. This follows because greater intramodal and intermodal competition are expected in the former environment than in the latter environment.

Since the Civil Aeronautics Board (CAB) began to allow airlines more freedom prior to the passage of the Airline Deregulation Act of 1978, it may be argued that deregulation was in place prior to 1978. In order to investigate the impact of a different starting point for deregulation (i.e., other than the year 1978) on the DEG coefficient in the aircraft-accident function, both 1976 and 1977 were considered as starting points (i.e., the first time period for which DEG is assigned a one). With 1976 and 1977 being starting points for deregulation, the DEG coefficient was approximately -0.003 and thus ap-

(5) An inspection of the first stage estimated values of ME (that are used in the 2SLS estimation of function [1]) reveals that the antilog values lie within the expected relative range of zero to one.

proximately equal to the DEG coefficient of -0.002 found for equation (1-1).

Equation (1-2) in Table 1 represents 2SLS log-linear parameter estimates of function [1] with the variables PAT and log AM being deleted. The parameter estimates are consistent with those found in equation (1-1) except for the parameter estimate for log ME. The sign of the parameter estimate is now incorrect (in being positive); however, the parameter estimate remains insignificant.

To account for possible simultaneous equation bias with respect to FAC and FAI, the latter variables were considered as endogenous variables in a four-equation simultaneous-equation model. The model consists of function [1] and [2] as well as functions for FAC and FAI; 2SLS parameter estimates of log-linear function specifications were found. The number of FAA air traffic controllers (FAC) was expressed as a function of the number of aircraft departures (AD), aircraft accidents (AA), time trend (TEC) and the binary variable (PAT). The number of FAA safety inspectors (FAI) was expressed as a function of the number of aircraft in operation of scheduled U.S. certified route air carriers (data taken from the FAA Statistical Handbook of Aviation), aircraft accidents (AA), time trend (TEC) and the binary variable (DEG). A number of insignificant variables and incorrect parameter signs were found in estimation of the FAC and FAI functions. Hence, the estimation results for these functions are not reported. The parameter estimates of the aircraft-accident function [1] in the four-equation simultaneous-equation model are presented as equation (1-3) in Table 1. Since the parameter estimates of equation (1-3) are generally consistent with the parameter estimates of equations (1-1) and (1-2), a simultaneous-equation bias with the respect to FAC does not appear to exist.

In the 2SLS estimation of relative-maintenance expenditure function [2], a multicollinearity problem was encountered. Specifically, the correlation coefficient for log AA and TEC was -0.88; the correlation coefficient for log AM and log FAI was 0.84. Consequently, the variables, log AM and TEC, were dropped from estimation of function [2]. Equation (2-1) in Table 2 represents 2SLS log-linear parameter estimates of function [2], with the above two variables being deleted prior to estimation.

The estimated coefficient of the operating-ratio explanatory variable in equation (2-1) has the expected negative sign and is significant at the five percent level. Thus, we have support for the claim that as the profitability of air carriers declines (or their operating ratio increases), we would expect air carriers to decrease their relative maintenance expenditure. However, based upon our estimation of aircraft accident function [1], we do not have support for the continuance of the argument, i.e., a decrease in the relative maintenance expenditure of air carriers, in turn, is expected to result in an increase in aircraft accidents.

The estimated coefficient of the aircraft-accident explanatory variable has the expected positive sign and is significant at the one percent level. Thus, if the number of aircraft accident increases, air carriers are expected to increase their relative expenditure on maintenance. In our estimation of aircraft-accident (AA) function [1], ME is an insignificant variable. In our estimation of relative-maintenance expenditure (ME) function [2], AA is a highly significant variable. Hence, the question arises: if ME is not a significant determinant of AA, why do airlines respond to an increase in AA by increasing ME? The rationale is as follows. Following aircraft accidents, the FAA generally issues Airworthiness Directives dictating changes in airline procedures and/or aircraft design. These directives, in turn, generally result in increases in the relative maintenance expenditures of airlines.

The explanatory variable, the number of FAA aviation safety inspectors (FAI), is significant in equation (2-1) at the five percent level and its parameter estimate has the expected positive sign. The binary variable (DEG) representing deregulation has an incorrect sign but is insignificant. Hence, it can be concluded that economic deregulation has not (after controlling for the remaining explanatory variables in the relative-maintenance expenditure function) had a significant impact on the relative maintenance expenditures of air carriers. The binary variable (DEG) was dropped and the relative-maintenance expenditure function was reestimated to obtain the parameter estimates under equation (2-2) appearing in Table 2. Based upon the DW statistic, the test for the presence of serial correlation is inconclusive for both equations. From a comparison of the parameter estimates and levels of significance for the explanatory variables in equations (2-1) and (2-2), one may conclude that the results are stable.

Previously, we stated that a four-equation simultaneous-equation model was estimated to account for possible simultaneous-equation bias with respect to FAC and FAI. The parameter estimates of the relative-maintenance expenditure function [2] in this four-equation model are presented as equation (2-3) in Table 2. The parameter estimates of equation (2-3) are generally consistent with the parameter estimates of equations (2-1) and (2-2). However, unlike the parameter estimates for log FAI in equation (2-1) and (2-2), the parameter estimate for log FAI in equation (2-3) is no longer significant (6).

CONCLUSIONS AND POLICY IMPLICATIONS

The concern has been expressed, especially in the media, that economic deregulation of the U.S. airline industry has had a negative impact on the industry's safety performance. Support for this concern is primarily based upon the hypothesis that economic deregulation has reduced the profitability of air carrers which, in turn, has resulted in their cutback on such safety expenditures as maintenance; consequently, this cutback has resulted in a less safe airline industry. This hypothesis has also been used to argue for economic reregulation of the U.S. airline industry. The results of this paper, however, only support this hypothesis in part. Under deregulation, the profitability (as measured by the operating ratio) of air carriers has been relatively low in comparison with that prior to deregulation. Our empirical results indicate that a decrease in the profitability of air carriers (or an increase in their operating ratio) will result in a decrease in their relative maintenance expenditure. However, relative maintenance expenditure was not found to be a significant determinant of aircraft accidents (7).

After controlling for the remaining explanatory variables in the aircraft-accident function, a significant negative relationship was found between aircraft accidents and the deregulation binary variable. The implication is that air carrers have a greater incentive ex ante in an economically deregulated environ-

(6) Aircraft accidents can also affect the profits of air carriers. Goble (1986) considered air-carrier profits to be a function of aircraft accidents. However, estimation results of the function were not reported since the study was primarily concerned with the estimation of the aircraft-accident function. A discussion of litigation and court costs incurred by air carriers following aircraft accidents are discussed in Chalk (1985). In a study by Chance and Ferris (1987), stock prices of air carriers following aircraft crashes were analyzed. It is assumed that a carrier's stock price reflects its profitability. Chance and Ferris (1987) conclude that the negative impact on the stock price of a carrier that incurs a crash is immediate and not prolonged. Also, the crash has no significant impact on the stock prices of carriers not involved in the crash. Alternatively, in an analysis of the stock price of an aircraft manufacturer whose aircraft was involved in a crash, Chalk (1986) concludes that the impact was long-term. For further discussion, see Chalk (1984).

(7) This result is also supported by Golbe (1986, p. 317) with the statement that airline data do "not indicate a need for regulators to be concerned with safety effects as profits fall".

ment (as opposed to an economically regulated environment) to provide safety, because the magnitude of loss (as related to profit and market shares) ex post from unsafe practices is likely to be greater in the former (more competitive) environment than in the latter (less competitive) environment. Alternatively, after controlling for the remaining explanatory variable in the relative-maintenance expenditure function, the deregulation binary variable was found not to be a significant determinant of relative maintenance expenditures of air carriers. The implication is that relative maintenance expenditure is not a good proxy for airline safety. For example, air carrier maintenance expenditures do not include such safety-related expenditures as crew training. Also, technological change over time may mean that maintenance inputs can decline without decreasing the output of safety. The argument that relative maintenance expenditure is not a good proxy for airline safety is also supported by the fact that relative maintenance expenditure was not found to be a significant determinant of aircraft accidents.

A highly significant negative relationship was found between aircraft accidents and pilot expertise. Our measure of pilot expertise, commercial pilot expertise, has had a consistent trend (through the year 1984) of improvement under deregulation. The rationale for this improvement is as follows. Because the pilot expertise requirement of scheduled certified route air-carrier service is generally more stringent than that for other types of commercial air service and since the former type of air service has significantly increased under deregulation, it therefore follows that commercial pilot expertise (as defined by PE) has improved under deregulation.

Based upon the results of this paper, policy recommendations with respect to U.S. airline safety may be made. First, if the FAA safety program is to be expanded, consideration should be given first to the hiring of FAA controllers as opposed to FAA inspectors. In our simultaneous-equation model, the number of FAA controllers was found to be significant in explaining aircraft accidents; the number of FAA inspectors was found to be significant in explaining relative maintenance expenditure, but relative maintenance expenditure was not found to be significant in explaining aircraft accidents. Recently, the U.S. Department of Transportation (DOT) proposed the hiring of additional FAA controllers but not FAA inspectors.

Second, given that a highly significant negative relationship was found between aircraft accidents and pilot expertise, consideration should be given to placing even tighter stringent rating-requirements on airline pilots. Recently, the FAA administrator, Mr. Allan McArtor, inferred that pilot deficiency (a breakdown in pilot professionalism and pilot vigilance) was a primary cause of the current number of reported near mid-air aircraft collisions and stated that he was planning an industry-wide review of pilot training and proficiency to improve flight-crew performance (McGinley, 1987) (8).

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(8) Given the expansion of air service under deregulation, a number of airlines are facing a pilot shortage. The significant expansion of service by such airlines as Continental, for example, has exceeded the ability of the airline to train new pilots. Another pilot concern is the apparent stress and low morale of many pilots. Given the competitive environment and expansion of air service under deregulation, pilots are facing increasing airport delays, stricter work rules and lower pay in some instances. The Air Line Pilots Association recently announced plans to undertake an exhaustive review of cockpit stress.

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