Financial performance and safety in the aviation industry

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Abstract

This paper investigates whether financial factors, which are presumed to influence an airline's maintenance, purchasing, and training policies, are associated with the air carrier's safety performance. Using global data from 110 airlines in 26 countries over the period 1990 - 2009, we document an inverse relationship between the profitability of air carriers and their accident propensity. Other financial variables such as liquidity, asset utilization, and financial leverage also appear to affect an airline's safety record, although these findings do not reach significance in all models. Flight equipment maintenance and overhaul expenditures are negatively related to accident rates. In addition, our results show that country-level variables related to the legal and economic environment have a significant effect on airline safety. Specifically, airlines in countries with strong law enforcement, more stringent regulatory systems, and better economic performance have superior safety performance. A series of robustness tests confirms our findings.

1. Introduction

Although flying is one of the safest modes of transportation, aviation accidents can still have devastating effects – both directly, in terms of human fatalities and damage to the aircraft and structures on the ground, and indirectly through their impact on consumer confidence. Based on statistics provided by the International Civil Aviation Organization (ICAO), the global number of accidents of scheduled commercial airlines per million departures ranged between 2.1 and 3.1 from 2012 to 2016.[1] According to the Aviation Safety Network, in 2016, there were 19 fatal airline accidents involving civil aircraft with a minimum capacity of 14 passengers; these resulted in 325 fatalities worldwide.[2]

A 2014 survey conducted by TheStreet, Inc. estimates that one in every three adult Americans has some degree of anxiety about flying internationally.[3] Given the public's fear of flying, and the potential for devastating consequences, it is not surprising that researchers have attempted to determine the factors that may affect accident likelihood and that authorities have been keen to develop more effective regulatory procedures. In this context, the impact of financial pressures on the safety standards and accident track-records of airlines has been a long-standing public concern, especially in countries with relatively lax governmental controls. However, there has been little empirical research on this issue.

Several studies of the relationship between an airline's financial health and its safety record have employed short time series and small cross-sectional data sets to examine airline performance. These studies find no evidence that U.S. airlines in financial distress forego the

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[1] See the 2017 ICAO Safety Report at https://www.icao.int/safety/Documents/ICAO_SR_2017_18072017.pdf
[2] See Niall McCarthy, Statista-Aviation Safety, January 05, 2017, https://www.statista.com/chart/7437/2016-was-one-of-the-safest-years-in-aviation-history/
[3] "1 in 3 Americans Fears International Travel and Flights, Poll Shows", Ted Reed, TheStreet, July 31, 2014, http://www.thestreet.com/story/12827707/1/1-in-3-americans-fears-international-travel-and-flights-poll-shows.html

necessary safety, training, and maintenance investments and thereby compromise levels of flight safety (see Sobin and Armore, 1980; Golbe, 1986; Kanafani and Keeler, 1989; Adrangi et al., 1997). Similarly, studies that examine the relationship between profitability and air carrier safety generally produce mixed results (Wang et al. 2013; Madsen, 2013).

One of the difficulties in obtaining consistent findings in this area is the rarity of airline accidents, together with the small sample size used in most studies. This restricts the potential power of any statistical tests (Rose, 1990; Madsen, 2013). A comprehensive international sample is therefore needed to obtain more accurate results. A further potential limitation of these earlier studies is that they were carried out before the industry was deregulated in most countries, as a result of which it became increasingly competitive. Thus, some carriers opted to pursue technological developments that were designed to increase profits rather than to invest in safety measures and reduced their expenditures on maintenance and on pilot training. In the recent Southwest Airlines accident[4], the `National Transportation Safety Board (NTSB)[5] investigator found a fan blade that had broken twice and argued that these cracks could have been detected during more frequent maintenance inspections. Finally, there is no study to date that explores the impact of an airline's financial performance and governmental regulations on airline safety in a cross-country context. This study aims to close these gaps in the literature.

This paper makes major contributions of both a theoretical and applied nature. First, as mentioned, research that examines the relationship between an airline's financial condition and its safety performance is limited. This study employs a comprehensive data set that covers aviation accidents and financial performance data for airlines around the globe from 1990 to 2009. Second, this study is the first to control for and examine the impact of governmental

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[4] See CNN report "Hidden crack in Southwest jet engine at center of NTSB investigation" (April 19, 2018) at https://www.cnn.com/2018/04/19/us/southwest-ntsb-investigation/index.html

[5] See NTSB website at https://www.ntsb.gov/about/Pages/default.aspx

regulations and other country factors on aviation safety. The results of this research should be of interest both to academics and to regulators who develop, oversee, and implement policies targeted at improving aviation safety on a national and supranational level. If the financial condition of airlines is an important factor that affects aviation safety, the International Civil Aviation Organization (ICAO), the Federal Aviation Authority (FAA), and other regulatory authorities should consider allocating more resources to the supervision of financially weak airlines (Noronha and Singal, 2004). Moreover, the results of this study will be important for air carriers and airline passengers who are undoubtedly concerned about their safety.

At the level of individual firms, our results suggest that lower profitability is correlated with higher accident rates while variations in airlines' asset utilization or financial leverage do not significantly affect their accident propensity. On a country level, our results provide evidence of a significant relationship between governmental regulations and air carrier safety. The coefficients on country variables (e.g., the efficiency of the judicial system, the rule of law, and corruption) are positive with respect to safety and highly significant.

The remainder of this paper is organized as follows. Section 2 reviews the relevant literature. Section 3 provides information on the origin and composition of the dataset, while our hypotheses and methodology are discussed in Section 4. The empirical results are set out in Section 5 and the robustness tests are presented in Section 6. Section 7 provides our conclusions and Section 8 discusses the limitations of our research and suggestions for further work.

2. Literature review

2.1 Specifics of the aviation industry

At the beginning of the 21st century, mankind witnessed the most devastating misfortune in aviation history: the terrorist attacks of September 11. The attacks generated an enormous fear of air travel and constituted an exogenous demand shock; it took the industry 17 months to overcome the reduction in passenger demand before it returned to its pre-disaster state (Cento, 2008). Although the U.S. government offered generous financial assistance to the industry, several airlines applied for bankruptcy protection. Moreover, the 2002 SARS outbreak, combined with the 2003 Iraq war, caused a second demand shock. As recorded by Cento (2008), following the 9/11 terrorist attacks and SARS outbreak, passenger travel demand decreased by about 36 percent and 30 percent, respectively. During those years, the industry appeared to undergo the most difficult period in its history.

Stricter security measures at airports and advancements in technology greatly contributed to restoring passenger confidence in air travel; in addition, the rise of low cost carriers (LCC) injected new energy into the tight global aviation industry and allowed the sector to experience an increase in passenger demand (Berry et al., 2007).

However, the growth phase ended with the onset of the economic crisis in 2008, resulting in the largest revenue decline and capacity reduction since 9/11. Hence, allocating airport resources properly and organizing seat capacity and flight connectivity became important determinants of an airline’s ability to generate sufficient air traffic and to make a profit during the economic crisis (Dobruszkes et al., 2011). Morrell (2011) also observes that, in the context of the recession, the industry implemented many changes in order to cut costs and share risks such as reducing fares, eliminating old aircraft, downsizing, and implementing corporate strategies such as mergers and acquisitions. Overall, the airline industry is very sensitive to external shocks, fluctuations in the global economic environment, and political turmoil (Morrell, 2011; Franke et al., 2011). Therefore, it is important to consider the macro-economic environment in any analysis of the determinants of accident rates.

More recent studies have focused on other aspects of aviation safety. When measuring safety, Madsen et al. (2016) argue that near-misses, even though innocuous, are an important index and can be used to understand accident causation and improve safety levels. In another study, Fleischer et al. (2015) have investigated the effect of disclosing an airline's safety record on consumers' flight choices. Finally, Brown (2017) examines whether low-cost carriers incur a higher probability of aircraft accidents.

This study identifies four major direct causes of accidents based on the accident descriptions provided on the website Planecrashinfo.com, which is one of the main databases we employ for this study. These categories include: (1) human error, (2) mechanical failure, (3) weather, and (4) criminal activity. Admittedly, not all accidents have a single cause. In fact, they may be caused by a series of events, mistakes, and failures, which relate directly to one another. Hence, this study classifies aviation accidents using the first major cause listed in the accident description.

*** Insert Table 1 about here ***

Table 1 provides information on the causes of fatal accidents that occurred worldwide from 1950 to 2010 based on data provided by the PlaneCrashInfo[6] accident database. Accidents involving aircraft with 18 or fewer passengers aboard, military aircraft, private aircraft, and helicopters are excluded. Table 1 shows that pilot error was by far the most frequent culprit,

[6] See http://planecrashinfo.com/database.htm

accounting for 53 percent of all accidents. This finding is consistent with Wiegmann et al. (2001) and Shappell et al. (2004), who also identify pilot error as the most prominent cause of aircraft accidents. Pilot errors can be attributed to a range of organizational influences, including deficient supervision, inappropriate planning of flights, inadequate training (Johnson et al., 2003), willful violation of rules, and corruption to bypass regulatory oversight (Wiegmann et al., 2001). The second most frequent cause in Table 1 is mechanical failure, accounting for nearly 20 percent of accidents. Prior academic studies (Sexton et al., 2000; Baker et al., 2001; Wiegmann et al., 2001) show that ground crews' lack of experience and aircraft manufacturer miscalculations are the main reasons for mechanical failure. The third important cause of aircraft accidents is adverse weather including wind, poor visibility, and turbulence (Knecht et al., 2010). However, some of these weather-related accidents may have been avoided if the flight crew had been properly trained to cope with the respective weather conditions. In that regard, Knecht et al. (2010) point out that training, experience, and equipment are crucial in order to successfully overcome dangerous meteorological situations. Another category, criminal activities, includes airline disasters caused by explosive devices, shoot-downs, and hijackings. The events of September 11, 2001, when 2,996 people were killed, and the shoot-down of Malaysia Airlines flight MH 17 on July 17, 2014, which led to the death of 283 passengers and 15 crew members, are among the most prominent cases in this category.

2.2 Accidents and airline finances

Several prior papers have examined the relationship between an airline's finances and its safety record. Many critics have argued that airlines sacrifice safety investments in striving for higher profits, especially during times of increasing competition in the airline industry (Lee, 1996; Roland, 1997). They argue that financial constraints might cause air carriers to reduce maintenance and training budgets to keep outdated airplanes in service. Many of the earlier studies find little or no evidence for a link between an airline's financial and safety performance (Graham and Bowes, 1979; Golbe, 1986; Bier et al., 2003). However, Rose (1990), using more extensive data sets and a direct measure of safety, finds that profitability is correlated with lower accident and incident rates, particularly for smaller carriers. In direct contrast, Dionne et al. (1997) report a strong negative relationship between profitability and safety for small airlines operating in the Canadian airline industry. We note that both Rose and Dionne et al. employ a similar index of safety – one that is based on accidents involving fatalities, severe injuries or aircraft damage.

Using data from the U.S. airline industry, Madsen (2013) reexamines the relationship between airline profitability and airline accident rates and proposes that the inconsistency in the prior literature can be related to variations in risk appetite as a function of profitability. Madsen argues that, as a firm approaches its profitability target, saving on investments in safety may allow it to achieve its aspirations in terms of profitability; however, if it is performing far below (or far above) the target level there is a much weaker incentive to reduce such investments. Hence, as his data show, airlines that are performing below their aspirations in terms of profitability will demonstrate a negative association between profitability and safety, whereas those performing above their aspirations will demonstrate a positive relationship. In other words, Madsen argues that the link between profitability and safety in the aviation industry is not linear and depends on the airlines' profitability goals.

In exploring the relationship between airline profitability and safety performance, Rose (1990) documents that a 7.6% increase in the operating margin of individual carriers is associated with a 7.4% decrease in the airline's accident rate. The logic underlying her findings is that decision making on safety investments is driven by the tradeoff between the costs of additional safety enhancements and the benefits of reducing accident risk, for example in the form of lower insurance premiums. Airlines that under-invest in safety will suffer penalties from airline passengers, employees, and insurance companies who are unwilling to travel with, work for, or insure airlines with sub-par safety performance. However, if the management of an airline believes that the benefits derived from additional safety-enhancing investments are lower than the costs of that investment, they may choose to reduce their investment to the lowest level consistent with regulatory guidelines. In particular, if airlines face financial distress, they may allocate less money, manpower, and material resources to safety-enhancing projects, particularly if they feel that the chance of an accident is low. Rose also notes that the effect of airline profitability on safety performance is more pronounced for small and medium sized carriers and that it is not statistically significant for larger airlines. Her results are challenged by Dionne et al. (1997) who find a positive relationship between profitability and accident rates using a sample of Canadian airlines. Dionne et al. argue that prior results that find no statistical significance may be biased by the methodology used to measure safety performance, i.e., by looking at fatal accidents, which are quite rare and are not a perfect measure of safety. Hence, the authors expand the operational measure of accidents to include incidents involving bodily injury or material damages and report an inverse relationship between financial performance and safety. In a study of how debt financing affects a firm's product quality, Maksimovic and Titman (1991) point out that when facing financial difficulties, highly leveraged firms are more likely to sacrifice their product quality compared to unlevered firms in the same industry. Insofar as aviation safety resembles product quality, the capital structure of an airline would be expected to affect its safety record in the manner outlined by Maksimovic and Titman.

Raghavan and Rhoades (2005) examine the U.S. airline industry after its deregulation using accident rates as a measure of safety. Their results are consistent with Rose (1989, 1990); i.e., they find a negative relationship between financial performance and accident rates among air carriers, especially among smaller regional carriers. Noronha and Singal (2004) employ a different approach using bond ratings as a proxy for financial health rather than profitability. In line with Rose, they report that airlines with higher bond ratings tend to have fewer accidents than those with lower bond ratings. Similarly, Phillips and Sertsios (2013), treating an airline's safety record as a reflection of its product quality, find that U.S. airlines between 1997 and 2008 sacrificed their product quality (i.e., safety) in order to regain profitability when under financial distress. However, Wang et al. (2013), in their analysis of a sample of 28 U.S. airlines from 1991 to 2008, find no statistically significant relationship between an airline's financial condition and its safety performance. In summary, the empirical evidence on whether an airline's financial health has an impact on its safety record is mixed, leaving the important regulatory and policy questions that flow from this relationship unanswered.

3. Data

This study provides empirical evidence drawn from both North American and international sources. The sample consists of 110 airlines from 26 countries that were operating during the period from 1990 to 2009.[7] Due to the entry and exit of several air carriers during that timeframe, as well as instances of missing data, the dataset is not fully balanced.[8] If an airline

[7] We terminate our sampling in 2009 to allow the aviation authorities in each country (such as the National Transportation Safety Board (NTSB) in the U.S.) to have completed their analysis and reporting of each accident. As an added benefit, the 2009 end-date avoids the undue influence of the recent financial crisis and subsequent recovery on our financial profitability measures.

[8] The authors are delighted to provide, on request, a list of the airlines included in the dataset together with their operating periods and all major accidents.

was never involved in an accident but otherwise had all available data for this study, it is reflected in the sample with an accident frequency of zero.

While the sample selection is driven by the usual data availability limitations, our study covers airlines from a variety of geographic locations, with distinct variations in economic strength and demographic characteristics. The 26 countries in the sample are drawn from the developed, the developing, and the least developed parts of the world. Specifically, these countries include: Argentina, Austria, Brazil, Canada, Chile, Colombia, Ecuador, France, Germany, India, Italy, Japan, Kenya, Malaysia, Mexico, the Netherlands, Pakistan, Portugal, Singapore, South Korea, Spain, Switzerland, Thailand, Turkey, the U.K., and the U.S. Hence the sample provides data on a broad cross-section of the global aviation industry.

The data on global aviation disasters were obtained from the National Transportation Safety Board (NTSB) and two online databases: aviation-safety.net[9] and planecrashinfo.com. To ensure the accuracy and reliability of these databases, we compare the details of every overlapping record among the databases. In addition, we cross-referenced the data to airline accident reports listed on Wikipedia. No inconsistencies or spurious data entries were found during these cross-checks.

As Rose (1989) points out, the use of airline accident rates as a proxy for safety is particularly appropriate for studies whose purpose is to investigate air carrier safety as opposed to air system safety. This is because most accidents (defined as events involving fatalities, serious injuries, or substantial aircraft damage[10]) are due to air carrier deficiencies such as pilot error, inadequate training or aircraft maintenance problems, whereas most general aviation

[9] See the Aviation Safety Network database at https://aviation-safety.net/database/databases.php.

[10] The NTSB defines an accident as "an occurrence associated with the operation of an aircraft that takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage" (see http://www.ntsb.gov/Pages/Report.aspx).

incidents are due to air traffic control faults or unusual natural events. Hence, in order to focus on air carrier characteristics, and to allow for a comparison of the results to prior studies, our analysis is restricted to aviation accidents rather than incidents. Furthermore, we eliminate accidents caused by illegal acts (e.g., hijacking, sabotage, shoot-downs) and wildlife hits, as those accidents do not reflect poor safety practices by the airline. Also excluded are flights that carry fewer than 18 passengers. These criteria help us focus on the causation of major failures in airline safety. Table 2 outlines the distribution of aviation accidents among the sample countries.

*** Insert Table 2 about here ***

To evaluate the financial status of our sample airlines prior to any accident, we use data on air carrier finances from the International Civil Aviation Organization (ICAO) as recorded in its database module "M3: Air Carrier Finances". In line with Flouris and Walker (2005), we consider information on each airline's current assets, current liabilities, sales, total assets, total liabilities, flight equipment maintenance and overhaul expenses, net income, and stockholder's equity in our analysis.

4. Methodology

Raghavan and Rhoades (2005) use OLS regressions to examine the link between the financial performance of airlines and accident rates post-deregulation and find a significant inverse relationship between profitability and air carrier safety, but only for small regional carriers. This study follows their approach and expects to find a strong relationship between an airline's financial condition and its accident rate. This study aims to examine whether airlines experiencing financial difficulties have poorer safety performance than airlines in a stronger financial position. Specifically, the research hypotheses are: (1) Better financial health of an airline improves the airline's safety performance after controlling for other relevant factors. (2) Airlines in countries with less robust legal regulation, poorer law enforcement, and inferior economic performance are likely to have poorer safety performance.

One of the difficulties in studying airline accident rates is the problem of accurately quantifying safety performance per unit of exposure to risk (e.g., in terms of passenger kilometers or seat kilometers flown, or the number of takeoffs and landings). To overcome the lack of such airline capacity data for most international (non-US) airlines, we introduce a novel proxy measure which differs from those used in prior studies of airline safety performance. For instance, Dionne et al. (1997) measure accident rates relative to the number of hours flown for Canadian airlines while Madsen (2013) employs the number of takeoffs and the average number of miles flown per departure by US airlines as a base variable in their accident rate calculations. Unfortunately, due to data limitations, these and similar utilization variables (e.g., the number of flights, the number of air miles (or hours) flown, or the number of take-offs/landings) are not available in an international context. We thus substitute the air carrier's operating revenue as a proxy measure of these variables. Since revenue is typically derived from the transport of passengers and baggage, it is reasonable to assume that, ceteris paribus, operating revenue reflects the extent of the airline's risk in terms of number of flights or distance flown.

Therefore, we measure an airline's accident rate by dividing the number of accidents it experiences during a given time-frame by its operating revenues during that period.

In this paper, we select a four-year time span because this medium-to-long term observation window could reasonably encompass economic activities associated with an airline disaster and subsequent recovery. In addition, to ensure the comparability of our results with studies that use one-year time frames in their analysis and to enhance the robustness of our findings, we perform a series of additional tests over shorter observation windows.

Four categories of financial ratios that are frequently used in the literature to evaluate a firm's performance and financial health are considered in our estimations: (1) The *current ratio*, a liquidity proxy. The current ratio is a balance sheet ratio that is traditionally used in finance to measure the ability of a firm to pay off its short-term debt obligations using its short-term assets. It provides information about the efficiency of a firm's operating cycle as well as the possibility of a firm running into liquidity problems. It is generally considered an indicator of bad financial health when the current ratio is low. (2) The *debt ratio*, a measure of financial leverage. The debt ratio is an extensively used financial ratio that reflects the firm's ability to pay off its debt in the long run. The ratio represents the proportion of assets that are financed by debt and helps investors and creditors evaluate the debt burden of a company and its risk of insolvency. The higher the ratio, the more leveraged the firm. (3) *Total asset turnover*, an activity ratio. Total asset turnover is an important index that measures how efficiently and effectively a firm uses its assets. The higher the total asset turnover ratio, the greater the productivity of the firm's assets, either due to more efficient operations or increased sales demand. The fourth category includes a number of *profitability ratios*, which aim to capture an airline's current and expected future profitability. (4a) The *net profit margin* measures the percentage of revenue available to shareholders after all operating expenses, interest, and taxes have been paid. As such, a firm's net profit margin reflects whether a company is good at converting revenue into profit available to shareholders. (4b) *Return on assets* (*ROA*) measures overall earning power or profitability expressed as the percentage of profit that a company earns in relation to its overall resources. This gives an indication of how efficient a business is in using its assets to generate net income.

(4c) *Return on equity* (*ROE*) measures how much profit a company earns in relation to the total amount of shareholder equity on its balance sheet. Firms with a higher ratio are better at pursuing shareholder wealth maximization.

We define an additional control variable, i.e., the *maintenance ratio*, to control for the effect of direct maintenance expenditures on safety. The maintenance ratio is defined as an airline's expenditure on flight equipment maintenance and overhaul divided by its total revenue. We use this variable to control for the overall attempt of an airline to update and maintain its air fleet, thereby keeping it secure and safe.

Because airline operations are influenced by the regulatory and macro-economic environment in a given country, we further consider a series of country-level variables that measure, among other things, the country's economic strength, the robustness of the regulatory/legal framework in the country, and whether the country is politically stable. We argue that the accident propensity of airlines is higher in countries with greater political instability, due to a lack of consistent regulatory policies.

The particular country variables employed to measure the economic, legal, and political attributes of each country are: (1) the *gross domestic product* (*GDP*) *per capita* which is an indicator of the country's economic well-being and economic growth; (2) *registered carrier departures* (*Departures*) which capture the number of domestic and international takeoffs of air carriers registered in the country and reflect air transportation usage in the country. We argue that the more developed the air transport sector in a given country, the stronger the regulatory oversight of the aviation sector; and (3) a country's *unemployment rate* which is widely recognized as a key indicator of the country's economic well-being. In addition, we follow La

Porta et al. (1998) and consider (4) the *efficiency of the judicial system*[11], (5) the *rule of law*[12], and (6) the level of *corruption*[13] to assess differences in the institutional environment across countries. These six measures are scored from zero to ten, with lower scores representing a lower quality institutional environment. Furthermore, we employ (7) a *common law dummy* to identify whether the legal system of a given country originates from English common law. The variable equals one if the origin is English common law and zero otherwise. There is a vast literature which shows that common law countries have more effective institutions and policies than countries with legal systems that originate from civil law. For example, common law countries grant more freedom to the entry of new businesses (Djankov et al., 2002) and provide better quality of contract enforcement and stronger protection of private property (Djankov et al., 2003). They are also associated with more highly developed financial systems (La Porta et al., 1997; Djankov et al., 2008) and less corruption (Treisman, 2000).

As explained above, our dependent variable in the main model is a novel proxy for airline safety performance, defined as the number of accidents during a four year period divided by the operating revenue of the airline. This is based on the rationale that, in the absence of available data concerning the number of flights or air miles flown, the airline's operating revenue can be used as a proxy for its capacity. We are unaware of any studies that employ this or similar accident propensity measures in an international context. Previous research has generally used

[11] Using data from the country risk rating agency Business International Corp., La Porta et al. (1998) assess the efficiency and integrity of the legal environment as it affects business, particularly for foreign firms.
[12] Using data provided in the International Country Risk (ICR) guide, La Porta et al. (1998) assess the law and order tradition in a given country. Their rule of law varaible ranges from zero to 10, with lower scores for less tradition for law and order.
[13] Again using the International Country Risk (ICR) guide, La Porta et al. (1998) assess the corruption in government. Lower scores indicate that high government officials are likely to demand special payments and that illegal payments are generally expected throughout lower levels of government in the form of bribes connected with import and export licenses, exchange controls, tax assessment, policy protection, or loans.

capacity-based accident rates rather than passenger- or cost-based measures of accidents, but direct capacity measures are not available for many non-U.S. and non-European airlines.

In the robustness section, we repeat our analyses using the (unadjusted) number of accidents as the dependent variable. In any given time frame this may be zero or a positive number. Due to the non-normality of the accident distribution, we employ a Poisson probability model which suits the stochastic specification of airline accidents. A further advantage of this estimation technique is that it captures the irregular and discrete nature of accidents and has been widely used to model accident probabilities. In these additional analyses, we utilize a time frame of one year for each airline in our sample, instead of the four year span used in the accident ratio measure of the airline's safety performance.

To summarize, our empirical analysis employs a series of ordinary least squares and Poisson regressions designed to assess the impact of an airline's financial condition and a country's macro-economic and institutional environment on accident risk. Table 3 provides a description of the operational measurement of each of our explanatory variables.

*** Insert Table 3 about here ***

We estimate the ordinary least squares (OLS) and Poisson regression models as follows:

$$\frac{N(Accidents)}{OperatingRevenue} = \beta_0 + \beta_1 Liquidity + \beta_2 Leverage + \beta_3 Activity + \beta_4 Profitability + \beta_5 ln(GDPperCapita) + \beta_6 ln(Departures) + \beta_7 Unemployment + \beta_8 LegalVariables + \varepsilon$$

$$\log(N(Accidents)) = \beta_0 + \beta_1 Liquidity + \beta_2 Leverage + \beta_3 Activity + \beta_4 Profitability + \beta_5 MaintenanceRatio + \beta_6 ln(GDPperCapita) + \beta_7 ln(Departures) + \beta_8 Unemployment + \beta_9 LegalVariables + \varepsilon$$

The main focus is on the first four variables in the OLS regression (and the first five in the Poisson regression), which represent the financial condition of an airline. The dependent variable is the airline's accident rate (number of accidents in the Poisson regression) as a proxy for safety performance.

In addition to the firm-level variables used to investigate an airline's financial condition, the models include the seven country-level variables described above. Due to their high correlation with each other (see Section 5), the GDP per capita, the number of country-wide registered departures, and the unemployment rate are each included in a separate model specification. The remaining four variables relating to the institutional environment (the efficiency of the judicial system, the rule of law, the corruption index, and the common law dummy) exhibit low inter-correlations, and are included both jointly and separately (i.e., in different model specifications) so as to observe their individual and combined effects (see Section 5). In our regression specification, we denote these four variables as a single variable labeled "LegalVariables" for expositional brevity. Similarly, a firm's profitability ratios are grouped under the variable groups "Profitability" in our regression specification.

5. Empirical results

The reasoning behind the first hypothesis is that financial factors influence an airline's maintenance, purchasing, and training policies and thereby its safety performance. To test this hypothesis, we examine whether the seven financial proxies used here can explain differences in airline safety performance after controlling for other relevant factors. Panel A of Table 4 provides descriptive statistics for the firm-specific variables used in this study. We note that the number of accidents recorded for the airlines in our study ranges from zero to five during the sample period. In Panel B, we perform a preliminary univariate analysis to explore whether airlines that experienced accidents during the sample period differ significantly in terms of their financial performance from those that did not. In line with our first hypothesis, we find that accident-free airlines have a significantly higher current ratio, total asset turnover, and ROE (although the latter difference is only marginally significant based on the mean ROE).

*** Insert Table 4 about here ***

The second hypothesis states that airlines in countries with less robust legal regulations, weaker law enforcement, and poorer economic performance have poorer safety performance. Table 5 lists all countries in the sample by GDP rank (2012) and shows the macroeconomic and institutional variables for each country.

*** Insert Table 5 about here ***

Before the regressions are estimated, we calculate the Pearson correlation coefficients between each variable pair (Table 6). We observe high correlations between a country's GDP, corruption index, and rule of law (with correlation coefficients >0.8). As noted above, to avoid multicollinearity problems in the subsequent regression models, those three variables are included in separate model specifications. In addition, we employ our profitability proxies (net profit margin, ROA, and ROE) in separate models to examine whether the results are sensitive to the use of different predictors.

*** Insert Table 6 about here ***

Table 7 reports the results for the OLS regression analyses. In all regressions, the dependent variable is an airline's accident rate (i.e., accident frequency divided by its operating revenue) during a four-year period. The first column shows the results of the basic model. We first focus on the interpretation of variables related to an airline's financial condition. As shown in Models 1 and 2 of Table 7 (Panel A), the estimated parameters for net profit margin and ROA are negative and significant, indicating that higher profitability is associated with a lower accident rate. If an airline's net profit margin or ROA increases by 10%, it leads to a decline of 19.26% or 16.15% respectively in its accident rate. The variables that measure an airline's liquidity, asset turnover, and financial leverage have negative but statistically non-significant coefficients. The results for ROE (another index of profitability) in Model 3 of Panel A are not statistically meaningful. This may be due to the major difference between ROE and ROA – debt. It could be argued that for the airline industry whose capital demand is greater than that of other industries, the ROA of a company is likely to be a more meaningful measure of financial performance than ROE. With respect to the macroeconomic environment, we find the natural log of GDP per capita to be significantly negatively related to accident rates. Specifically, the coefficient of Ln(GDP per Capita) in the base model is -0.3055 with a p-value of 0.0001, indicating that airlines in countries with higher GDP per capita have better safety performance. One possible explanation for this result is that developed or industrialized countries have stricter safety regulations; hence airports and air traffic control personnel have to achieve higher safety standards.

Next, we estimate different variations of our base model to control for multicollinearity between highly correlated variables and to examine how each country variable affects aviation safety when viewed alone. The results are presented in Table 7, Panel B. Model 10 of Panel B reports a regression with Ln(GDP per Capita) as the only country-level explanatory variable. The results again indicate that countries with higher GDP per capita perform significantly better in terms of safety performance than countries with lower GDP per capita. Model 11 of Panel B shows that if Ln(Departures) is the only country-level explanatory variable entered into the model, it has a significant negative impact; i.e., the greater the number of domestic and international takeoffs by air carriers within a country, the lower the accident rates of its airlines. A common-sense interpretation for this finding is that higher air transportation usage within a country is associated with greater concern about aviation infrastructure including, for instance, the country's air traffic control systems and its aviation safety systems. Panel B, Models 12-16 replicate Models 10 and 11 by adding a single country-level variable at a time. The coefficients for the three variables related to the legal environment (the efficiency of the judicial system, the rule of law, and corruption) are negative and highly significant. These findings support the second hypothesis that airlines in countries with less robust legal regulations, worse law enforcement, and poorer economic performance are likely to have poorer safety performance. The unemployment rate of a country has almost no influence on an airline's safety performance, with a coefficient that is roughly zero. Similarly, the common law dummy has no significant effect in the last model.

*** Insert Table 7 about here ***

In order to avoid any distorting effects that extreme values may have on the results, we perform a robustness test in which we winsorize the six firm-level financial variables at the 5th and 95th percentile. The outcomes (untabulated[14]) are little affected by this winsorization except for ROE, which becomes marginally significant at the 10% level. Overall, the results continue to suggest that higher profitability for an airline is associated with a decrease in its accident rate. The results also contribute to the evidence that airline accidents display endemicity; that is,

[14] The results are available from the authors upon request.

airlines in countries with weaker legal systems and economic performance tend to have poorer safety performance.

Next, we carry out an alternative test to investigate the nature of the relationship between a firm's financial performance and its safety performance. This robustness test employs a commonly used measure of a firm's financial health, Altman's Z-score (Altman (1968, 2001)). The higher this score, the lower the probability of business failure for a company. The Z-score measure has been commonly used in the academic literature to evaluate an airline's financial condition (e.g., Vasigh et al., 2010; Wang et al., 2013). In keeping with our main hypothesis, we expected that financial distress will reduce an airline's willingness and ability to invest in maintenance, purchasing, and training and thereby harm its safety performance. Thus, we expect to find an inverse relationship between Altman's Z-score and an airline's accident rate. The untabulated results of the analysis show that the Z-score coefficients have negative signs, as expected, in all models. However, the results are insignificant. At the same time, significant results are confirmed for the relationship between an airline's accident rate and Ln(GDP per Capita), the efficiency of the judicial system, the rule of law, and corruption – with p-values of 0.0043, 0.0469, 0.0131, and 0.0056, respectively.[15]

In summary, although there is no uniform effect of all financial performance indicators on safety performance, this study shows that an airline's profitability has a significant negative association with its accident rate. Moreover, as noted above, the legal and economic environment of a given country also has a significant effect on airline safety.

[15] The results are available from the authors upon request.

6. Robustness checks

To ensure that our results are not driven by our choice of estimation method (i.e., the OLS framework used in our main analysis) or our choice of variable definitions, we employ a series of robustness checks. Specifically, we estimate a series of Poisson regressions in which the dependent variable is the number of accidents during a one-year (rather than a four-year) period and an airline's maintenance ratio is added as an additional explanatory variable. Our results are presented in Table 8. We first focus on the interpretation of variables related to an airline's financial condition. Again, the first column of Panel A shows the results for the base model and indicates that the maintenance ratio has a negative, significant ($p<0.05$) coefficient; increasing the maintenance expenditure ratio by one unit causes a decrease in the log of the number of accidents by 1.007 units. Thus, it seems likely that airlines have fewer accidents when they spend more on flight equipment maintenance and overhaul expenses. Whilst the net profit margin variable is not significant, it retains the negative sign observed in the OLS regression model. In the next two models, we replicate the analysis, replacing the net profit margin with ROA and ROE, respectively. As with the net profit margin, the sign of the coefficient is negative for both measures, albeit not significant. Furthermore, the coefficient of the maintenance ratio stays negative and significant for Models 2 and 3.

In Models 4 through 8, we re-run the test considering only one of the financial ratio variables at a time so as to measure their separate effects. In Model 4, we retain the maintenance ratio, operating revenue (in $ millions) and total asset turnover while removing the other profitability variables. The coefficient of the total asset turnover remains negative and significant at the 1% level suggesting that more efficient airlines have fewer accidents. In Model 5, we replace the total asset turnover with the current ratio and observe the same sign as in the base model (negative), although the variable loses its significance. In Model 6, we add the debt ratio and drop the current ratio. The coefficient of the debt ratio is negative and significant at the 5% level. This constitutes a change from the OLS regression where, although the coefficient of the debt ratio was negative, it did not reach statistical significance. The previous literature on product quality and airline safety (Maksimovic and Titman, 1991; Dionne et al., 1997) suggests that highly leveraged airlines are more prone to sacrifice quality than less-leveraged airlines. In contrast, we find that highly leveraged airlines have fewer accidents. One possible reason for this result is that the respective airlines spend more on maintenance and fleet updates. These airlines may update their fleets to survive in the industry even at the expense of more debt. Similarly, Phillips and Sertsios (2013) report that although product quality decreases as airlines face financial distress, product quality increases if these distressed airlines enter bankruptcy protection and begin reconstruction.

In Model 7, we only retain the maintenance ratio and operating revenue. This has no effect on their sign and their levels of significance remain unchanged. Finally, in the last model, we only retain the maintenance ratio. The magnitude of the coefficient then increases from about 1.2 to 1.8, while it retains its negative sign and 1% significance level.

The coefficient of the operating revenue is positive and highly significant throughout Models 1 to 7. A common-sense interpretation of this finding is that the more flights an airline undertakes in a year, the greater the number of accidents.

*** Insert Table 8 about here ***

With regard to the macroeconomic variables, shown in Panel B, in the first model we find the coefficient for Ln(GDP per Capita) to be negatively associated with the number of accidents (coefficient of -0.453 with a p-value of 0.0001). This indicates that airlines in countries with higher GDP per capita have better safety performance. Next, we estimate three models designed to control for any multicollinearity between the institutional environment variables by examining how each of these country-level variables affects aviation safety when viewed alone. The results are provided in Models 9 to 11 of Panel B. As mentioned above (see Section 4), these measures are scored from zero to ten, with lower scores representing a lower quality institutional environment. The results show that all three variables have negative and highly significant coefficients. This confirms our hypothesis that airlines in countries with less robust regulatory systems, poorer law enforcement, and greater levels of corruption are likely to have poorer safety performance. In Models 12 to 15, we re-run the base model, again with one macroeconomic variable at a time. The results demonstrate a negative coefficient for the unemployment rate and for Ln(Departures), although these results are not significant. In Model 13, the results again indicate that countries with a higher GDP per capita have significantly better safety performance than countries with a lower GDP per capita.

In order to avoid any distorting effects that extreme values may have on the results, we perform a robustness test in which we winsorize the seven firm-level financial variables at the 5th and 95th percentile. The results, summarized in Table 9, are little affected by the winsorization except for the following findings. Firstly, ROE and ROA become significant at the 10% level. Secondly, the net profit margin changes its sign compared to the non-winsorized analysis in Table 8. This could be due to the fact that net profit margin is affected by total asset turnover and/or ROA in accordance with the following equation:

Net Profit Margin = ROA* Total Asset Turnover

*** Insert Table 9 about here ***

The coefficient of the winsorized maintenance ratio is relatively unaffected compared to the results from the regular Poisson regressions provided in Table 8. The winsorized variables in the base model (Model 1) show that airlines with higher profits in terms of ROA and greater spending on maintenance and overhaul activities experience fewer accidents.

7. Conclusions

The purpose of this study is to examine whether financially distressed airlines exhibit poorer safety performance. The study regresses the accident frequency of our sample's airlines, adjusted for operating revenues, on six firm-level financial variables and seven country-level variables during the period 1990 to 2009. Overall, we find a negative relationship between an airline's profitability and its accident rate.

In a series of robustness tests, we employ Poisson regressions instead of OLS regressions to assess whether the use of OLS regressions with ratio-based dependent variables generates any incorrect inferences. We also add the maintenance ratio to control for an airline's efforts to update its air fleet and train its pilots, as this variable should affect its safety performance. In almost all models, the results from the robustness tests are consistent with the main regressions. Airlines that have low profitability have a higher risk profile. This is consistent with the common-sense notion that an unprofitable or insolvent airline may reduce its safety investments by flying older airplanes (i.e., not upgrading its fleet) or by saving on pilot training and aircraft maintenance. Accordingly, airlines with higher profit aspirations are more likely to be concerned about securing their customers' confidence and thus may pay more attention to security improvements and accident avoidance.

This study further examines whether a country's macroeconomic and institutional environment affects the safety of airlines which are headquartered in that country. As expected, the results suggest that airlines based in countries with stronger law enforcement, more stringent legal regulations, and better economic performance have better safety performance. These findings remain consistent regardless of whether we use financial ratios or Altman's Z-score to measure financial performance; they are also invariant to the type of regression – i.e., whether an OLS or Poisson regression is employed.

The unique contributions of the study are (1) that it is the first to explore the drivers of safety performance on a global basis and (2) that it intodoces a novel index of capacity when computing accident rates. The research question is addressed using extensive data from 110 airlines in 26 countries and by examining the relationship between airlines' financial performance and safety in a cross-country context.

The results of this study have important policy implications for both the airline industry and regulators. To allocate resources more efficiently, regulators may find it beneficial to focus their supervision on financially weak airlines. Moreover, as noted earlier, pilot errors remain the most frequent cause of aviation accidents. Thus, developing and refining policies that reduce accidents caused by pilot errors should be a prime goal for regulators. Various approaches come to mind to address this problem, such as reducing working hours or adding more shifts in order to avoid pilots being too stressed or too tired, improving the working conditions for pilots, and enhancing the supervision of the cockpit during cruising (see, e.g., Gittell et al., 2004, who conclude that firm-level wage variations (as a proxy for the experience of flight personnel) are associated with firm-level variations in service quality, productivity, and profits). Given the association between poor financial performance and accident rates observed in this study, it is reasonable to conclude that pilots of financially weak airlines are more likely to experience the aforementioned problems (inadequate training, unfavorable working conditions, unreasonable flight schedules, etc.). In addition, it is possible that airlines in financial distress have lower hiring standards, such as requiring fewer hours of flight experience. The strategies employed by regulators should therefore take account of the greater risks attached to airlines that are in a weak financial state, particularly insofar as these may affect the selection, training and management of pilots.

8. Limitations

This study does not come without limitations. Most importantly, it is constrained by the unavailability of certain types of data and by the methodology adopted. In particular, more reliable measurement of each airline's safety performance would have required detailed flight data such as takeoffs, landings, and passenger miles flown; these are not available for the complete sample of airlines included in this study. There is, in effect, a tradeoff between the reliability of the accident measures and the generalizability of the results across a global sample of airlines. Also, additional control variables that capture, for example, the landing and takeoff risks at different airports around the world[16] would be helpful in improving the explanatory power of the model.

[16] Hong Kong (China) and Lima (Peru), for example, were/are known as difficult airports for landings/take-offs; thus airlines in these countries may be exposed to higher risk (regardless of their financial condition). Hong Kong addressed the problem by building a new state-of-the-art airport at Chek Lap Kok that commenced operations in 1998.

Furthermore, future studies could control for cultural differences between countries in relation to their attitudes to risk. For example, Hofstede's "uncertainty dimension"[17] which provides a means of assessing cross-national differences in uncertainty avoidance and risk taking (Hofstede, 2001; Hofstede et al., 2010) might be used to improve global predictions of safety performance. A further limitation of the present study is that it does not distinguish between airlines that entered (or did not enter) into bankruptcy protection. Phillips and Sertsios (2013) report that although safety decreases as airlines face financial distress, it increases if these distressed airlines enter bankruptcy protection. We were not able to identify all bankruptcy filings for our sample firms; further, bankruptcy laws differ from country to country, making a cross-country comparison difficult. In future studies, and assuming the data are available, a firm's bankruptcy protection status could be incorporated as a binary control variable. Alternatively, one could consider bankruptcy protection as a "treatment" and then examine its effectiveness using a difference-in-difference design.

Despite these limitations, the present study has taken an important step towards a better understanding of the relationship between an airline's financial condition and its safety performance. Exploring other data sources that contain detailed flight data would perhaps be the most effective means of enhancing the explanatory power of our model.

[17] Hofstede examines how cultures differ between countries based on six cultural dimensions. Those dimensions are: power distance, individualism versus collectivism, masculinity versus femininity, uncertainty avoidance, long-term versus short-term orientation, and indulgence versus restraint (cf., Hofstede, 2001 and Hofstede et al., 2010).

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Table 1: Causes of fatal accidents per decade

This table provides information on the causes of fatal accidents that occurred worldwide from January 1950 to December 2009 based on information provided by PlaneCrashInfo.com. Aircraft with 18 or fewer passengers aboard, military aircraft, private aircraft, and helicopters are excluded. "Pilot error (in connection with bad weather)" represents accidents in which pilots made errors during flights in bad weather conditions. "Pilot error (mishandling of equipment)" represents accidents in which pilot errors occurred in connection with some type of mechanical failure. "Other human error" relates to accidents caused by several types of human factors, consisting of errors made by air traffic controllers, incorrect loading of aircraft, fuel contamination, and inappropriate performance of maintenance. “Weather related” refers to accidents that occurred due to severe weather conditions such as thunderstorms, lighting, fog, icing, and turbulence. “Mechanical failure” refers to accidents that occurred due to mechanical system failure or flaws in the plane’s design. “Criminal activities” includes crashes caused by explosive devices, shoot downs, and hijackings. “Wildlife strike” relates to accidents caused by wild animals such as birds, bats, and ground animals. For accidents with multiple causes, the most prominent cause is used.

Cause	1950s	1960s	1970s	1980s	1990s	2000s	Average
Pilot Error	42%	34%	25%	29%	29%	34%	31%
Pilot Error (In Connection with Bad Weather)	10%	17%	14%	16%	21%	18%	16%
Pilot Error (Mishandling of Equipment)	6%	8%	5%	2%	5%	5%	6%
Total Pilot Error	58%	59%	44%	47%	55%	57%	53%
Other Human Error	3%	8%	9%	5%	8%	6%	6%
Weather-Related	16%	8%	14%	14%	8%	6%	13%
Mechanical Failure	21%	18%	20%	21%	18%	22%	20%
Criminal Activities	3%	5%	11%	12%	10%	9%	8%
Wildlife Strike	0%	2%	2%	1%	1%	0%	1%

Table 2: Distribution of aviation accidents among sample countries

This table shows the distribution of aviation accidents among our sample countries and provides the following statistics for each country: population, GDP, and the number of air passengers carried. The data are retrieved from the World Bank database, which defines a country's population as all residents of that country, regardless of legal status or citizenship (based on midyear 2017 estimates). GDP is measured as the total gross value added by all resident producers plus taxes and minus subsidies not included in the product's value. All GDP data are measured in current U.S. dollars. *Passengers carried* is calculated as the sum of all domestic and international aircraft passengers of airlines registered in the country. Data for the first year of the sample (1990), the last year of the sample (2009), and the annual average for the full 1990-2009 sample period are reported. Source: World Bank Database

		Average 1990-2009				*1990*			*2009*		
Country	*Accidents*	*Passengers carried (million)*	*GDP ($ billion)*	*GDP growth (%)*	*Population (million)*	*Passengers carried (million)*	*GDP ($ billion)*	*Population (million)*	*Passengers carried (million)*	*GDP ($ billion)*	*Population (million)*
Argentina	1	6.6	234.4	3.8	36.5	5.4	141.4	32.6	5.7	307.2	40.0
Austria	2	6.0	248.3	2.2	8.0	2.5	164.8	7.7	8.5	383.7	8.4
Brazil	16	31.6	784.3	2.5	172.7	19.1	462.0	149.6	67.9	1,620.2	193.5
Canada	4	31.9	835.9	2.3	30.7	20.6	582.7	27.8	52.6	1,337.6	33.7
Chile	1	4.7	90.1	5.1	15.3	1.4	31.6	13.2	8.1	172.0	17.0
Colombia	7	8.9	112.6	3.5	39.6	5.3	40.3	33.3	12.1	234.4	45.8
Ecuador	7	1.8	30.7	3.1	12.4	0.8	15.2	10.1	2.9	62.5	14.8
France	11	46.5	1,720.5	1.6	61.2	36.0	1,244.2	58.4	58.3	2,619.7	64.7
Germany	2	60.0	2,400.4	1.5	81.8	22.1	1,714.5	79.4	103.4	3,298.2	81.9
India	16	22.5	602.2	6.3	1,032.4	10.9	326.6	868.9	54.4	1,365.4	1,190.1
Italy	10	28.8	1,431.7	1.0	57.6	19.8	1,138.1	56.7	33.2	2,111.1	60.2
Japan	5	95.6	4,373.5	1.0	126.4	76.2	3,103.7	123.5	86.9	5,035.1	127.6
Kenya	2	1.5	14.9	2.9	31.2	0.8	8.6	23.4	2.9	30.6	39.8
Malaysia	5	16.4	109.5	6.0	23.1	10.2	44.0	18.2	23.8	202.3	27.8
Mexico	6	18.3	643.1	2.7	102.2	14.3	262.7	86.1	15.7	895.4	116.4
Netherlands	2	19.8	489.4	2.4	15.8	8.6	294.9	15.0	29.1	796.3	16.5
Pakistan	7	5.4	84.3	4.2	141.1	5.2	40.0	111.1	5.3	168.2	170.1
Portugal	1	6.9	144.8	1.9	10.3	3.5	77.7	10.0	9.9	234.1	10.6
Singapore	2	14.3	100.2	6.2	3.9	7.0	36.1	3.0	18.4	194.1	5.0
South Korea	6	30.0	583.0	5.3	46.4	15.7	263.8	42.9	34.2	834.1	49.2
Spain	13	36.9	819.5	2.6	41.2	21.7	521.0	38.9	49.3	1,454.3	45.9
Switzerland	3	11.8	326.2	1.5	7.2	8.6	244.0	6.7	14.7	509.5	7.7
Thailand	2	15.4	156.8	4.7	61.9	8.2	85.3	56.6	19.6	263.7	66.3
Turkey	6	12.3	311.4	3.9	62.7	4.3	150.7	54.0	31.3	614.6	71.2
UK	8	71.7	1,666.2	2.3	59.1	47.1	1,019.3	57.2	102.5	2,208.0	61.8
US	70	600.5	10,113.2	2.5	279.5	464.6	5,979.6	249.6	679.4	14,417.9	306.8

Table 3: Overview of explanatory variables

This table provides an overview of the explanatory variables used in the subsequent analysis. Panel A provides definitions for the firm-level explanatory variables. Panel B provides sources and descriptions for the country-level explanatory variables.

Variable	Source	Description
Panel A: Firm-level Explanatory Variables		
Operating Revenue ($million)	ICAO database	The air carrier's operating revenue, which is typically derived from the transport of passengers and baggage.
Maintenance Ratio	ICAO database	Maintenance Ratio = Flight Equipment Maintenance and Overhaul Expense/Total Revenue
Current Ratio	ICAO database	Current Ratio = Current Assets/Current Liabilities
Total Asset Turnover	ICAO database	Total Asset Turnover = Sales/Total Assets
Debt Ratio	ICAO database	Debt Ratio = Total Liabilities/Total Assets
Net Profit Margin	ICAO database	Net Profit Margin = Net Income/Sales
ROA	ICAO database	The return on assets, ROA = Net Income/Total Assets
ROE	ICAO database	The return on equity, ROE = Net Income/Stockholders' Equity
Panel B: Country-level Explanatory Variables		
Ln(GDP per Capita)	World Bank database	Natural log of GDP per capita
Ln(Departures)	World Bank database	Natural log of the number of domestic and international takeoffs of air carriers registered in the country
Unemployment	World Bank database	Unemployment rate (in %)
Efficiency of the Judicial System	La Porta et al. (1998)	Assessment of the efficiency and integrity of the legal environment as it affects business. Scale from zero to ten, with lower scores representing lower efficiency levels (La Porta et al., 1998)
Rule of Law	La Porta et al. (1998)	Assessment of the law and order tradition in the country. Scale from zero to ten, with lower scores for a weaker tradition of law and order (La Porta et al., 1998)
Corruption	La Porta et al. (1998)	Assessment of the corruption in government. Lower scores indicate that high government officials are likely to demand special payments and illegal payments are generally expected throughout lower levels of government. Scale from zero to ten, with lower scores for higher levels of corruption (La Porta et al., 1998)
Common Law Dummy	Reynolds and Flores (1989)	Identifies whether the legal system of a given country originates from English common law (dummy variable: 1=yes, 0=no)

Table 4: Descriptive statistics

The sample for this study consists of 110 airlines from 26 countries during the period 1990 to 2009. Due to the entry and exit of several air carriers during that timeframe and due to missing data, the data set is unbalanced. A four-year time span is considered as the observation window, i.e., each airline's data are merged every four years. Thus, the final sample consists of 252 country four-year observations. An airline's safety performance is proxied by using the number of accidents of an airline during a four year period divided by the operating revenues of the airline over that four year period. Panel A provides sample summary statistics for the measures of safety performance and financial performance. This study distinguishes between airlines with and without accidents during a four year period (Panel B). For each subsample, the number of observations, as well as the mean and median for each firm-level financial variable are reported. T-tests and Mann-Whitney tests are employed to test for the equality of means and medians between each subsample. The last column reports p-values for both tests. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Descriptive statistics

Panel A. All airlines

Variable	Obs.	Mean	Median	Std.dev.	Min.	Max.
Accident Rate (per 4 years)	252	0.5198	0.0000	0.8947	0.0000	5.0000
Accident Frequency (per 4 years)	252	0.3641	0.0000	0.9644	0.0000	8.7648
Current Ratio	252	0.9512	0.8517	0.4706	0.2059	3.7177
Total Asset Turnover	252	1.2850	1.0846	0.7371	0.3038	4.1774
Debt Ratio	252	0.8823	0.8312	0.3113	0.3796	3.6260
Net Profit Margin	252	-0.0166	-0.0003	0.0847	-0.4531	0.2405
ROA	252	-0.0229	0.0012	0.1091	-0.6316	0.2382
ROE	252	0.0841	0.0855	1.0977	-8.3094	6.1399

Panel B. Subsample Equality Tests

Variable	Subsample 1 Airlines with accidents (N=87) Mean, Median	Subsample 2 Airlines without accidents (N=165) Mean, Median	Tests of differences: Means (p-value) Medians (p-value)
Current Ratio	0.8604	0.9991	0.0258**
	0.7830	0.8905	0.0354**
Total Asset Turnover	1.0808	1.3927	0.0013***
	0.9564	1.2065	0.0073***
Debt Ratio	0.8796	0.8837	0.9204
	0.8473	0.8294	0.5480
Net Profit Margin	-0.0221	-0.0137	0.4533
	-0.0056	0.0042	0.2782
ROA	-0.0297	-0.0192	0.4685
	-0.0034	0.0052	0.2181
ROE	-0.0807	0.1710	0.0836*
	0.0543	0.0920	0.2195

Table 5: Country characteristics

This table lists all countries in the sample by GDP rank based on 2012 data and shows the country-level variables for each country. Variable definitions are provided in Table 3. Following La Porta et al. (1998), this study considers the efficiency of the judicial system, the rule of law, and corruption to characterize the different institutional environments across countries. These measures are scored from zero to ten, with lower scores representing a lower quality institutional environment of a country. In addition, we employ a common law dummy to identify whether the legal system of a given country originates from English common law. This variable equals one if the origin is English common law and zero otherwise.

GDP Rank (based on 2012 rankings by the United Nations)	Country	Efficiency of the Judicial System	Rule of Law	Corruption	Common Law
1	USA	10	10	8.63	1
3	Japan	10	8.98	8.52	0
4	Germany	9	9.23	8.93	0
5	France	8	8.98	9.05	0
6	UK	10	8.57	9.1	1
7	Brazil	5.75	6.32	6.32	0
9	Italy	6.75	8.33	6.13	0
10	India	8	4.17	4.58	1
11	Canada	9.25	10	10	1
13	Spain	6.25	7.8	7.38	0
14	Mexico	6	5.35	4.77	0
15	South Korea	6	5.35	5.3	0
17	Turkey	4	5.18	5.18	0
18	Netherlands	10	10	10	0
20	Switzerland	10	10	10	0
26	Argentina	6	5.35	6.02	0
27	Austria	9.5	10	8.57	0
28	Thailand	3.25	6.25	5.18	1
32	Colombia	7.25	2.08	5	0
34	Malaysia	9	6.78	7.38	1
35	Singapore	10	8.57	8.22	1
36	Chile	7.25	7.02	5.3	0
43	Pakistan	5	3.03	2.98	1
44	Portugal	5.5	8.68	7.38	0
63	Ecuador	6.25	6.67	5.18	0
88	Kenya	5.75	5.42	4.82	1

Table 6: Correlation coefficients

This table reports Pearson correlation coefficients between each pair of variables. A high correlation between a country's GDP per capita, the corruption index, and the rule of law (with correlation coefficients >0.8) is observed. To avoid any multicollinearity problems in the subsequent regression models, those three variables are included separately.

	Current Ratio	Total Asset Turnover	Debt Ratio	Net Profit Margin	ROA	ROE	Ln(GDP per Capita)	Ln (Departures)	Unemploy-ment	Efficiency of the Judicial System	Corruption	Rule of Law	Common Law Dummy
Current Ratio	1.0000												
Total Asset Turnover	-0.0725	1.0000											
Debt Ratio	-0.2773	0.3600	1.0000										
Net Profit Margin	0.2592	-0.0548	-0.4004	1.0000									
ROA	0.3046	-0.2499	-0.6420	0.7908	1.0000								
ROE	-0.0339	0.0601	0.1230	0.1262	0.0327	1.0000							
Ln(GDP per Capita)	-0.0840	0.1083	-0.0753	0.1287	0.0665	0.1525	1.0000						
Ln(Departures)	-0.0702	0.1133	0.0456	0.0377	0.0053	0.1288	0.6386	1.0000					
Unemployment	-0.0713	0.1752	0.0663	-0.2021	-0.1164	-0.1055	-0.0560	-0.1807	1.0000				
Efficiency of the Judicial System	0.0766	0.0295	-0.1013	0.2042	0.1362	0.1109	0.6399	0.6617	-0.3229	1.0000			
Corruption	-0.0017	0.0850	-0.0434	0.1512	0.0836	0.1408	0.8681	0.5593	-0.0563	0.7836	1.0000		
Rule of Law	-0.0293	0.0360	-0.0365	0.1521	0.0830	0.1822	0.8852	0.6765	-0.1664	0.6970	0.8920	1.0000	
Common Law Dummy	0.0556	-0.0288	-0.0446	0.1969	0.1566	0.0562	0.1598	0.5527	-0.4262	0.6088	0.3361	0.3506	1.0000

Table 7: OLS regression results

This table provides regression results for models in which an airline's accident frequency divided by its operating revenue during a four-year period is regressed on six firm-level financial variables and seven country-level variables during the sample period from 1990 to 2009. As noted in Table 6, there is a high correlation between the GDP per capita, the corruption index, and the rule of law for our sample countries. Thus, only Ln(GDP per capita) is included in the base model. Panel A reports the regression results for a series of models that consider an airline's financial condition. Model 1 is the base model. Models 2 and 3 vary from the base model by using different profitability measures. Models 4 to 9 estimate each financial variable's impact on accident frequency while controlling for other relevant factors. Panel B reports the regression results related to the macroeconomic environment of a given country. Each country variable is included separately to observe its individual effect. The results are reported in Models 10 to 16. For each variable, the coefficient and the corresponding p-value (in parentheses) are reported. In the last three rows, we report the adjusted R^2, the p-value for an F-test, and the number of observations for each regression. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Panel A. Summary of Firm-Level Results (DV=Accident Rate)									
Variable	**Base model**	**Variations on base model**							
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**	**Model 9**
Constant	2.6373***	2.7726***	2.4505***	2.4675***	2.2432***	2.2809***	2.2461***	2.2589***	2.1564***
	(0.0000)	(0.0000)	(0.0001)	(0.0000)	(0.0000)	(0.0001)	(0.0000)	(0.0000)	(0.0001)
Current Ratio	-0.1169	-0.1175	-0.1662	-0.1503					
	(0.3747)	(0.3738)	(0.2054)	(0.2330)					
Total Asset Turnover	-0.0074	-0.0384	-0.0317		-0.0420				
	(0.9321)	(0.6560)	(0.7145)		(0.6038)				
Debt Ratio	-0.2785	-0.4199	-0.0541			-0.0505			
	(0.2133)	(0.1008)	(0.7997)			(0.7908)			
Net Profit Margin	-1.9262**						-1.7002**		
	(0.0151)						(0.0182)		
ROA		-1.6153**						-0.9427*	
		(0.0236)						(0.0841)	
ROE			-0.0745						-0.0762
			(0.1703)						(0.1553)
Ln(GDP per Capita)	-0.3055***	-0.3181***	-0.3205***	-0.3268***	-0.3157***	-0.3187***	-0.2901***	-0.3035***	-0.3077***
	(0.0001)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0002)	(0.0001)	(0.0001)
Ln(Departures)	0.0715	0.0828	0.0921*	0.0852	0.0934*	0.0933*	0.0647	0.0749	0.0936*
	(0.1921)	(0.1281)	(0.0924)	(0.1139)	(0.0842)	(0.0881)	(0.2335)	(0.1677)	(0.0814)
Efficiency of the Judicial System	0.0082	0.0035	0.0072	0.0089	-0.0026	-0.0034	0.0043	0.0011	-0.0040
	(0.8833)	(0.9504)	(0.8994)	(0.8745)	(0.9628)	(0.9522)	(0.9374)	(0.9842)	(0.9427)
Unemployment	0.0012	0.0061	0.0043	0.0054	0.0074	0.0060	0.0011	0.0047	0.0034
	(0.9472)	(0.7308)	(0.8131)	(0.7601)	(0.6792)	(0.7355)	(0.9484)	(0.7886)	(0.8489)
Common Law Dummy	-0.0763	-0.0816	-0.1479	-0.1394	-0.1371	-0.1383	-0.0661	-0.0872	-0.1392
	(0.6905)	(0.6706)	(0.4387)	(0.4641)	(0.4724)	(0.4695)	(0.7292)	(0.6493)	(0.4642)
Adjusted R^2	0.1122	0.1094	0.0973	0.0995	0.0953	0.0945	0.1147	0.1052	0.1017
F-test (p-value)	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
N	252	252	252	252	252	252	252	252	252

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Panel B. Summary of Country-Level Results (DV=Accident Rate)								
	Base model	**Variations on base model**						
Variable	**Model 1**	**Model 10**	**Model 11**	**Model 12**	**Model 13**	**Model 14**	**Model 15**	**Model 16**
Constant	2.6373***	2.9648***	1.5404***	1.3435***	1.5738***	1.7790***	0.5258*	0.5681**
	(0.0000)	(0.0000)	(0.0042)	(0.0005)	(0.0000)	(0.0000)	(0.0628)	(0.0348)
Current Ratio	-0.1169	-0.1130	-0.0455	-0.0173	-0.0639	-0.0491	-0.0241	-0.0244
	(0.3747)	(0.3831)	(0.7342)	(0.8966)	(0.6239)	(0.7050)	(0.8583)	(0.8564)
Total Asset	-0.0074	-0.0020	-0.0435	-0.0490	-0.0475	-0.0254	-0.0653	-0.0626
Turnover	(0.9321)	(0.9810)	(0.6199)	(0.5720)	(0.5751)	(0.7648)	(0.4658)	(0.4771)
Debt Ratio	-0.2785	-0.2518	-0.1344	-0.1624	-0.1418	-0.1648	-0.1357	-0.1371
	(0.2133)	(0.2546)	(0.5573)	(0.4758)	(0.5243)	(0.4581)	(0.5588)	(0.5534)
Net Profit	-1.9262**	-2.0227***	-2.3664***	-2.1018***	-1.9480**	-1.9788**	-2.4350***	-2.4318***
Margin	(0.0151)	(0.0079)	(0.0028)	(0.0082)	(0.0120)	(0.0104)	(0.0028)	(0.0028)
Ln(GDP per		-0.2381***						
Capita)	-0.3055***							
	(0.0001)	(0.0000)						
Ln(Departures)	0.0715		-0.0725**					
	(0.1921)		(0.0357)					
Efficiency of the	0.0082			-0.0917***				
Judicial System	(0.8833)			(0.0059)				
Rule of Law					-0.1206***			
					(0.0000)			
Corruption						-0.1575***		
						(0.0000)		
Unemployment	0.0012						0.0035	
	(0.9472)						(0.8351)	
Common Law	-0.0763							-0.0310
Dummy	(0.6905)							(0.8078)
Adjusted R^2	0.1122	0.1193	0.0430	0.0553	0.0958	0.1008	0.0258	0.0258
F-test (p-value)	0.0000	0.0000	0.0073	0.0019	0.0000	0.0000	0.0433	0.0430
N	252	252	252	252	252	252	252	252

Table 8: Poisson regression results

This table provides regression results for models in which the log of an airline's number of accidents is regressed on eight firm-level financial variables and seven country-level variables during the sample period from 1990 to 2009. As noted in Table 6, there is a high correlation between the GDP per capita, the corruption index, and the rule of law for our sample countries. Thus only Ln(GDP per capita) is included in the base model. Panel A reports the regression results for a series of models that consider an airline's financial condition. Model 1 is the base model. Models 2 and 3 vary from the base model by using different profitability measures. Models 4 to 8 estimate each financial variable's impact on accident frequency while controlling for other relevant factors. Panel B reports the regression results related to the macroeconomic environment of a given country. Each country variable is included separately to observe its individual effect. The results are reported in Models 1 to 8 in Panel B. For each variable, the coefficient and the corresponding p-value (in parentheses) are reported. In the last row, we report the number of observations for each regression. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Panel A. Summary of Firm-Level Results (DV=Number of Accidents)

	Base model							
VARIABLES	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**
Maintenance Ratio	-1.007**	-1.028**	-1.040**	-1.013**	-1.200**	-1.213**	-1.208**	-1.839***
	(0.018)	(0.016)	(0.015)	(0.016)	(0.013)	(0.012)	(0.011)	(0.010)
Operating Revenue ($ Millions)	0.121***	0.123***	0.121***	0.120***	0.116***	0.115***	0.115***	
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	
Total Asset Turnover	-0.572***	-0.571***	-0.577***	-0.590***				
	(0.003)	(0.003)	(0.003)	(0.001)				
Current Ratio	-0.0248*	-0.0261*	-0.0243*		-0.0109			
	(0.065)	(0.051)	(0.073)		(0.495)			
Debt Ratio	-0.712	-0.865*	-0.675			-0.719**		
	(0.118)	(0.058)	(0.130)			(0.042)		
Net Profit Margin	-0.162							
	(0.613)							
Efficiency of the Judicial System	-0.0655	-0.0645	-0.0635	-0.0698	-0.0417	-0.0424	-0.0591	-0.0822
	(0.434)	(0.442)	(0.453)	(0.403)	(0.646)	(0.638)	(0.504)	(0.359)
Ln(Departures)	0.170	0.169	0.172	0.147	0.0739	0.110	0.0807	0.238**
	(0.134)	(0.137)	(0.133)	(0.195)	(0.491)	(0.311)	(0.453)	(0.029)
Ln(GDP per Capita)	-0.453***	-0.457***	-0.450***	-0.416***	-0.361***	-0.400***	-0.355***	-0.319***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)	(0.002)	(0.003)
Unemployment	0.00471	0.00413	0.00461	0.00564	-0.0141	-0.0138	-0.0148	-0.0298
	(0.883)	(0.898)	(0.886)	(0.859)	(0.697)	(0.702)	(0.681)	(0.373)
Common Law Dummy	0.0653	0.0737	0.0617	0.0846	0.267	0.243	0.296	0.0700
	(0.883)	(0.813)	(0.842)	(0.781)	(0.410)	(0.460)	(0.354)	(0.833)
ROA		-0.643						
		(0.240)						
ROE			-0.0352					
			(0.136)					
Constant	0.581	0.741	0.500	-0.0376	-0.364	0.145	-0.397	-1.864**
	(0.565)	(0.452)	(0.626)	(0.968)	(0.704)	(0.884)	(0.677)	(0.043)
Observations	1,695	1,695	1,694	1,698	1,695	1,698	1,728	1,728

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Panel B. Summary of Country-Level Results (DV=Number of Accidents)								
	Base model							
VARIABLES	**Model 1**	**Model 9**	**Model 10**	**Model 11**	**Model 12**	**Model 13**	**Model 14**	**Model 15**
Maintenance Ratio	-1.007**	-0.766***	-0.814**	-0.819***	-0.755**	-0.910***	-0.766**	-0.796**
	(0.018)	(0.009)	(0.010)	(0.009)	(0.011)	(0.008)	(0.023)	(0.025)
Operating Revenue ($ Millions)	0.121***	0.113***	0.123***	0.119***	0.111***	0.129***	0.101***	0.100***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Total Asset Turnover	-0.572***	-0.555***	-0.564***	-0.566***	-0.491***	-0.555***	-0.498***	-0.498***
	(0.003)	(0.003)	(0.004)	(0.003)	(0.007)	(0.006)	(0.004)	(0.005)
Current Ratio	-0.0248*	-0.0122	-0.0170	-0.0139	-0.00968	-0.0212	-0.00973	-0.0110
	(0.065)	(0.380)	(0.219)	(0.314)	(0.474)	(0.107)	(0.472)	(0.430)
Debt Ratio	-0.712	-0.371	-0.448	-0.413	-0.324	-0.565	-0.370	-0.394
	(0.118)	(0.374)	(0.291)	(0.339)	(0.447)	(0.208)	(0.384)	(0.354)
Net Profit Margin	-0.162	-0.0783	-0.0383	-0.0863	-0.163	-0.159	-0.183	-0.220
	(0.613)	(0.742)	(0.863)	(0.723)	(0.601)	(0.599)	(0.583)	(0.547)
Efficiency of the Judicial System	-0.0655	-0.147***						
	(0.434)	(0.006)						
Ln(Departures)	0.170				-0.0877			
	(0.134)				(0.205)			
Ln(GDP per Capita)	-0.453***					-0.377***		
	(0.000)					(0.000)		
Unemployment	0.00471						-0.0110	
	(0.883)						(0.701)	
Common Law Dummy	0.0653							0.183
	(0.833)							(0.381)
Corruption			-0.249***					
			(0.000)					
Rule of Law				-0.162***				
				(0.002)				
Constant	0.581	-0.934	-0.276	-0.849	-1.085	1.494*	-2.105***	-2.257***
	(0.565)	(0.119)	(0.656)	(0.133)	(0.247)	(0.076)	(0.000)	(0.000)
Observations	1,695	1,695	1,695	1,695	1,695	1,695	1,695	1,695

Table 9: Poisson regression results after winsorizing

In order to avoid any effects that extreme values may have on the results, the models are re-estimated using winsorized data, i.e., data in which the bottom and top 5% of all observations in terms of the eight firm-level financial variables (maintenance ratio, operation revenue, current ratio, total asset turnover, the debt ratio, net profit margin, ROA, and ROE) are removed. For each variable, the coefficient and the corresponding p-value (in parentheses) are reported. In the last row, we report the number of observations for each regression. *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Summary of Firm-Level Results (DV=Number of Accidents)									
VARIABLES	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**	**Model 9**
Maintenance Ratio	-0.932**	-1.002**	-1.030**	-1.194**	-1.213**	-1.013**	-1.178**	-1.189**	-1.271***
	(0.025)	(0.019)	(0.016)	(0.013)	(0.011)	(0.016)	(0.013)	(0.012)	(0.009)
Operating Revenue ($ Millions)	0.123***	0.121***	0.121***	0.115***	0.116***	0.121***	0.115***	0.115***	0.117***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Current Ratio	-0.348*	-0.331*	-0.314*	-0.135					
	(0.082)	(0.081)	(0.097)	(0.473)					
Debt Ratio	-1.194*	-1.250**	-1.081*		-0.868**				
	(0.074)	(0.024)	(0.050)		(0.034)				
Total Asset Turnover	-0.649***	-0.586***	-0.585***			-0.597***			
	(0.002)	(0.002)	(0.002)			(0.001)			
Net Profit Margin	2.357						0.526		
	(0.645)						(0.387)		
Efficiency of the Judicial System	-0.0419	-0.0348	-0.0377	-0.0321	-0.0369	-0.0687	-0.0580	-0.0418	-0.0428
	(0.670)	(0.694)	(0.672)	(0.732)	(0.685)	(0.411)	(0.509)	(0.644)	(0.642)
Ln(Departures)	0.174	0.156	0.158	0.0645	0.101	0.142	0.0846	0.0763	0.0761
	(0.142)	(0.162)	(0.162)	(0.551)	(0.353)	(0.211)	(0.431)	(0.480)	(0.489)
Ln(GDP per Capita)	-0.517***	-0.499***	-0.488***	-0.367***	-0.408***	-0.417***	-0.364***	-0.366***	-0.359***
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.001)	(0.002)
Unemployment	0.00967	0.00431	0.00380	-0.0137	-0.0130	0.00589	-0.0144	-0.0135	-0.0151
	(0.863)	(0.890)	(0.904)	(0.702)	(0.717)	(0.853)	(0.688)	(0.708)	(0.680)
Common Law Dummy	-0.0174	0.0265	0.0300	0.260	0.244	0.0786	0.274	0.257	0.278
	(0.992)	(0.931)	(0.922)	(0.420)	(0.459)	(0.797)	(0.391)	(0.429)	(0.395)
ROA	-2.331*	-0.514						0.349	
	(0.0907)	(0.514)						(0.497)	
ROE			-0.0675*						-0.0766**
			(0.056)						(0.031)
Constant	1.693	1.696	1.450	-0.145	0.399	0.0327	-0.367	-0.358	-0.421
	(0.205)	(0.145)	(0.231)	(0.886)	(0.696)	(0.973)	(0.700)	(0.708)	(0.666)
Observations	1,695	1,695	1,694	1,695	1,698	1,698	1,728	1,698	1,697