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Flying safe: The impact of corporate governance on aviation safety

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ABSTRACT

This study examines the impact of various measures of corporate governance on airline safety, addressing a significant gap in the literature that explores safety performance within the aviation industry. Using data from seventy countries spanning the period from 1990 to 2016, we investigate the relationship between corporate governance quality indicators and airline accident rates while controlling for airlines' financial health. Our findings suggest that airlines with less qualified and busier directors, as well as those experiencing higher degrees of director succession, are more prone to accidents. Conversely, longer CEO tenure is associated with a lower accident rate. Furthermore, our findings highlight the importance of a well-developed regulatory environment and transportation infrastructure: airlines based in countries with more stringent legal regulations, robust law enforcement, and superior air transport infrastructure exhibit better safety performance. Our research underscores the critical role of corporate governance in ensuring airline safety and emphasizes the significance of regulatory frameworks and infrastructure investments in shaping safety outcomes in the aviation industry. These results carry significant policy implications for aviation safety regulators responsible for developing, overseeing, and implementing policies aimed at improving aviation safety.

1. Introduction

In light of recent events, such as the January 2024 mid-air panel blowout involving Alaska Airlines' Flight 1282 with 171 passengers on board[1] as well as various other reported incidents and accidents that tend to hit our mainstream media on a recurring basis, aviation safety continues to be a paramount concern. Based on information provided by the Aviation Safety Network,[2] there have been over 12,000 fatalities from plane crashes in North America alone since 1946. Fortunately, aviation safety has improved over the years, with a declining trend in global aviation accidents over the past three decades.[3] However, accidents still have catastrophic impacts, both directly, in terms of human fatalities and damage to aircraft and ground structures, and indirectly, through their impact on the families of victims and other stakeholders. In this study, we take advantage of a unique dataset and focus on an important aspect of aviation safety that has not been empirically explored in prior research: the impact of the corporate governance quality of airlines on their safety record.

Internal airline factors, such as busy flight turnaround causing flight crew stress, insufficient training, and poor aircraft maintenance can affect the probability of accidents. An example of this is the negligence of aircraft maintenance by unexperienced subcontractors that was the main reason to the 2003 crash of Air Midwest Flight 5481.[4] Additionally, the 2013 crash of Asiana Airlines Flight 214 and the 2009 crash of Continental Connection Flight 3407 were due, in part, to inadequate training of pilots and pilot fatigue, respectively.,[5,6] This view is

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[1] https://www.reuters.com/business/aerospace-defense/mid-air-blowout-puts-boeing-back-hot-seat-2024-01-07.

[2] https://aviation-safety.net.

[3] We follow Rose (1989) who employs airline accidents as a proxy for safety, arguing that they are a better measure than airline incidents to investigate air carrier safety as opposed to air system safety. The global airline accident rate was 1.93 accidents per million departures in 2021, representing a 9.8% decrease compared to 2020. Please refer to International Civil Aviation Organization (ICAO) Safety Reports (available at https://www.icao.int/safety/pages/safety-report.aspx).

[4] https://www.ntsb.gov/investigations/AccidentReports/Reports/AAR0401.pdf.

[5] https://www.ntsb.gov/investigations/accidentreports/reports/aar1401.pdf.

[6] https://www.ntsb.gov/investigations/AccidentReports/Reports/AAR1001.pdf.

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supported by the existing literature, which shows that internal factors such as the number of hours of training that pilots receive, a pilot's performance history, airline privatization, and the age of air fleets affect the accident rate in the aviation industry (Gudmundsson, 2004; Flouris and Walker, 2005; Wang et al., 2013; Ochieng and Ahmed, 2014; Asker and Kiraci, 2016).

In addition, several studies provide empirical evidence that financial constraints may cause air carriers to reduce maintenance costs and training expenses and to keep outdated airplanes in service in order to meet profitability targets (e.g., Rose, 1990; Li et al., 2004; Madsen, 2013; Fardnia et al., 2020). Thus, airlines play a significant role in ensuring the safety of passengers and reducing the likelihood of accidents (e.g., Savage, 2012; Madsen, 2013; Marais and Robichaud, 2012). However, the airline industry is highly prone to external shocks, such as the COVID-19 crisis, which has highlighted the industry's vulnerability to unexpected events. Additionally, the economic, institutional, and political environment of countries affect airline operations (Nelson and Drews, 2008; Morrell, 2011; Voltes-Dorta and Pagliari, 2012; Walker et al., 2014). In spite of the important role that these factors play in aviation safety, the impact of the quality of corporate governance on airline safety is not well explored in the literature. This study aims to fill that gap.

Using a large international sample covering the years 1990–2016, we investigate the following two primary research questions concerning aviation safety.[7] First, does the quality of an airline company's corporate governance affect its safety performance? To answer this question, we consider the characteristics of directors and CEOs that oversee airline operations and examine whether these characteristics affect an airline's safety performance. Second, which country characteristics interplay with the safety record of airlines operating out of that country? The insights we provide in this context have important policy implications both for the airline industry and regulators.

Previewing our main findings, we find the following: there is a negative relationship between an airline's corporate governance quality and its accident propensity; airlines with a younger board of directors tend to have fewer accidents; and the longer the tenure of the CEO in an airline, the lower the number of accidents. We also find that airlines with busier directors have higher incident propensity. Finally, our results suggest that airlines based in countries with stronger law enforcement, more stringent legal regulations, and better air transport infrastructure have better safety performance.

Our study contributes to the existing body of research on aviation safety by examining the influence of an airline's corporate governance characteristics on its safety performance in a broad cross-country setting. Additionally, we enhance understanding of the relationship between airline management and aviation safety. For example, our findings reveal significant correlations between certain corporate governance factors and accident rates, shedding light on potential areas for improvement in airline management practices to enhance safety outcomes.

There are several benefits to conducting a comprehensive analysis like this. First, by employing a sample of airlines around the world, we are able to consider critical country-level factors (e.g., macroeconomic, regulatory, legal, and infrastructure-related variables) that cannot be examined in a single country context, but which are of vital importance when exploring the determinants of an airline's safety performance. Thus, we add to prior studies which examine corporate governance issues across borders (e.g., Aggarwal et al., 2005; Gaitán et al., 2018). Second, the aviation industry is heavily regulated and is subject to stringent safety regulations. As a result, despite poor financial performance and poor governance practices, airlines may not be able to overlook safety standards (and thereby heighten their accident susceptibility). This makes the connection between accident rates, corporate governance characteristics, and financial performance even more difficult to identify. Third, while U.S. airlines do not seem to learn from past accidents (Madsen et al., 2016), our results highlight the importance of corporate governance quality for airline safety in an international setting. Finally, given that airline accidents are extremely rare, a large sample is required to separate accidents for which no fault is attributable to the airline from accidents that are truly the airline's fault (Lofquist, 2010; Oster et al., 2013).

The findings of our study carry significant policy implications for aviation safety regulators responsible for developing, overseeing, and implementing policies aimed at improving aviation safety. For example, the Federal Aviation Authority (FAA), the International Civil Aviation Organization (ICAO), and other regulators may find it beneficial to allocate more resources to the supervision of airlines with poor governance practices. In addition, our international analysis indicates that pilot errors and mechanical failures are responsible for about 75% of airplane accidents. Therefore, it should be a top priority for the executives of airlines to ensure that their corporate governance structure can formulate and enhance policies aimed at diminishing accidents stemming from these two factors. Numerous strategies can be contemplated to tackle this challenge: for instance, recruiting highly qualified and less burdened directors capable of offering more effective monitoring to enhance the management of airlines and their resources. This includes initiatives such as improving working conditions for pilots, intensifying pilot training programs, and implementing more rigorous mechanical inspection procedures, among others.

The remainder of this paper is organized as follows. Section 2 reviews the relevant literature. Section 3 develops our hypotheses. Section 4 provides information on the origin and composition of the dataset. Our methodology is discussed in Section 5. Section 6 presents the empirical results. Robustness tests are presented in Section 7. Finally, Section 8 discusses the main results and Section 9 provides a summary and offers concluding remarks.

2. Literature review

2.1. Aviation safety

While a significant portion of the literature on aviation safety originates from engineering disciplines aiming to improve the technological aspects of aviation to alleviate safety risks (e.g., Rodrigues and Cusick, 2012; Goglia et al., 2008), early economic studies of airline safety focused on the potential effects of the Airline Deregulation Act (ADA) of 1978.[8] Michel and Shaked (1984), Rhoades and Waguespack (1999), and Savage (1999) examine the effectiveness of industry regulations in preventing accidents as well as the potential impact of regulations on the economic and financial performance of the airline industry. While they arrive at different conclusions, their findings indicate that the safety records for new entrant airlines in the early 1990s were worse than for established carriers. In addition, deregulation increased the costs of monitoring managerial performance as well as intensifying agency problems (e.g., Kole and Lehn, 1997; Lee, 1997).

Most economic studies of airline safety follow a reactive approach which analyzes accidents, investigates their causes, and provides corrective solutions. For example, by examining variations in aviation safety among different countries, several researchers find that

[7] We end our sample period in 2016 to ensure that accident investigators have sufficient time to determine the cause of a given accident. As an added benefit, this also eliminates any undue biases from the COVID-19 pandemic which has had a significant effect on the global aviation industry since March 2020.

[8] This act transformed the aviation industry in the United States and eliminated government control over many aspects of this industry. Other countries took similar steps to liberalize aviation industry services. For more details, see Michel and Shaked (1984) or Rhoades and Waguespack (1999).

developing countries have much poorer safety records than their developed peers (Barnett, 2010; Barnett and Higgins, 1989; Barnett and Wang, 2000; Oster et al., 1992, 2010). The authors argue that differences in the regulatory structure of countries could be the main cause for the observed variations in aviation safety across borders, while citing economic well-being as another contributing factor. In addition, Marais and Robichaud (2012) find that inadequate maintenance significantly increases the accident risks of airlines. Also, Nelson and Drews (2008) investigate the effect of the adoption of strict product liability standards on the aviation industry. They find that as the liability insurance costs for new planes increased significantly over the past three decades, airplane manufacturers had to raise their prices accordingly. This has had a negative impact on the sale of new aircraft. The authors argue that the presence of older aircrafts is a big risk factor in the aviation industry and posit that the accident rate and the number of fatalities would be significantly lower if new sales had not been negatively affected by the increased liability standards.

The literature focusing on the effect of profitability on an airline's safety record yields mixed results. While Golbe (1986) finds no significant relationship between airline profitability and accident rates, Rose (1990) finds that accident rates are lower for medium and small airlines with higher profitability. Alternatively, Dionne et al. (1997) and Raghavan and Rhoades (2005) find a negative relationship between financial performance and accident propensity among air carriers. Noronha and Singal (2004) claim that the mixed results may be due, in part, to airlines enhancing their profitability in the short run by reducing investment in safety. More recently, Fardnia et al. (2020) examine airline accidents over the period 1990–2009 and find a significantly inverse relationship between the profitability of airlines and their accident propensity. The authors perform a series of robustness tests to confirm their results.

Using data sourced from the U.S. airline industry, Madsen (2013) reevaluates the connection between airline profitability and accident rates. The study offers a new perspective, suggesting that the mixed findings in earlier scholarly work may be due to the variation of risk acceptance shaped by varying levels of profitability. Madsen contends that if an airline is close to meeting its profitability target, it is more willing to increase its risk of accidents by spending less on safety. Conversely, when an airline is substantially above or below its profitability target, its incentives to reduce safety spending is considerably lower. In essence, Madsen posits that the relationship between profitability and safety in the aviation industry is nonlinear and depends on the airlines' profitability goals.

2.2. *Corporate governance in the aviation industry*

Some prior studies have examined corporate governance in the aviation industry; however the literature is silent about the relationship between corporate governance and aviation safety. Lu et al. (2012) examine the relationship between operating performance and corporate governance in 30 airline companies operating in the US. Their findings indicate that board size, the average age of the directors, and the percentage of outstanding shares owned by executive officers are significantly positively correlated with financial and marketing performance measures of the airlines. On the other hand, the number of committees and CEO duality both exhibit significant negative relationships with these performance measures.

Abeyratne (2000) examines the consequences of strategic airline alliances on aviation safety and finds that although such alliances tend to foster growth and increase route coverage, they may reduce safety due to increased traffic volume.

Nwabueze and Mileski (2008) focus on the failures of Swissair in early 2000s which made the company declare bankruptcy and seek creditor protection on October 4, 2002. The authors conclude that a systematically flawed decision-making process due to poor corporate governance was the main reason of the airline's financial, political, and social hardship. Similarly, Hermann and Rammal (2010) use the case of Swissair to demonstrate the importance of competent and industry-knowledgeable executive boards, not only to enhance company profits, but also stability and socially responsible decision-making. They find that the alliance and acquisition strategy pursued by Swissair's management and the lack of leadership and accountability by the CEO and chairman of the board were the main contributing factors to the company's collapse. In addition, Mustilli and Izzo (2009) analyze the management structure of airlines in Italy, and conclude that airlines should put more emphasis on corporate governance as the aviation industry is characterized by complex product systems and a high degree of agency problems among stakeholders which makes the decision-making process harder for executives.[9]

Goll et al. (2008) explore the connection between top management characteristics, business strategies, and firm performance in major U.S. airlines. The authors find that, after the deregulation of the industry, airlines with younger, better educated, and less seasoned (low tenure) managers have better service strategies as well as higher financial performance. However, they do not find significant relationships among these attributes before the deregulation indicating that managerial discretion and corporate governance play more important roles in a deregulated environment. Finally, the authors call for future research by noting that their "… study is based on one industry in one country and as a result raises questions regarding the generalizability" of their findings – a challenge that we aim to tackle in our study by using data from seventy countries.

Suhardjanto et al. (2017) examine the effect of ownership structure on airlines' financial performance in Asia and Australia from 2010 to 2015. Their findings indicate that foreign and government ownership are positively related to the financial performance of airlines, while institutional ownership shows a negative (but insignificant) effect on financial performance.

3. Hypothesis development

Traditionally, corporate governance is viewed as the set of rules that provides a formal structure to the relationship among the board of directors, shareholders, and managers with a view to resolve assumed agency conflicts between principals and agents (Berle and Means, 1932). More recently, corporate governance is viewed as the "… rights and responsibilities among the parties with a *stake* in the firm" (Aoki, 2001, p. 11) as well as the configurations of organizational processes that affect both financial and nonfinancial firm-level outcomes (Aguilera et al., 2008, 2012, 2015; Gill, 2008; Jain and Jamali, 2016; Windsor, 2006). Considering the fact that passengers' safety is one of the main nonfinancial outcomes of airlines (Lofquist, 2010; Oster et al., 2013), we argue that, while controlling for financial outcomes, better corporate governance should be positively associated with higher safety in the aviation industry.

Several internal and external corporate governance mechanisms have been recognized in the literature, among which the board of directors and CEO seem to play more important roles (Fama and Jensen, 1983; Jensen, 1993), especially for highly regulated industries with complex relationships among stakeholders such as the aviation industry (Admati, 2017). In addition, the aviation literature provides ample evidence showing the importance of managerial discretion in airlines' success/failures (e.g., Hermann and Rammal, 2010; Mustilli and Izzo, 2009). Thus, in our study, we focus on the corporate governance attributes of the board of directors and CEO in framing our hypotheses.[10]

[9] Similarly, Davis and Callahan (2012) examine the structure of Air Astana (the main carrier in Kazakhstan) and emphasize the importance of corporate governance.

[10] Because we are analyzing airlines from 70 countries, availability of data is another factor confining us to the characteristics of the board and the CEO.

3.1. Board characteristics

In terms of board characteristics, we consider several different attributes that could potentially affect airlines' safety, including professional qualifications, succession, heterogeneity, busyness, size, and independence. We discuss each attribute separately below.

3.1.1. Professional qualifications

The first characteristic we focus on is the professional qualification of the directors. Fama and Jensen (1983) contend that board duties require substantial expertise. Consistent with this notion, a large body of the literature documents the importance of the qualifications of individual directors. For example, Erel et al. (2021) use machine learning algorithms and find that male directors who hold more directorships and have fewer qualifications tend to be less desirable and provide poorer internal oversight. Similarly, Chemmanur and Fedaseyeu (2018) and Fedaseyeu et al. (2018) find that director qualifications and experience are important determinants of their board function as well as their compensation. We expect that boards with more qualified directors will be better at monitoring their CEOs to steer the airlines toward success, including safer operations.

3.1.2. Succession

Next, we focus on the age of the directors. Amore et al. (2021) and Horner (2016) examine the age clustering effect of board members and find that clustered boards with a large proportion of ready-to-retire directors shirk their monitoring responsibilities. Following the authors, we use the succession factor to proxy for the age clustering of directors. The succession factor measures the clustering of directors around the retirement age, with a lower number presenting a higher risk of succession. Thus, we conjecture that airlines with a lower risk of succession have a lower risk of accidents.

3.1.3. Heterogeneity

Third, we focus on the heterogeneity among board members, which we expect to influence characteristics such as cohesiveness, integration, and communication (Wagner et al., 1984), as well as conformity and conflict (Ancona, 2015). Heterogeneous top management teams may consider a wider range of alternatives and solutions to problems (Boeker, 1997). Thus, diversity among the board members is frequently viewed as having a positive influence on the monitoring quality of a board. The empirical literature in the field supports this view. Louch (2000) measures the age-related distance between directors on the board and shows that a higher age difference reduces the probability of established connections among individuals. In another study, Chidambaran et al. (2022) find that age, ethnicity, and gender diversity explain both director turnover and director promotions to more influential positions on boards. Thus, we anticipate that airlines with younger directors and a wider age range among the directors have a lower number of accidents because the directors have fewer established connections and can settle conflicts more objectively and efficiently. In addition, we anticipate that airlines with greater ethnic and gender diversity among their board members would exhibit a lower number of accidents.

3.1.4. Busyness

Fich and Shivdasani (2006) present evidence suggesting that overly busy boards are associated with weak corporate governance and poor monitoring of management. Erel et al. (2021) provide similar findings. Thus, we expect that airlines with busier boards and those with directorship at other firms will have less time to allocate to each firm they serve on and that they provide poorer monitoring, leading to poorer safety standards and higher accident rates. In other words, airlines with less occupied board members should have a lower risk of accidents.

3.1.5. Size

Jensen (1993) and Chiang and Lin (2007) argue that larger board sizes may lead to some problems, including coordination and communication issues, allowing the CEO to easily affect the board decisions, resulting in higher agency problems. Meanwhile, more directors on the board can lead to better brainstorming and higher-quality decision-making. In addition, the more directors on the board, the higher the firm's ability to acquire key resources from outside (Zahra and Pearce, 1989; Xie et al., 2003). Thus, the relationship between board size and safety in the aviation industry is an empirical question.

3.1.6. Independence

Lastly, with respect to board composition and independence, there are two types of directors: dependent (executive) and independent (non-executive). Some studies find that independent directors may be particularly effective monitors as they reduce conflict of interest between insiders and shareholders (e.g., Weisbach, 1988; Dahya et al., 2002). Thus, an appropriate, not excessive, number of independent directors should be more efficient in monitoring and providing advising functions and thus should improve corporate governance and firm performance (De Andres and Vallelado, 2008; Harris and Raviv, 2008). Therefore, we expect that airlines with more independent boards have a lower risk of accidents.

3.2. CEO characteristics

In terms of CEO characteristics, we consider three main CEO attributes that could potentially affect airlines' safety, including tenure, age, and duality. We discuss each attribute separately below.

3.2.1. CEO tenure

The literature is mixed about the effect of CEO tenure on the firm; some studies provide evidence indicating that CEO tenure positively affects the quality of management and, consequently, firm performance (e.g., Michel and Hambrick, 1992), while other studies find a negative relationship between CEO tenure and performance (e.g., Bantel and Jackson, 1989; Wiersema and Bantel, 1992). Fich and Shivdasani (2007) explain the impact of CEO duality in a litigation context and report that fraudulent firms are more likely to exhibit CEO duality. In another study, Miller and Shamsie (2001) report that CEO tenure exhibits an inverse U-shaped relationship with firm performance: as CEO experience grows, it has a positive influence on firm performance, but the willingness of CEOs to take on risks declines as they approach retirement. Similarly, Barker and Mueller (2002) examine how CEO characteristics affect R&D spending and report that CEOs with longer tenure tend to act more in their own interest, which results in weaker corporate governance practices and poorer performance. Thus, the relationship between CEO tenure and safety in the aviation industry is an empirical question.

3.2.2. CEO age

The existing literature provides different views about the effect of CEO age on management. From a management dynamics perspective, we can argue that young managers may be less committed to established norms, thus displaying a higher propensity for adopting innovative and pioneering strategies (Hambrick and Mason, 1984). From an executive job demand perspective, it is also likely that younger managers have less experience and thus more likely to innovate. In addition, senior managers may have a higher degree of risk aversion, while younger managers may be more willing to undertake risky strategies (Carlsson and Karlsson, 1970; Hitt and Tyler, 1991; Vroom and Pahl, 1971). Moreover, certain characteristics, such as flexibility, may decrease with age, whereas rigidity and resistance to change tend to increase with age (Wiersema and Bantel, 1992). Thus, while older managers' risk aversion may improve airlines' safety by being conservative and strict about procedures and protocols, they may close the door to innovation and new technologies that may improve safety.

3.2.3. CEO duality

As for duality, the literature yields no conclusive results either. Baliga et al. (1996) and Bhagat and Bolton (2008) show that when the firm separates the functions of the CEO and the chairman, its performance is better than that of firms with CEO duality. In the presence of duality, the board finds itself in a weak position in relation to the CEO, which may complicate the introduction of new ideas and innovation (Chen and Hsu, 2009; Zahra et al., 2000). Nevertheless, Dalton et al. (1998) and Jensen (1993) observe that CEO duality helps the CEO control information more effectively and eliminates ambiguity with respect to leadership. Thus, while CEO duality can improve airlines' safety in terms of a more transparent safety culture, it could also worsen safety by giving too much power to CEOs and putting the board in a weak position.

3.3. Country characteristics

The extant literature provides ample evidence indicating that country characteristics, including the legal protection of investors and the level of economic and financial development, influence corporate governance at the firm level. For instance, Bushman et al. (2004) examine different potential determinants of corporate transparency while investigating whether countries' legal/judicial regimes and political economies affect transparency. They find that governance transparency is primarily related to a country's legal/judicial regime, whereas financial transparency is primarily related to its political economy. Dyck and Zingales (2004) examine corporate governance in 39 countries and find that a common law legal origin could constrain management by lowering the standard of proof in legal suits and increasing the scope of management decisions subject to judicial review. Stulz and Williamson (2003), along with Hope (2003), also examine corporate transparency; they find that corporate governance is significantly affected by country characteristics.

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 a better quality of contract enforcement and more reliable 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).

The airlines in our study are headquartered in various countries around the globe. We contend that the level of development and infrastructure of a given country can potentially affect the safety performance of airlines headquartered there through different channels. Following the literature (e.g., Bushman et al., 2004; Dyck and Zingales, 2004), we argue that the accident propensity of airlines is higher in countries with a higher level of corruption, poorer law enforcement, and a less developed legal environment, due to a lack of consistent regulatory policies and the laxer enforcement of those policies. In addition, we expect airlines in countries whose economies are in poor health, whose technical infrastructure is antiquated, and/or whose aviation sector is underdeveloped to incur a higher accident risk (Fardnia et al., 2020; Oster et al., 2013).

4. Data

4.1. Sample description

This study provides empirical evidence drawn from both North American and international sources. The sample consists of 372 airlines operating in 70 countries between 1990 and 2016. 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.[11]

We retrieve our data from the following sources.

1. The International Civil Aviation Organization (ICAO) offers several databases, including three modules entitled Air Carrier Finances, Air Carrier Fleet, and Air Carrier Personnel, from which we retrieved data for all airlines.
2. Data about the governance characteristics of airlines are accessible through the BoardEx database, in particular, the Organizational Summary section.

We manually reference and cross-check each airline from the ICAO database in BoardEx to ensure that we find exact matches and increase the matched sample size. In case we cannot find an exact match in the BoardEx database, we use the data of the parent airline instead of the airline subsidiary.[12]

We investigate a broad range of airlines that are headquartered in different countries with various levels of development. These countries vary with respect to their economic strength, demographics, geography, infrastructure, and institutional environment. As such, our sample provides a comprehensive representation of the worldwide aviation industry.

We obtain data on global aviation disasters from the National Transportation Safety Board (NTSB) and two online databases: aviation-safety.net 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-reference the data with airline accident reports listed on Wikipedia. No inconsistencies or spurious data entries were found during these cross-checks.

Based on the classification scheme provided by the International Civil Aviation Organization (ICAO), accidents differ from incidents in several respects. Accidents include occurrences in which a person is fatally or seriously injured, the aircraft sustains damage or structural failure, or the aircraft is missing or completely inaccessible.[13] Accidents of this nature are frequently considered to be due to air carrier deficiencies such as pilot error, inadequate training, or aircraft maintenance problems. In contrast, aviation incidents tend to be less severe and are frequently attributed to air traffic control failures or unusual natural events. We follow the prior literature (e.g., Haunschild and Sullivan, 2002; Madsen, 2009, 2013; Madsen et al, 2016; Rose, 1989, 1990, 1992) and employ airline accidents as a proxy for safety, arguing that they are a more appropriate measure than airline incidents to investigate air carrier safety as opposed to air system safety. This view is also consistent

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

[12] Our results remain similar if we remove these airlines from our sample.

[13] Specifically, ICAO 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 sustains damage or structual failure, or in which the aircraft is missing or is completely inaccessible" (see http://www.icao.int/Pages/default.aspx).

with the National Transportation Safety Board's definition of an aviation accident as an event that takes place during the operation of an aircraft that causes the death or serious injury of a person or causes structural failure or significant structural damage to the aircraft.[14]

4.2. Accident causes

The website planecrashinfo.com breaks down accident causes into five categories: (1) pilot error, (2) mechanical failure, (3) weather-related, (4) criminal activity, and (5) other. Because many accidents are attributed to more than one cause, we focus our analysis on the primary cause listed in the accident description.

Table 1 provides information on the primary causes of fatal accidents that occurred in each decade since 1950. Accidents involving aircraft with 18 or fewer passengers aboard, military aircraft, private aircraft, and helicopters are excluded. Consistent with the literature (Wiegmann and Shappell, 2001; Shappell and Wiegmann, 2004) that identify pilot errors as the primary cause of aircraft accidents, the table shows that, on average, pilot errors account for 49 percent of all accidents. Pilot errors can be attributed to a broad range of organizational influences, including inadequate supervision, inappropriate planning of flights, inadequate training, willful violation of rules, and corruption to bypass regulatory oversight (Wiegmann and Shappell, 2001; Johnson and Holloway, 2004).

The second most prominent cause is mechanical failure, which accounts for 23 percent of all accidents. Previous academic studies (Sexton et al., 2000; Baker et al., 2001; Wiegmann and Shappell, 2001) show that ground crew lack of experience and aircraft manufacturer miscalculations are the main reasons for mechanical failures.

The third and fourth most frequent causes of accidents include adverse weather and other causes, respectively, each accounting for approximately ten percent of all accidents. Weather-related accidents include poor visibility, severe turbulence, severe winds, icing, thunderstorms, lightning strikes, etc. (Knecht and Lenz, 2010). However, Knecht and Lenz also report that weather alone is rarely the sole cause, and they point out that the lack of weather-related training, pilot inexperience, and poor-quality equipment are contributing factors. Finally, the last category is criminal activity, accounting for approximately eight percent of all accidents. This category includes accidents caused by hijackings, planes being shot down, explosive devices, and pilot suicide. Following Fardnia et al. (2020), we eliminate accidents due to criminal activity as well as accidents caused by wildlife hits from our subsequent analysis, as these accidents do not reflect poor safety practices by the airline.

5. Methodology

We follow the existing literature and define our main dependent variable as the number of accidents experienced by an airline in a calendar year (e.g., Haunschild and Sullivan, 2002; Madsen, 2009; 2013;, Madsen et al, 2016; Rose, 1992). Prior studies use Negative Binomial and/or Poisson distributions to model airline accidents, while the latter is more frequently used (Dionne et al., 1997; Kennedy, 2003; Madsen et al., 2016; Pérez-Granja et al., 2024; Rose, 1990, 1992). The Poisson distribution describes random events that occur independently over time and requires the assumption that the mean and the variance of the count variable are approximately equal (the equidispersion assumption).

To determine the appropriate model for our count data, we conducted the Cameron and Trivedi Score Test for Overdispersion, comparing the fit of the Poisson model versus the Negative Binomial model (Cameron and Trivedi, 1985, 1990). The test yielded a p-value of 0.361 for the coefficient on the predicted counts ($\hat{y}$). Since this p-value is well above the typical significance threshold ($p > 0.05$), we fail to reject the null hypothesis that the data are equidispersed, indicating no significant overdispersion. Additionally, we calculate the Dispersion Index (see Kokonendji and Puig, 2018; Serinaldi, 2013) for our data and obtain a value of 0.99988. To test for equidispersion, we compare this value with the Chi-Squared test and obtain a p-value of 0.001, indicating that the assumption of equidispersion holds. Based on this result, the Poisson model provides an adequate fit for the data, compared to the Negative Binomial model. We provide further empirical support for the choice of Poisson model using Likelihood Ratio Test (LRT), Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC) in the Appendix.[15]

Our independent variables consist of governance characteristics, a set of macro-level variables, and financial measures. Similar to the prior literature, we estimate a series of Poisson regressions while clustering the data at the airline-year level. The Poisson model is specified as follows:

$$P(y_{it}) = \frac{exp(-\lambda_{it})^* \lambda_{it}^{Y_{it}}}{y_{it}!} \quad (1)$$

$$Ln(\lambda_{it}) = \beta_0 + \beta_1{}^*(Corporate\ Governance\ Characteristics)_{t-1} + \beta_2{}^*(Institutional\ \&\ Macroeconomic\ Variables)_{t-1} + \beta_3{}^*(Control\ Variables)_{t-1} + \varepsilon \quad (2)$$

where i indexes airlines, t indexes years, and λ is the Poisson parameter. The dependent variable is the number of accidents in the Poisson regression as a proxy for safety performance. The focus is on the lagged corporate governance characteristics of airlines in the Poisson regression (Equation (2)). We also include lagged financial variables in our model to control for the financial health of airlines. We include lagged variables as prior literature state that the use of contemporary variables could create endogeneity problems (i.e., Rose, 1990; Wang et al., 2013; Pérez-Granja et al., 2024).[16] In addition, we follow the literature and include firm and year fixed effects in our models to reduce any omitted variable biases (i.e., Pérez-Granja et al., 2024; Petersen, 2008). Fixed-effects (FE) models focus on within-group variation by controlling for unobserved, time-invariant characteristics within each entity. This approach is particularly effective when omitted variables may correlate with the independent variables, as it isolates the impact of predictors by

[14] National Transportation Safety Board. NTSB Form 6120.1 Pilot/Operator Aircraft Accident/Incident Report, 2018.Available at: https://www.ntsb.gov/Documents/6120_1web_Reader.pdf, Accessed September 7, 2023.

[15] Poisson regressions also require the assumption that observations (in our study, accident in each calendar year) are independent. Madsen et al. (2016) examine airlines learning from experience with accidents while using quarterly accident counts as their dependent variable. They argue that it is standard practice in the literature on organizational learning from accidents to define learning as a change in (safety) performance. Interestingly, they find that airline safety does not improve following incidents when the focal event has no clear warnings of significant danger. This finding provides additional support for the assumption that the observations in our study are random and independent of each other. Baum and Dahlin (2007) also support this view.

[16] We thank the anonymous referee for pointing this out.

Table 1
Causes of Fatal Accidents by 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. For accidents with multiple causes, the most prominent cause is used.

Cause	1950s	1960s	1970s	1980s	1990s	2000s	2010s	Average
Pilot Error	50%	53%	49%	42%	49%	50%	57%	50%
Mechanical Failure	26%	27%	19%	22%	22%	23%	21%	23%
Weather-Related	15%	7%	10%	14%	7%	8%	10%	10%
Criminal Activities	4%	4%	9%	12%	8%	9%	8%	8%
Other	5%	9%	13%	10%	14%	10%	4%	10%

eliminating any entity-specific, constant effects (Petersen, 2008).

Table 2 provides detailed definitions for all variables used in our study. The focus in Panel A is on the attributes that we conjecture could affect airlines' corporate governance structure at the firm level, while in Panel B, we list the country-level attributes that could be important in our analysis from a macro- and socioeconomic perspective.

Our first group of variables is related to the *corporate governance characteristics* of airlines. As discussed in Section 3, we focus on two categories: (1) board characteristics and (2) CEO characteristics. In terms of board characteristics, we utilize various variables from BoardEx in our regression analysis. These variables include the *average number of qualifications* (a proxy showing how qualified directors are), the *succession factor* (measuring the clustering of directors around retirement age, with a lower number presenting a higher risk of succession), the *gender ratio* (measuring gender diversity), the *board size* (measuring the total number of directors on the board), the *nationality mix* (measuring cultural diversity), the *standard deviation of the age of directors* (measuring age diversity), an *independent director ratio* (measuring the percentage of non-executive directors on the board), *busy board* (capturing the number of other directorships held by each director), the *standard deviation of the busy board*, and the average directors' time to retire (see also Section 3.1).

To capture the impact of CEO characteristics on the safety performance of airlines, we include *CEO tenure*, *CEO age*, and a *CEO duality dummy* in our analysis (see Section 3.2).

In terms of country characteristics, as discussed in Section 3.3, we assume that the level of development and infrastructure of a given country can potentially affect the safety performance of airlines headquartered there. To control for such country-level determinants of airline safety, we consider a series of variables that proxy for the level of corruption, the quality of law enforcement, the legal environment, the quality of air transport infrastructure in a given country, as well as the state of the country's economy.

Specifically, the country-level variables used in the study are: (1) *registered carrier departures* (Ln(*Departures*)), which captures the number of domestic and international takeoffs of air carriers registered in the country and reflects air transportation usage in the country. We argue that the higher the flight volume in a given country, the higher the number of accidents, and (2) a country's *unemployment rate,* which is widely recognized as a key indicator of a country's economic well-being. Moreover, following La Porta et al. (1998), we employ proxies for the quality of law and order in each country and consider (3) the *efficiency of the judicial system*, (4) the *rule of law*, and (5) the level of *corruption*. These measures are compiled by private credit risk agencies to assess differences in the institutional environment across countries. These three institutional environment measures are scored from zero to ten, with lower scores representing a lower-quality institutional environment. Moreover, we employ an additional macro-level control variable, i.e., (6) the *quality of air transport infrastructure.* The quality of a country's air transport infrastructure is defined as the quality (extensiveness and condition) of air transport in a given country in a given year. We retrieve the variable from the Global Competitiveness Index Dataset provided by the World Economic Forum. The variable originally ranges from one to seven. We adjust the scale from one (underdeveloped) to ten (most developed) to increase the variable's comparability with the institutional variables mentioned above. Finally, we employ (7) an *English legal origin 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.

We use a series of control variables throughout all models: the *average utilization factor*, which captures the airline's accident risk in terms of total hours flown over total days available (Backx et al., 2002; Gudmundsson, 2002). In addition, we use several financial ratios that are frequently used in the literature (e.g., Fardnia et al., 2020; Raghavan and Rhoades, 2005) to evaluate a firm's performance and financial health: the *current ratio*, a liquidity proxy, *total asset turnover*, an activity ratio, and *the growth ratio,* recognizing that sustainable growth is an important lever of business success. We also include two *profitability ratios*, which aim to capture an airline's current and expected future profitability and financial health: the *net profit margin*, and the *Z Score.*[17] The Altman Z Score model has been successfully used to predict firm failures in various industries as early as the 1980s. More recently, scholars have employed this variable to predict the bankruptcy of carries in the aviation industry (Gritta et al., 2008; Stepanyan, 2014).

Following the literature (e.g., Fardnia et al., 2020; Madsen et al., 2016), we also include two additional control variables, namely the *maintenance ratio* to control for the effect of direct maintenance expenditures on safety and the *operating revenue* to control for the effect of airline size on safety. The *maintenance ratio* is defined as an airline's expenditures 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.

The *operating revenue* is defined as an airline's annual operating revenue reported in billions of dollars (e.g., Fardnia et al., 2020; Madsen et al., 2016). We employ this variable in all models to capture the natural tendency for larger airlines to have more accidents. We note that one of the limitations when analyzing airline accident rates lies in accurately assessing safety performance in relation to the level of exposure to risk. This exposure is typically measured in terms of passenger kilometers, seat kilometers flown, or the number of takeoffs and landings. For instance, Dionne et al. (1997) measure accident rates based on the number of hours flown for Canadian airlines, while Madsen (2013) use the number of takeoffs, average miles flown per departure,

[17] We calculate the Z Score using the formula for US and foreign firms because we study the global aviation industry. Specifically, we follow Altman et al. (2014) and consider Z Scores below 1.1 as representative of a firm's distress zone, and above 2.6 as indicative of its safe zone (after discounting 3.25 from the score). The Z Score itself is calculated as:$Z = 6.56X1 + 3.26X2 + 6.72X3 + 1.05X4 + 3.25$, where$X1 =$ Working capital/Total assets, where X_1 measures liquid assets in relation to the size of the company.$X2 =$ Retained earnings/Total assets, where X_2 measures profitability that reflects the company's age and earning power.$X3 =$ Earnings before interest and taxes/Total assets, where X_3 measures operating efficiency apart from tax and leveraging factors. It recognizes operating earnings as being important to long-term viability.$X4 =$ Book value of equity/Book value of total liabilities. This variable adds a market dimension that highlights security price fluctuations as a possible red flag.

Table 2
Definitions of Variables
This table provides an overview of the explanatory variables used in our subsequent analysis. Panel A provides sources and definitions for the firm-level explanatory variables. Panel B provides sources and descriptions for the country-level explanatory variables.

Panel A: Firm-level Explanatory Variables

Variable	Source	Description
Accident	ICAO & NTSB	Number of accidents experienced by an airline in a calendar year.
Avg. Number of Qualifications	BoardEx	Average number of professional and academic qualifications of directors on the board
Succession Factor	BoardEx	Measurement of the clustering of directors around retirement age on a given date; a lower number represents a higher risk of succession
Gender Ratio	BoardEx	Male directors/Total directors
Board Size	BoardEx	Number of directors on the board
Nationality Mix	BoardEx	Proportion of directors from other (non-domestic) countries
Std. Dev. of Age of Directors	BoardEx	Standard deviation of the ages of directors for all the directors on a given date
Independent Director Ratio	BoardEx	Number of outside or supervisory directors/ Board size
Busy Board	BoardEx	Number of other directorships held by each director of the firm (Average across all directors on the board)
Std. Dev. of Busy Board	BoardEx	Standard deviation of Busy Board
Avg. Dir. Time to Retire	BoardEx	Average time to retirement for all directors on a given date, assuming a retirement age of 70
Ln (CEO Tenure)	BoardEx	Natural logarithm of the airline CEO's tenure on a given date
Ln (CEO Age)	BoardEx	Natural logarithm of the airline CEO' age on a given date
CEO Duality Dummy	BoardEx	Dummy variable indicating whether or not the CEO is also the chairman of the board. Equals one if yes and zero otherwise
Avg. Airline Utilization Factor	ICAO database	Average of total hours flown/Total days available for each airline's air fleet
Net Profit Margin	ICAO database	Net income/Total revenue
Maintenance Ratio	ICAO database	Flight equipment maintenance and overhaul expense/Total revenue
Current Ratio	ICAO database	Current assets/Current liabilities
Total Asset Turnover	ICAO database	Sales/Total assets
Growth Rate	ICAO database	ROE * Retention ratio/(1- ROE * Retention ratio)
Z Score	ICAO database	Z = 6.56X1 + 3.26X2 + 6.72X3 + 1.05X4 + 3.25, where X1 = Working capital/Total assets, X2 = Retained earnings/Total assets, X3 = Earnings before interest and taxes/Total assets, X4 = Book value of equity/Book value of total liabilities.
Operating Revenue	ICAO database	Total operating revenue, in billions of dollars

Panel B: Country-level Explanatory Variables

Variable	Source	Description
Ln (Departures)	World Bank database	Natural logarithm of the number of domestic and international airplane takeoffs per year in a given 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
Rule of Law	La Porta et al. (1998)	Assessment of the law and order tradition in a given country. Scale from zero to ten, with lower scores for a weaker tradition of law and order
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
English Origin Dummy	Reynolds and Flores (1989)	Dummy variable that identifies whether or not the legal system of a given country originates from English common law (1 = yes, 0 = no)
Quality of Air-Transport Infrastructure	The World Economic Forum (WEF)	Assessment of the quality of airports in a given country based on data from the WEF Executive Opinion Survey. The individual responses are aggregated to produce a country score. Scale from zero (underdeveloped) to ten (most developed). (We adjusted the scale form its original range which went from one to seven)

and other utilization variables for U.S. airlines. Unfortunately, due to data limitations, these utilization variables are not accessible in an international setting. Thus, we use the *operating revenue* of the airlines and argue that because operating revenue is primarily generated from the transportation of passengers and baggage, it is reasonable to assume that, all else being equal, operating revenue reflects the airline's level of risk in terms of the number of flights or distance traveled.

6. Empirical results

6.1. Descriptive statistics and univariate tests

Panel A of Table 3 provides descriptive statistics for the firm-specific variables used in this study. Of particular interest is the number of accidents experienced by an airline in a particular year, which is denoted as "*Accident*" in the table. Not surprisingly, we observe that the median of the accident variable is zero, indicating that most airlines do not have a record of accidents. However, the number of accidents recorded for the airlines in our sample varies between a minimum of zero to a maximum of five during out sample period. This is consistent with prior studies showing that aviation accidents are extremely rare, yet controversially high for some airlines (e.g., Lofquist, 2010; Oster et al., 2013).

In Panel B of Table 3, we split our sample into two subsamples: a subsample of airlines (firm-year observations) with accidents and a subsample without accidents. For each subsample, we then report the mean and median for each variable. In the last two columns, we test for the equality of means and medians between the two subsamples and report the p-values for both a *t*-test for the difference in means and a Wilcoxon median test. We observe that the mean and median of the busy board variable are significantly higher for the subsample with accidents than the subsample without accidents, showing that airlines that have accidents also have busier boards of directors. As expected, the succession factor exhibits higher mean and median values for the subsample without accidents than the subsample with accidents, indicating that airlines that have accidents also have a higher risk of succession. An interesting observation is that the mean and median board size is significantly higher for the subsample with accidents than the subsample without accidents, suggesting that airlines that have accidents also have larger boards of directors. This finding is in line with the literature that suggests that boards that are too large are less efficient and provide

Table 3
Summary Statistics and Univariate Tests
Panel A provides summary statistics for all variables used in our study. Panel B reports the mean and median of firm-and country-level characteristics for our subsamples of airlines with and without accidents during our 1990–2016 sample period. The last three columns of Panel B report p-values for t-tests of differences in means, Wilcoxon tests of differences in medians, and the Chi-Square test between each subsample.

Panel A: Summary Statistics

Variable	Airlines	Mean	Median	Std. Dev.	Min	Max
Accident	701	0.038	0	0.226	0	5
Avg. Number of Qualifications	107	1.951	2	0.527	0.4	4
Succession Factor	107	0.367	0.3	0.171	0	1
Gender Ratio	107	0.870	0.889	0.110	0.4	1
Board Size	107	11.514	11	4.791	3	27
Nationality Mix	107	0.204	0.2	0.217	0	0.8
Std. Dev. of Age of Directors	107	7.297	7.2	2.079	0	14.8
Independent Director Ratio	107	0.822	0.863	0.134	0	1
Busy Board	107	2.143	2	0.752	1	4.5
Std. Dev. of Busy Board	107	1.241	1.2	0.689	0	4.7
Avg. Dir. Time to Retire (Years)	107	10.913	10.5	4.091	2.377	28.5
CEO Tenure (Years)	107	5.747	4.5	4.491	1.1	26.6
CEO Age (Years)	107	58.818	60	6.452	40	79.5
CEO Duality Dummy	107	0.445	0	0.497	0	1
Avg. Airline Utilization Factor	602	7.073	7.1	4.652	0.166	29.4
Net Profit Margin	701	0.005	0.010	0.078	−0.234	0.271
Maintenance Ratio	701	0.116	0.106	0.066	0	0.375
Current Ratio	680	1.133	0.905	0.997	0.044	7.211
Total Asset Turnover	679	1.631	1.139	1.571	0.211	10.588
Growth Ratio	651	0.154	0.018	1.362	−3.109	6.968
Z Score	635	3.691	3.683	2.142	−1.616	10.746
Operating Revenue ($ Billion)	658	0.766	0.241	1.266	0.001	7.39
Unemployment Rate (%)	701	7.771	6.7	4.526	0.16	39.3
Ln (Departures)	701	12.335	12.333	2.173	4.394	16.127
English Origin Dummy	701	0.387	0	0.487	0	1
Efficiency of the Judicial System	701	5.889	5.92	1.515	1	8.9
Corruption	701	6.540	6.32	2.339	1.08	10
Rule of Law	701	7.219	8.33	2.084	1.58	10
Qual. of Air Tran. Infrastructure	701	7.303	7.85	1.398	2.86	9.77

Panel B: Univariate Tests – Characteristics of Firms With/Without Accidents

Airlines with Accidents (Firm-Year Observations)				Airlines without Accidents (Firm-Year Observations)			Chi-Square Test
Variable	Obs.	Mean	Median	Obs.	Mean	Median	p-Value
Avg. Number of Qualifications	96	1.937	1.941	890	1.953	2	
Succession Factor	95	0.305	0.3	865	0.374	0.3	
Gender Ratio	94	0.854	0.846	867	0.872	0.889	
Board Size	93	12.568	12	881	11.405	10	**0.025**
Nationality Mix	92	0.170	0.15	851	0.207	0.2	
Std. Dev. of Age of Directors	96	6.976	7.1	898	7.332	7.2	
Independent Director Ratio	95	0.849	0.9	877	0.819	0.857	
Busy Board	95	2.234	2.071	894	2.133	2	
Std. Dev. of Busy Board	94	1.223	1.2	887	1.243	1.2	
Avg. Dir. Time to Retire (Years)	96	9.478	8.722	911	11.065	10.65	
CEO Tenure (Years)	96	5.478	3.75	986	5.775	4.5	
CEO Age (Years)	96	61.253	61.55	910	59.666	59.6	
CEO Duality Dummy	93	0.569	1	839	0.431	0	**0.002**
Avg. Airline Utilization Factor	131	8.776	8.853	3578	7.011	7	
Net Profit Margin	211	−0.002	0.012	5924	0.0008	0.009	
Maintenance Ratio	211	0.1167	0.102	6217	0.1166	0.106	
Current Ratio	204	0.979	0.795	5979	1.138	0.909	
Total Asset Turnover	207	1.205	0.932	6001	1.646	1.148	
Growth Ratio	170	0.137	0.030	4830	0.155	0.017	
Z Score	197	3.274	3.305	5402	3.707	3.699	
Operating Revenue ($ Billion)	204	0.979	0.795	5758	0.736	0.228	
Unemployment Rate (%)	264	6.944	6.17	6138	7.807	6.7	
Ln (Departures)	270	13.572	13.396	8136	12.294	12.295	
English Origin Dummy	266	0.530	1	8089	0.382	0	**0.001**
Efficiency of the Judicial System	266	6.059	6.745	8090	5.884	5.92	
Corruption	266	7.069	8.52	8090	6.522	6.32	
Rule of Law	266	7.492	8.57	8089	7.210	7.8	
Qual of Air Tran. Infrastructure	266	7.614	8.26	8090	7.292	7.85	

lower-quality monitoring (e.g., Chiang and Lin, 2007; Jensen, 1993).

Moreover, we observe that airlines with accidents have older CEOs than airlines without accidents. Contrary to our expectations, the independent director ratio exhibits higher mean and median values for the subsample with accidents than the subsample without accidents. This may be due to potential endogeneity (which we will address in our multivariate setup), or it may be due to the fact that airlines with accidents have larger boards than airlines without accidents, which may also affect their composition. From a financial perspective, airlines in the subsample without accidents have a higher current ratio, greater asset turnover, and larger Z Scores compared to airlines in the subsample with accidents, with all differences being statistically significant.

Additionally, in Table A1 of the Appendix, we compare the mean and median of the number of accidents for a series of subsamples that are formed around the median of our independent variables (below-median vs. above-median).[18] Our results in there provide additional support for our main hypotheses, suggesting that both an airline's corporate governance as well as its home country's institutional environment affect its safety performance.

6.2. Correlation analysis

Before we estimate our regressions, we calculate the Pearson correlation coefficients between each variable pair. The correlations are reported in Table 4. We indicate in bold the correlation coefficients that exceed a threshold of 0.5 in absolute terms. In our subsequent analysis, we include these variables separately in our regressions to mitigate any multicollinearity concerns.

6.3. Poisson regression analysis

Tables 5 and 6 provide the results of a series of Poisson regressions as per our model discussed in Section 5 (Equation (2)). In Table 5, we focus on the relationship between accident rates and airlines' corporate governance variables (board and CEO characteristics) while controlling for firm-level and country-level determinants. We further explore the individual effects of each country-level variable in more detail in Table 6.

To assess the potential adverse effects of multicollinearity, we compute the variance inflation factor (VIF) for each independent and control variable, as well as the eigenvalues for linear combinations of these variables based on the correlation matrix. The highest VIF observed for any of the explanatory variables is 5.08, specifically for *corruption*. This value is well below the conventional threshold of VIF >10, which is typically used to indicate problematic collinearity (Haunschild and Sullivan, 2002). Similarly, when examining the largest condition index for any linear combination of explanatory variables based on their eigenvalues, we found it to be 13.96. Once again, this value falls comfortably below the traditional cutoff of a condition index >30, which is considered indicative of collinearity concerns. Consequently, we conclude that multicollinearity does not adversely affect the results of our analysis. Nevertheless, we include the explanatory variables both jointly and separately in different model specifications to mitigate any remaining multicollinearity concerns while observing their individual and combined effects.[19]

Additionally, we note that the number of observations changes in our models. The reason for this variation in observations is rooted in the nature of our study, which is a panel data analysis encompassing different countries with inherent data limitations. To ensure inclusivity and robustness in our analysis, we chose to allow the number of observations to change in different regressions based on the availability of data. Our approach is consistent with established practices in the field where researchers often face similar data challenges, especially in cross-country analyses (e.g., Dong et al., 2019; Fardnia et al., 2020; Miller, 2009). Flexibility in sample size has been acknowledged as a pragmatic approach to handle variations in data availability while maintaining the integrity of the analysis. Moreover, we rigorously test our models by running them on subsets of the dataset with fully available data. The results obtained from these subsets are both qualitatively and quantitatively consistent with those presented in our paper, providing confidence in the robustness of our findings.

Model 1 of Table 5 focuses on several board characteristic variables, including the *average number of qualifications* of directors on the board, the *succession factor*, the *gender ratio*, and the *board size*. Consistent with our hypotheses, the coefficient of the *average number of qualifications* is negative and statistically significant, indicating that airlines in which directors are more qualified have fewer accidents; increasing the average number of qualifications of directors by one unit causes a decrease in the log of the number of accidents by 1.97 units. The *succession factor* exhibits a significantly negative coefficient, suggesting that airlines with a lower risk of succession also have fewer accidents.

The *board size* variable exhibits a significantly positive coefficient, suggesting that airlines have more accidents when they have more directors on their board – possibly because boards that become too large are less efficient and provide poorer monitoring than smaller boards. This is consistent with the literature examining the optimal board size suggests that boards should neither be too large nor too small with boards consisting of approximately six members often considered to be ideal (e.g., Chemmanur and Fedaseyeu, 2018).

The *Busy Board* variable exhibits a statistically significant positive coefficient, indicating that airlines with busier directors on the board have more accidents. This is as expected as busy directors are less likely to fulfill their monitoring role in an airline, thereby increasing the likelihood of an accident. Also, the *standard deviation of the busy board* exhibits a negative coefficient, which is statistically significant, suggesting that the higher the heterogeneity of busyness among board members, the lower the number of accidents. Intuitively, when there are less busy directors on a board (which increases the *standard deviation of the busy board* variable), it may cancel the adverse effects of busy directors on the number of accidents.

Moreover, the *average directors' time to retire* also shows a negative, but insignificant coefficient. The coefficient remains negative and becomes borderline significant in Model 4, providing weak support for the notion that an airline with a younger board of directors will have fewer accidents. This provides partial evidence for our expectation that directors who are at earlier stages of their career and further from retirement are better monitors and are less likely to take on additional risk at the expense of the shareholders. Similarly, the *standard deviation of the age of directors* exhibits a positive (albeit marginally insignificant) coefficient. The coefficient remains positive and becomes significant at 10% level, offering weak support for our expectation that airlines with directors from a wider age range also have more accidents. This is probably due to the fact that directors from the same age group behave more homogeneously and have fewer conflicts compared to boards with directors who are more diverse in terms of their age.

In Model 2, we test the effects of CEO characteristics, including *CEO tenure*, *CEO age*, and *CEO duality* on an airline's safety performance. Our results show that CEO tenure has a significantly negative coefficient indicating that the longer the CEO's tenure in an airline, the lower the number of accidents. An interpretation for this finding is that although the CEO's tenure may influence his/her risk-taking behavior, and, consequently the firm's performance adversely, the CEO's insights that come with experience may cancel the negative effects of a seasoned CEO's risk-adversity. Finally, as expected, CEO duality exhibits a positive coefficient, which is not statistically significant, however.

In Models 3, we exclusively focus our attention on financial variables to examine whether our results confirm or contradict previous findings in the literature (see, e.g., Fardnia et al., 2020). We observe that the *current ratio* and *total asset turnover* have negative coefficients (although only the *total asset turnover* is statistically significant), suggesting that

[18] For binary variables, we define the subsamples based directly on the underlying variable values (zero or one).

[19] Due to the high correlation between the *efficiency of the judicial system*, *corruption, the rule of law*, and the *quality of air transport infrastructure* (see Table 4), we only include the *rule of law* (together with other country-level controls) in our models in Table 5. In un-tabulated tests, we re-estimate the models using the other variables (the *efficiency of the judicial system*, *corruption*, and the *quality of air transport infrastructure*) and find similar results. All other variables are included both jointly and separately (i.e., in different model specifications) to observe their individual and combined effects.

Table 4
Correlation Matrix
This table reports Pearson correlation coefficients for all pairwise combinations of the independent variables used in our analysis. Correlation coefficients that exceed a threshold of 0.5 in absolute terms are marked in bold.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)
(1) Avg. Number of Qualifications	1.00																											
(2) Succession Factor	0.10	1.00																										
(3) Gender Ratio	−0.08	0.07	1.00																									
(4) Board Size	−0.35	−0.19	0.10	1.00																								
(5) Nationality Mix	−0.18	0.19	−0.01	0.06	1.00																							
(6) Std. Dev. of Age of Directors	−0.17	0.60	0.24	−0.12	0.04	1.00																						
(7) Independent Director Ratio	0.29	0.05	−0.08	−0.00	−0.19	−0.05	1.00																					
(8) Busy Board	0.18	−0.33	0.06	0.24	−0.01	−0.29	0.09	1.00																				
(9) Std. Dev. of Busy Board	0.25	−0.21	0.18	0.29	0.005	−0.18	0.04	**0.79**	1.00																			
(10) Avg. Dir. Time to Retire	0.17	**0.70**	−0.06	−0.13	0.22	0.01	0.07	−0.26	−0.18	1.00																		
(11) Ln (CEO Tenure)	0.11	0.11	0.09	−0.09	−0.12	0.03	0.26	−0.08	−0.05	0.12	1.00																	
(12) Ln (CEO Age)	0.05	−0.23	0.14	0.14	−0.12	−0.05	−0.03	0.24	0.23	−0.37	0.20	1.00																
(13) CEO Duality Dummy	−0.07	−0.24	0.06	0.37	−0.44	−0.23	0.15	0.14	0.04	−0.06	0.28	0.19	1.00															
(14) Avg. Airline Utilization Factor	0.15	0.07	0.01	0.06	0.23	−0.11	−0.01	−0.03	0.12	0.20	−0.01	−0.02	−0.07	1.00														
(15) Net Profit Margin	0.05	0.15	0.10	−0.01	0.01	0.11	−0.04	−0.08	−0.02	0.04	0.10	−0.17	−0.06	0.09	1.00													
(16) Maintenance Ratio	−0.03	−0.29	0.07	0.03	−0.22	−0.19	0.07	0.04	−0.07	−0.19	−0.02	0.13	0.25	−0.32	−0.14	1.00												
(17) Current Ratio	0.16	0.16	0.16	−0.21	0.08	0.16	0.01	−0.15	−0.09	0.08	0.24	0.05	−0.18	0.01	−0.01	−0.05	1.00											
(18) Total Asset Turnover	0.21	−0.07	0.02	−0.01	−0.01	−0.03	0.10	0.07	0.26	−0.12	−0.07	0.02	−0.17	0.25	0.01	−0.04	−0.06	1.00										
(19) Growth Ratio	−0.04	0.03	−0.09	0.13	0.06	−0.06	−0.01	−0.03	0.001	0.10	0.08	−0.14	−0.02	0.16	0.29	−0.11	0.09	−0.10	1.00									
(20) Z Score	0.15	0.23	0.14	−0.08	0.22	0.12	−0.11	−0.13	−0.03	0.14	0.18	−0.05	−0.26	0.18	0.42	−0.20	**0.60**	−0.01	0.43	1.00								
(21) Operating Revenue	−0.06	−0.04	−0.12	0.25	0.16	−0.03	−0.08	−0.04	−0.02	−0.07	−0.17	0.06	0.08	0.06	0.08	−0.17	−0.15	−0.28	0.11	−0.01	1.00							
(22) Unemployment Rate	0.10	−0.21	−0.11	−0.22	−0.09	−0.12	−0.04	−0.08	−0.09	−0.19	−0.01	0.06	−0.04	−0.02	0.06	0.11	0.05	0.01	−0.05	−0.07	0.13	1.00						
(23) Ln (Departures)	0.33	−0.32	0.08	−0.33	−0.44	−0.09	0.05	0.08	0.01	−0.24	0.04	0.06	0.21	−0.20	−0.03	0.37	0.07	−0.03	−0.19	−0.07	−0.14	0.18	1.00					
(24) English Origin Dummy	0.21	−0.20	0.11	−0.38	−0.16	−0.05	−0.22	0.11	0.05	−0.14	0.01	0.01	−0.05	−0.26	0.02	0.17	0.11	−0.12	−0.14	−0.04	−0.19	0.18	**0.76**	1.00				
(25) Efficiency of Judicial System	−0.23	0.04	−0.01	0.40	0.34	−0.05	−0.22	0.05	0.09	0.11	−0.03	0.04	−0.17	0.16	0.04	−0.12	−0.06	0.07	0.12	0.09	−0.03	−0.31	**−0.54**	−0.29	1.00			
(26) Corruption	−0.21	0.07	−0.05	**0.50**	0.27	−0.04	0.01	−0.01	0.04	0.10	−0.05	0.07	−0.01	0.28	−0.02	−0.09	−0.13	0.14	0.10	0.05	0.12	−0.30	**−0.67**	**−0.74**	**0.80**	1.00		
(27) Rule of Law	−0.02	0.22	−0.09	0.20	0.03	0.12	0.41	−0.07	−0.02	0.15	0.17	−0.15	0.04	0.20	0.11	−0.10	−0.04	0.10	0.23	0.12	0.06	−0.34	−0.42	**−0.68**	0.26	**0.55**	1.00	
(28) Qual. of Air Tran. Infrastructure	0.16	−0.06	−0.12	0.21	−0.29	−0.05	0.36	−0.01	−0.02	−0.01	0.08	−0.01	0.24	0.13	0.03	0.18	−0.07	0.16	0.02	0.03	−0.06	−0.18	0.06	−0.40	0.27	**0.52**	**0.57**	1.00

Table 5
Poisson Regression Results – Firm Level Analysis
This table provides regression results for a series of Poisson regressions (based on Equation (2)) in which the log of an airline's number of accidents is regressed on various firm-level corporate governance measures, while controlling for financial and country-level attributes. Model 1 focuses on the board characteristics, Model 2 focuses on CEO characteristics, and Model 3 focuses on financial performance metrics. In the last column, Model 4, we include all variables together. For each variable, we report the coefficient and the corresponding p-value (in parentheses). Significance at the 10%, 5%, and 1% levels is indicated by *, **, and ***, respectively.

Dependent Variable: Number of Accidents	Model 1	Model 2	Model 3	Model 4
Avg. Number of Qualifications $_{t-1}$	−1.969***			−1.668***
	(0.005)			(0.006)
Succession Factor $_{t-1}$	−3.849**			−7.200**
	(0.041)			(0.013)
Gender Ratio $_{t-1}$	−1.515			−0.642
	(0.386)			(0.771)
Board Size $_{t-1}$	0.128*			0.347**
	(0.072)			(0.029)
Nationality Mix $_{t-1}$	0.238			−0.873
	(0.764)			(0.399)
Std. Dev. of Age of Directors $_{t-1}$	0.206			0.357*
	(0.114)			(0.085)
Independent Director Ratio $_{t-1}$	1.388			4.006*
	(0.435)			(0.095)
Busy Board $_{t-1}$	0.536**			0.701**
	(0.043)			(0.017)
Std. Dev. of Busy Board $_{t-1}$	−0.570**			−0.814**
	(0.031)			(0.026)
Avg. Dir. Time to Retire $_{t-1}$	−0.037			−0.086*
	(0.672)			(0.095)
Ln (CEO Tenure) $_{t-1}$		−0.337**		−0.265*
		(0.041)		(0.074)
Ln (CEO Age) $_{t-1}$		1.148		−0.677
		(0.373)		(0.682)
CEO Duality Dummy $_{t-1}$		0.029		0.036
		(0.932)		(0.942)
Net Profit Margin $_{t-1}$			−1.410**	−0.144
			(0.029)	(0.338)
Maintenance Ratio $_{t-1}$			−0.195***	−0.227***
			(0.001)	(0.001)
Current Ratio $_{t-1}$			−0.020	−0.014
			(0.143)	(0.440)
Total Asset Turnover $_{t-1}$			−0.011***	−0.048*
			(0.003)	(0.054)
Growth Ratio $_{t-1}$			0.114	−0.075
			(0.301)	(0.819)
Z Score $_{t-1}$			−0.118	−0.073
			(0.153)	(0.241)
Operating Revenue $_{t-1}$			0.263***	0.312***
			(0.001)	(0.001)
Avg. Airline Utilization Factor $_{t-1}$	0.066***	0.024	0.041	0.054*
	(0.004)	(0.200)	(0.129)	(0.051)
Unemployment Rate $_{t-1}$	0.015	0.038	0.718	0.157*
	(0.860)	(0.597)	(0.318)	(0.088)
Ln (Departures) $_{t-1}$	0.317*	0.276	0.214***	0.126
	(0.058)	(0.112)	(0.007)	(0.630)
English Origin Dummy $_{t-1}$	−0.483	−0.639	−0.191	−0.785
	(0.484)	(0.343)	(0.596)	(0.258)
Rule of Law $_{t-1}$	−0.346	−0.068	−0.143**	−1.255***
	(0.556)	(0.879)	(0.025)	(0.007)
Constant	−2.734	−9.930	−5.113***	9.892
	(0.653)	(0.144)	(0.001)	(0.262)
Firm fixed-effects	YES	YES	YES	YES
Year fixed-effects	YES	YES	YES	YES
Observations	576	582	2350	489
χ2 Test (p-value)	0.001	0.008	0.001	0.001
Pseudo R^2	0.078	0.024	0.10	0.198
Log likelihood	−182.781	−201.315	−418.050	−134.749
Akaike Information Criterion	397.561	420.630	860.100	321.498
Bayesian Information Criterion	467.258	459.928	929.246	430.499

Table 6
Poisson Regression Results – Country Level Analysis
This table provides regression results for models in which the log of an airline's number of accidents is regressed on various country-level attributes including the macroeconomic, institutional, and infrastructure environment of a given country. As discussed in Section 6.3, we include the explanatory variables both jointly and separately in different model specifications to mitigate any remaining multicollinearity concerns while observing their individual and combined effects. For each variable, we report the coefficient and the corresponding p-value (in parentheses). Significance at the 10%, 5%, and 1% levels is indicated by *, **, and ***, respectively.

Dependent Variable: Number of Accidents	Model 1	Model 2	Model 3	Model 4
Efficiency of the Judicial System	−0.190**			−0.396***
	(0.012)			(0.001)
Rule of Law	−0.152**			−0.121*
	(0.047)			(0.050)
Corruption	−0.098			−0.069
	(0.191)			(0.412)
Qual. of Air Tran. Infrastructure		−0.087**		−0.320***
		(0.046)		(0.001)
English Origin Dummy			0.065	0.387
			(0.714)	(0.122)
Unemployment Rate	0.046*	−0.024	−0.022	0.050*
	(0.081)	(0.178)	(0.216)	(0.057)
Ln (Departures)	0.302***	0.258***	0.242***	0.242***
	(0.001)	(0.001)	(0.001)	(0.001)
Constant	−5.426***	−6.109***	−6.062***	−5.314***
	(0.001)	(0.001)	(0.001)	(0.001)
Firm fixed-effects	YES	YES	YES	YES
Year fixed-effects	YES	YES	YES	YES
Observations	6419	6512	6419	6415
χ2 Test (p-value)	0.001	0.001	0.001	0.001
Pseudo R^2	0.042	0.036	0.036	0.049
Log likelihood	−1241.829	−1268.547	−1248.871	−1232.307
Akaike Information Criterion	2495.659	2545.095	2505.742	2480.615
Bayesian Information Criterion	2536.261	2572.221	2532.81	2534.746

more liquid and particularly more efficient airlines have fewer accidents (i.e., Fardnia et al., 2020). Moreover, the coefficient of the *maintenance ratio* is significantly negative, suggesting that when airlines increase their maintenance and overhaul expenses, they have fewer accidents. Similarly, the net profit margin exhibits significantly negative coefficient, confirming our expectation that more profitable airlines have a lower accident risk. *Operating revenue* exhibits positive and statistically significant coefficients, suggesting that larger airlines experience more frequent accidents.

In Model 4, we include all variables used in the previous columns to examine whether or not our findings still hold in a fully specified model. Other than the *net profit margin* and *CEO tenure*, all variables retain their signs and significance levels. In addition, the coefficients of the *standard deviation of the age of directors*, *independent director ratio* and *average director time to retire* become statistically significant at the 10% level, confirming our observations in Models 1–3.[20] Lastly, we note that all our findings in Table 5 are robust to the choice of Poisson model, as we find similar results using Negative Binomial regressions in Table A2 of the Appendix.

In Table 6, we exclusively focus on our institutional and macroeconomic variables and explore how each of them affects aviation safety when viewed alone. As mentioned above (see Section 5), other than the

[20] In all models, we include the average airline utilization factor which captures the airline's accident risk in terms of total hours flown over total days available. The variable exhibits a positive coefficient (that is only marginally significant in Models 2 and 3, however), providing a weak indication that airlines that employ their air fleet to a fuller extent (with possibly less time for maintenance between flights) are more prone to accidents.

Table 7

Zero-inflated Poisson Regression – Firm Level Analysis

This table provides regression results for a series of Zero-Inflated Poisson regressions (as discussed in Section 7.1). In each model, the log of an airline's number of accidents is regressed on various firm-level corporate governance measures, while controlling for financial and country-level attributes. Panels A reports how the coefficients can explain the excess of zeros (Logistic panel), while Panel B explains the number of accidents after discounting the zero cases (Poisson panel). Model 1 focuses on the board characteristics, Model 2 focuses on CEO characteristics, and Model 3 focuses on financial performance metrics. In the last column, Model 4, we include all variables together. For each variable, we report the coefficient and the corresponding p-value (in parentheses). Significance at the 10%, 5%, and 1% levels is indicated by *, **, and ***, respectively.

Panel A: *Inflate of zeros (Logistic panel)*				
Variables	Model 1	Model 2	Model 3	Model 4
Avg. Number of Qualifications $_{t-1}$	1.026**			1.496**
	(0.029)			(0.017)
Succession Factor $_{t-1}$	3.409**			5.844***
	(0.017)			(0.003)
Gender Ratio $_{t-1}$	2.630			−2.200
	(0.113)			(0.330)
Board Size $_{t-1}$	−0.009*			−0.062**
	(0.098)			(0.046)
Nationality Mix $_{t-1}$	0.261			−0.970
	(0.763)			(0.432)
Std. Dev. of Age of Directors $_{t-1}$	−0.216*			−0.393**
	(0.057)			(0.024)
Independent Director Ratio $_{t-1}$	1.094			−3.216
	(0.566)			(0.212)
Busy Board $_{t-1}$	−0.456*			−0.839***
	(0.085)			(0.007)
Std. Dev. of Busy Board $_{t-1}$	0.395			−0.362
	(0.295)			(0.477)
Avg. Dir. Time to Retire $_{t-1}$	−0.055			0.049
	(0.583)			(0.688)
Ln (CEO Tenure) $_{t-1}$		0.663**		0.174*
		(0.040)		(0.067)
Ln (CEO Age) $_{t-1}$		1.127		−1.358
		(0.466)		(0.558)
CEO Duality Dummy $_{t-1}$		0.384		0.368
		(0.233)		(0.458)
Net Profit Margin $_{t-1}$			−1.314*	−0.124
			(0.100)	(0.353)
Maintenance Ratio $_{t-1}$			−0.359***	−0.568***
			(0.001)	(0.001)
Current Ratio $_{t-1}$			−0.032	−0.020
			(0.170)	(0.374)
Total Asset Turnover $_{t-1}$			−0.019**	−0.056*
			(0.023)	(0.086)
Growth Ratio $_{t-1}$			0.095	−0.106
			(0.352)	(0.933)
Z Score $_{t-1}$			−0.019	0.075
			(0.264)	(0.653)
Operating Revenue $_{t-1}$			0.067***	0.051***
			(0.001)	(0.001)
Avg. Airline Utilization Factor $_{t-1}$	0.066**	0.024	−0.034	0.059*
	(0.012)	(0.367)	(0.717)	(0.057)
Unemployment Rate $_{t-1}$	0.005	0.069	0.004	0.142
	(0.955)	(0.390)	(0.882)	(0.197)
Ln (Departures) $_{t-1}$	0.242	0.115	0.241***	0.013
	(0.142)	(0.481)	(0.002)	(0.958)
English Origin Dummy $_{t-1}$	−0.599	−0.342	−0.382	−0.947
	(0.446)	(0.651)	(0.299)	(0.264)
Rule of Law $_{t-1}$	−0.370	−0.080	−0.141**	−1.534***
	(0.567)	(0.877)	(0.031)	(0.007)
Constant	0.053	−7.988	−5.457***	18.022
	(0.993)	(0.325)	(0.001)	(0.127)
Panel B: *Number of accidents* (Poisson panel)				
Avg. Number of Qualifications $_{t-1}$	−1.124**			−1.944***
	(0.014)			(0.007)
Succession Factor $_{t-1}$	−3.520**			−5.079**
	(0.032)			(0.024)
Gender Ratio $_{t-1}$	−1.459			1.726
	(0.402)			(0.546)
Board Size $_{t-1}$	0.036**			0.024*
	(0.049)			(0.062)
Nationality Mix $_{t-1}$	0.295			−1.276
	(0.716)			(0.313)
Std. Dev. of Age of Directors $_{t-1}$	0.195			0.451*
	(0.178)			(0.059)

(continued on next page)

Table 7 (*continued*)

Independent Director Ratio $_{t-1}$	1.210			2.995**
	(0.487)			(0.039)
Busy Board $_{t-1}$	0.619**			0.797***
	(0.040)			(0.006)
Std. Dev. of Busy Board $_{t-1}$	−0.788*			−0.940**
	(0.052)			(0.038)
Avg. Dir. Time to Retire $_{t-1}$	−0.070			−0.108
	(0.467)			(0.497)
Ln (CEO Tenure) $_{t-1}$		−0.449**		−0.539**
		(0.028)		(0.025)
Ln (CEO Age) $_{t-1}$		1.454		−0.168
		(0.240)		(0.923)
CEO Duality Dummy $_{t-1}$		0.066		0.173
		(0.876)		(0.684)
Net Profit Margin $_{t-1}$			−0.165	−0.079
			(0.314)	(0.903)
Maintenance Ratio $_{t-1}$			−0.155***	−2.259
			(0.001)	(0.708)
Current Ratio $_{t-1}$			−0.022	0.039
			(0.206)	(0.893)
Total Asset Turnover $_{t-1}$			−0.014**	−0.867***
			(0.010)	(0.008)
Growth Ratio $_{t-1}$			−0.105	−0.092
			(0.372)	(0.819)
Z Score $_{t-1}$			0.019	0.082
			(0.459)	(0.424)
Operating Revenue $_{t-1}$			0.305***	0.276**
			(0.001)	(0.011)
Avg. Airline Utilization Factor $_{t-1}$	0.169*	0.028	−0.007	0.044
	(0.051)	(0.332)	(0.720)	(0.366)
Unemployment Rate $_{t-1}$	−0.011	0.023	0.003	0.078
	(0.880)	(0.767)	(0.895)	(0.347)
Ln (Departures) $_{t-1}$	0.308*	0.306	0.214***	0.211
	(0.057)	(0.117)	(0.007)	(0.164)
English Origin Dummy $_{t-1}$	−0.309	−0.658	−0.174	0.887
	(0.552)	(0.287)	(0.630)	(0.183)
Rule of Law $_{t-1}$	−0.362	−0.025	−0.151**	−0.617
	(0.302)	(0.944)	(0.022)	(0.242)
Constant	−1.915	−10.835*	−4.445***	4.228
	(0.662)	(0.088)	(0.001)	(0.694)
Firm fixed-effects	YES	YES	YES	YES
Year fixed-effects	YES	YES	YES	YES
Observations	576	582	2350	489
χ2 Test (p-value)	0.001	0.001	0.001	0.001
Vuong statistic	−2.863***	−2.416**	−0.614	−3.239***

English origin dummy, these measures (the *efficiency of the judicial system*, *corruption*, and the *rule of law)* are scored from zero to ten, with lower scores representing a lower quality institutional environment and/or poorer enforcement of the law. We also employ the country-wide *departures* and *unemployment rate* variables in all models to control for the size of the overall aviation sector and economic well-being in a given country.

In Model 1, we find the coefficient of the *unemployment rate* to be positively, albeit significant at 10% level, associated with the number of accidents. This suggest that airlines in countries with higher unemployment experience higher accidents. Our results show a significant positive coefficient for Ln*(Departures)*, suggesting that airlines in countries with a large volume of flights experience more accidents – as expected. Moreover, we observe significantly negative coefficient for the *efficiency of the judicial system* and *rule of law* confirming our hypothesis that airlines in countries with less efficient judicial systems and poorer law enforcement are more likely to have poorer safety performance.

In Model 2, we examine how the *quality of a country's air transport infrastructure* affects the accident risk of airlines operating in that country. As expected, we observe a significant negative coefficient for the variable, suggesting that airlines in countries with better aviation infrastructures are less likely to have accidents. Additionally, in Model 3, we examine how the *English origin dummy* affects the accident risk of airlines operating in that country, however we do not observe significant coefficient for this variable. Finally, in Model 4, we estimate a fully specified model in which we include all country-level variables. The joint inclusion of some variables reduces the significance of others. However, each variable retains its expected sign.

7. Robustness tests

7.1. Zero inflated regression

Because our dependent variable has an excess of zero counts (aviation accidents are – fortunately – rare), we perform a robustness test in which we employ the zero-inflated regression variant of the Poisson model (Oster et al., 2010; Pérez-Granja et al., 2024) and re-do our analyses from Tables 5 and 6, with the results summarized in Tables 7 and 8, respectively. The zero-inflated Poisson model allows for over-dispersion in the data and combines the logit distribution and the Poisson distribution in a mixed process enabling us to have a large fraction of zeros without restricting the range of outcomes. See Long (1997) and Cameron and Trivedi (2005) for a discussion of the zero-inflated count data models.

Panels A of Tables 7 and 8 report how the coefficients can explain the excess of zeros. This means that a positive value implies that the probability of having an accident diminishes if the value of the variable grows. Panels B of the tables explains the number of accidents after

Table 8

Zero-inflated Poisson Regression– Country Level Analysis

This table provides regression results for a series of Zero-Inflated Poisson regressions (as discussed in Section 7.1). In each model, the log of an airline's number of accidents is regressed on various country-level attributes including the macroeconomic, institutional, and infrastructure environment of a given country. Panels A reports how the coefficients can explain the excess of zeros (Logistic panel), while Panel B explains the number of accidents after discounting the zero cases (Poisson panel). As discussed in Section 6.3, we include the explanatory variables both jointly and separately in different model specifications to mitigate any remaining multicollinearity concerns while observing their individual and combined effects. For each variable, we report the coefficient and the corresponding p-value (in parentheses). Significance at the 10%, 5%, and 1% levels is indicated by *, **, and ***, respectively.

Variables	Model 1	Model 2	Model 3	Model 4
Panel A: *Inflate of zeros*				
Efficiency of the Judicial System $_{t-1}$	1.213**			0.514*
	(0.018)			(0.079)
Rule of Law $_{t-1}$	0.597***			0.775***
	(0.003)			(0.001)
Corruption $_{t-1}$	0.893***			1.002***
	(0.001)			(0.001)
Qual. of Air Tran. Infrastructure $_{t-1}$		−0.315		0.307
		(0.227)		(0.350)
English Origin Dummy $_{t-1}$			1.631**	0.967**
			(0.027)	(0.029)
Unemployment Rate $_{t-1}$	0.054	0.041	0.152**	0.118*
	(0.557)	(0.617)	(0.037)	(0.076)
Ln (Departures) $_{t-1}$	−0.034	0.177	−0.215*	−0.140
	(0.806)	(0.469)	(0.089)	(0.360)
Constant	−4.463	1.111	2.272	−2.546
	(0.186)	(0.571)	(0.159)	(0.495)
Panel B: *Number of accidents*				
Efficiency of the Judicial System $_{t-1}$	0.606***			−0.028
	(0.005)			(0.966)
Rule of Law $_{t-1}$	0.228			0.345*
	(0.166)			(0.076)
Corruption $_{t-1}$	−0.456***			−0.621***
	(0.007)			(0.001)
Qual. of Air Tran. Infrastructure $_{t-1}$		−0.087**	−0.288	0.516
		(0.046)	(0.167)	(0.105)
English Origin Dummy $_{t-1}$				0.939***
				(0.002)
Unemployment Rate $_{t-1}$	−0.007	−0.024	0.006	0.046
	(0.921)	(0.178)	(0.934)	(0.424)
Ln (Departures) $_{t-1}$	0.269***	0.258***	0.403**	0.155
	(0.004)	(0.001)	(0.025)	(0.191)
Constant	−7.198***	−6.109***	−4.593***	−6.249***
	(0.001)	(0.001)	(0.002)	(0.004)
Firm fixed-effects	YES	YES	YES	YES
Year fixed-effects	YES	YES	YES	YES
Observations	6419	6512	6419	6415
χ2 Test (p-value)	0.001	0.001	0.001	0.001
Vuong statistic	2.002**	2.602***	1.974**	1.778*

discounting the zero cases. We observe that in both tables, the coefficients of our variables retain the same signs and significance levels as our results in Tables 5 and 6, thus confirming our earlier findings.

Additionally, we observe that Vuong statistic is significantly negative for all the models in Table 7 (except model 3). This indicates that the Poisson models in Table 5 relatively fit the data better than zero-inflated models in Table 7. Contrary, we find significantly positive Vuong statistics for all the models in Table 8 indicating that zero-inflated models relatively better fit the data compared to Poisson models in Table 6. We conjecture that this performance difference may arise from smaller sample sizes in Tables 5 and 7 compared to those of Tables 6 and 8

7.2. Potentially omitted Variables

In a second set of robustness tests, we further address the concern that potentially omitted variables may bias our result. This problem is common in studies of this kind and according to the literature in the area (Borenstein et al., 2010; O'Connell, 2007; Wooldridge, 2010), random-effects and fixed-effects models can be used to address omitted variable bias.

As noted in Section 5, following similar aviation studies (i.e., Pérez-Granja et al., 2024; Wang et al., 2013), we include firm and year fixed-effects in all our earlier models (Tables 5–8) to reduce any omitted variable biases. However, FE models come with challenges, such as losing between-group variation, which can limit our understanding of how entities (e.g., firms) differ in their overall levels of the dependent variable (Petersen, 2008). Therefore, to complement the fixed-effects analyses, we also apply random-effects (RE) models as a robustness test. RE models incorporate both within- and between-group variation, allowing us to capture both entity-specific changes over time and differences across entities. This approach assumes that unobserved factors are not correlated with the independent variables, which, if met, increases model efficiency and provides broader generalizability to the population level. However, the RE assumption can be restrictive, as unobserved factors are often related to the variables of interest.

Given the trade-offs between these two approaches, we use both FE and RE models to gain a comprehensive view of our results and address any concerns over potential omitted variable bias robustly. By reporting both models, we ensure that our findings are not overly dependent on a single estimation method, adding transparency and reliability to the analysis. While we performed the Hausman test to assess the suitability of the RE model, the results were inconclusive, reinforcing the importance of presenting both FE and RE results to provide a complete perspective.

Table 9 presents the coefficient estimates of Models 1–4 from Table 5 with random effects (instead of fixed-effects).[21] We observe that our

Table 9
Random-effects Panel Poisson Regression
To address any potentially omitted variable concerns related to our empirical modelling, we re-run our Poisson regression (from Table 5) using a random-effects panel Poisson regression. In each model, the log of an airline's number of accidents is regressed on various firm-level corporate governance measures, while controlling for financial and country-level attributes. Model 1 focuses on the board characteristics, Model 2 focuses on CEO characteristics, and Model 3 focuses on financial performance metrics. In the last column, Model 4, we include all variables together. For each variable, we report the coefficient and the corresponding p-value (in parentheses). Significance at the 10%, 5%, and 1% levels is indicated by *, **, and ***, respectively.

Dependent Variable: Number of Accidents	Model 1	Model 2	Model 3	Model 4
Avg. Number of Qualifications $_{t-1}$	−1.396**			−1.641**
	(0.012)			(0.012)
Succession Factor $_{t-1}$	−3.182			−6.874*
	(0.303)			(0.054)
Gender Ratio $_{t-1}$	−2.265			−0.580
	(0.251)			(0.785)
Board Size $_{t-1}$	0.044			−0.032
	(0.414)			(0.576)
Nationality Mix $_{t-1}$	0.664			−0.631
	(0.554)			(0.643)
Std. Dev. of Age of Directors $_{t-1}$	0.313*			0.384**
	(0.072)			(0.041)
Independent Director Ratio $_{t-1}$	3.340			4.122*
	(0.140)			(0.067)
Busy Board $_{t-1}$	0.584			0.471
	(0.128)			(0.230)
Std. Dev. of Busy Board $_{t-1}$	−0.757			−0.528
	(0.141)			(0.338)
Avg. Dir. Time to Retire $_{t-1}$	−0.043			0.094
	(0.636)			(0.390)
Ln (CEO Tenure) $_{t-1}$		−0.180		−0.213
		(0.408)		(0.454)
Ln (CEO Age) $_{t-1}$		0.801		−0.134
		(0.593)		(0.949)
CEO Duality Dummy $_{t-1}$		−0.039		−0.015
		(0.908)		(0.972)
Net Profit Margin $_{t-1}$			−1.370	−0.162
			(0.189)	(0.652)
Maintenance Ratio $_{t-1}$			−0.148**	−0.211**
			(0.044)	(0.012)
Current Ratio $_{t-1}$			−0.017	−0.014
			(0.683)	(0.838)
Total Asset Turnover $_{t-1}$			−0.012	−0.048
			(0.217)	(0.331)
Growth Ratio $_{t-1}$			0.095	−0.032
			(0.670)	(0.963)
Z Score $_{t-1}$			0.021	0.074
			(0.140)	(0.303)
Operating Revenue $_{t-1}$			0.304***	0.281***
			(0.001)	(0.006)
Avg. Airline Utilization Factor $_{t-1}$	0.059	0.019	−0.001	0.045
	(0.220)	(0.690)	(0.911)	(0.421)
Unemployment Rate $_{t-1}$	−0.015	0.023	−0.015	0.145
	(0.860)	(0.755)	(0.639)	(0.166)
Ln (Departures) $_{t-1}$	0.290	0.319	0.253***	0.133
	(0.264)	(0.104)	(0.009)	(0.646)
English Origin Dummy $_{t-1}$	−0.173	−0.791	−0.370	−0.827
	(0.849)	(0.320)	(0.309)	(0.365)
Rule of Law $_{t-1}$	−0.428	−0.096	−0.166**	−1.252**
	(0.422)	(0.834)	(0.040)	(0.041)
Constant Accident	−3.039	−8.897	−5.380***	6.802
	(0.619)	(0.255)	(0.001)	(0.549)
Constant lnalpha	0.192	0.088	0.086	−1.365
	(0.711)	(0.859)	(0.814)	(0.409)
Observations	576	582	2350	489
χ2 Test (p-value)	0.001	0.001	0.001	0.001
Number of Panel ID variables	346	82	82	67

Table 10
Cox Proportional Hazards Model Regression
To further address any methodology-related biasedness and to confirm our original findings in Table 5, we re-run our analysis using a series of Cox Proportional Hazards Model regression (as discussed in Section 7.3). Model 1 focuses on the board characteristics, Model 2 focuses on CEO characteristics, and Model 3 focuses on financial performance metrics. In the last column, Model 4, we include all variables together. For each variable, we report the coefficient and the corresponding p-value (in parentheses). Significance at the 10%, 5%, and 1% levels is indicated by *, **, and ***, respectively.

Dependent Variable: Number of Accidents	Model 1	Model 2	Model 3	Model 4
Avg. Number of Qualifications $_{t-1}$	−0.856**			−0.637*
	(0.033)			(0.087)
Succession Factor $_{t-1}$	−3.421**			−10.679***
	(0.046)			(0.008)
Gender Ratio $_{t-1}$	−0.611			4.919
	(0.867)			(0.651)
Board Size $_{t-1}$	0.204*			0.230**
	(0.064)			(0.041)
Nationality Mix $_{t-1}$	−0.018			−4.342
	(0.992)			(0.430)
Std. Dev. of Age of Directors $_{t-1}$	0.262			0.814**
	(0.292)			(0.032)
Independent Director Ratio $_{t-1}$	−1.244			1.597*
	(0.671)			(0.081)
Busy Board $_{t-1}$	0.972**			1.755***
	(0.018)			(0.007)
Std. Dev. of Busy Board $_{t-1}$	−1.185***			−1.444***
	(0.009)			(0.002)
Avg. Dir. Time to Retire $_{t-1}$	−0.029			−0.602
	(0.841)			(0.224)
Ln (CEO Tenure) $_{t-1}$		−0.602**		−0.653**
		(0.018)		(0.027)
Ln (CEO Age) $_{t-1}$		3.334		−5.732
		(0.214)		(0.380)
CEO Duality Dummy $_{t-1}$		−0.083		−0.359
		(0.902)		(0.896)
Net Profit Margin $_{t-1}$			−2.764**	−0.046
			(0.024)	(0.926)
Maintenance Ratio $_{t-1}$			−0.631	−3.329**
			(0.182)	(0.042)
Current Ratio $_{t-1}$			−0.012	−0.420
			(0.800)	(0.777)
Total Asset Turnover $_{t-1}$			−0.340**	−1.476***
			(0.017)	(0.002)
Growth Ratio $_{t-1}$			0.092	−0.014*
			(0.899)	(0.078)
Z Score $_{t-1}$			0.013	1.189
			(0.440)	(0.132)
Operating Revenue $_{t-1}$			0.054	0.079
			(0.114)	(0.299)
Avg. Airline Utilization Factor $_{t-1}$	0.129**	0.018	−0.001	−0.172
	(0.014)	(0.833)	(0.890)	(0.463)
Unemployment Rate $_{t-1}$	−0.403	−0.290	−0.025	1.156**
	(0.195)	(0.334)	(0.571)	(0.041)
Ln (Departures) $_{t-1}$	0.907*	0.646*	0.329***	0.845**
	(0.065)	(0.074)	(0.004)	(0.048)
English Origin Dummy $_{t-1}$	−3.400*	−2.818	−0.906*	−0.042
	(0.056)	(0.101)	(0.059)	(0.991)
Rule of Law	−2.860**	−2.059*	−0.022	−1.496**
	(0.037)	(0.073)	(0.838)	(0.047)
Observations	358	363	1810	288
χ2 Test (p-value)	0.001	0.001	0.001	0.001

[21] In an untabulated analysis, we also re-estimate our models from Table 6 with FEs and we observe that our results remain qualitatively the same.

findings remain qualitatively consistent with those reported in Table 5 indicating that our results are not subject to omitted variable bias.

7.3. Cox Proportional Hazards Model

One of the disadvantages of the Poisson regression model is that the failure rate (the accident rate in our study) is assumed to be constant throughout the period of investigation. Given the technological progress during our sample period, it is likely that this assumption is violated. The Cox Proportional Hazards Model relaxes this assumption and lets the failure rate remain unspecified. Moreover, in contrast to the Poisson regression model, it does not make any assumptions regarding the shape and distribution of the dependent variable.

Therefore, estimates are likely to be more robust under the Cox model. Many scholars have used the Cox Proportional Hazards Model in their analysis (e.g., Allen and Rose, 2006; Chen et al., 2012; Gupta et al., 2018). We follow prior studies that conduct survival analyses and perform a robustness test using the Cox model (see Table 10). For consistency with our previous tables and to aid the interpretation of our results, we report positive-negative coefficients instead of hazard ratios. Most of the results reported in Table 10 remain consistent with our original findings in Table 5.[22]

8. Discussion

8.1. Interpretation of main findings

Our findings demonstrate that poor governance characteristics, such as overburdened directors and weak board qualifications, are associated with higher accident rates. This aligns with prior studies, including Fich and Shivdasani (2006), which highlight how overburdened or unqualified directors impair effective oversight. Additionally, longer CEO tenure correlates with improved safety outcomes, consistent with findings that emphasize the value of stable and experienced leadership (Michel and Hambrick, 1992).

Our study connects insights from finance and aviation safety literature. On one hand, the finance literature indicates that corporate governance quality is intricately linked to corporate financial performance. On the other hand, the aviation literature shows that airlines with better financial stability tend to have stronger safety records (Fardnia et al., 2020). By simultaneously including proxies for governance quality and financial stability, we show that both independently affect aviation safety. This suggests two channels through which corporate governance influences safety. First, better governance enhances financial stability, which subsequently improves safety outcomes. Second, and more critically, corporate governance directly improves safety by fostering effective organizational structures and implementing rigorous safety standards, regardless of an airline's financial condition. This latter finding is particularly important, as financial stability is often influenced by external factors such as economic conditions and regulatory changes (Nelson and Drews, 2008; Morrell, 2011; Walker et al., 2014). Consequently, strong governance can alleviate the negative effects of external and financial pressures on passenger safety.

For example, the case of the Boeing 737 MAX underscores the dangers of prioritizing cost and market pressures over safety in governance decisions (Larcker et al., 2024). Boeing's reliance on a software patch instead of addressing fundamental structural issues illustrates the consequences of governance failures. This case parallels our findings, where shortcuts in governance correlate with increased safety risks.

8.2. Choice of Model

Most prior studies employ the Poisson model to analyze aviation safety (e.g., Madsen, 2013; Rose, 1990; Wang et al., 2013; Fardnia et al., 2020). However, Pérez-Granja et al. (2024) found that the equi-dispersion assumption of the Poisson model does not hold in their dataset, leading them to favor Negative Binomial and Zero-Inflated Negative Binomial models, with the latter performing best.

Similarly, we assessed the statistical properties of various models in our sample. Unlike Pérez-Granja et al. (2024), we found that the equi-dispersion assumption holds, making the Poisson model most suitable for firm-level analyses. For country-level analyses, however, the Zero-Inflated Poisson (ZIP) model performed better, likely due to the higher prevalence of zero observations in the dataset. We hypothesize that this difference in performance arises from sample size and data structure.

Selecting an appropriate model is particularly critical when working with limited sample sizes. Lambert (1992) highlighted the complexity and potential convergence issues of zero-inflated models in such contexts, as these models may struggle to distinguish between true zero-inflation and standard Poisson processes. Long and Freese (2006) further noted the reduced statistical power of ZIP models in small samples, where the zero-inflation component may be less stable. Similarly, Burnham and Anderson (2004) suggested that model selection criteria, such as AIC and BIC, tend to penalize complex models like ZIP in smaller datasets, favoring simpler alternatives like Poisson models. Empirical studies by Greene (1994) and Hilbe (2011) also indicate that ZIP models are optimal for larger datasets with clear excess zeros, as smaller samples may lead to overfitting.

9. Conclusions

We examine the impact of corporate governance quality on the safety of airlines in a broad cross-country setting. Using data from 70 countries during the period 1990 to 2016, we find a negative relationship between the quality of an airline's corporate governance and its accident propensity. Our results suggest that airlines with less qualified, older, and busier directors, as well as those with a higher risk of director succession, exhibit more frequent accidents. In addition, we observe that airlines with a lower level of age-clustering among the directors tend to have fewer accidents. Finally, the longer the CEO's tenure in an airline, the lower the number of accidents. Our findings demonstrate robustness through an extensive series of tests.

We further examine whether a country's macroeconomic and institutional environment, as well as its infrastructure, affect the safety of airlines headquartered in that country. As expected, our results indicate that airlines based in countries with stronger law enforcement, more stringent legal regulations, and better air transport infrastructure tend to perform better in terms of safety.

The findings of this study have important policy implications for both the airline industry and regulators. To allocate resources more efficiently, international regulatory authorities, such as the International Civil Aviation Organization (ICAO) and International Air Transport Association (IATA), as well as national agencies like the Federal Aviation Administration (FAA), should consider allocating additional resources to the supervision of financially weak airlines and those with lower corporate governance quality measures. Given the limited resources available to oversee operations in the industry, identifying factors that improve the efficiency of regulatory supervision is crucial.

Governments may also consider offering tax incentives, such as tax deductibility for certain airline expenses (e.g., maintenance, training of pilots, and supervision), which have been shown to affect accident propensity. This would at least partially incentivize financially distressed airlines not to sacrifice safety in order to meet cost-cutting targets. Furthermore, authorities should aim to improve governance quality within airlines through practices such as imposing a minimum

[22] In an untabulated analysis, we also re-estimate our models from Table 6 using Cox Proportional Hazards Model and we observe that our results remain qualitatively consistent with those reported in Table 6.

threshold of institutional ownership and encouraging more independent external audits.

Pilot errors remain the most frequent cause of aviation accidents. Therefore, developing and refining policies to reduce accidents caused by pilot errors should be a prime goal for both regulators and airlines. Various approaches could be considered to address this issue, such as reducing working hours, improving working conditions for pilots, and enhancing the supervision of the cockpit during cruising.

Given the impact of poor financial performance and weak governance on accident rates, it is reasonable to conclude that pilots at financially weak airlines, as well as those with poor governance, are more likely to experience conditions leading to an increase in accidents. Airlines in financial distress may have lower hiring standards, such as fewer flight experience hours required, which could further exacerbate safety risks. Therefore, regulatory strategies should consider the higher risks associated with airlines in weak financial states, particularly with respect to how these factors may affect the selection, training, and management of pilots.

Lastly, shareholders and activist investors of airlines should advocate for more qualified, younger, and less busy directors. When hiring a CEO, the boards of directors must take into account the fact that longer CEO tenure tends to correlate with fewer accidents, thus ensuring a stable and experienced leadership team.

CRediT authorship contribution statement

Hamed Khadivar: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Conceptualization. **Pedram Fardnia:** Writing – original draft, Validation, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Thomas Walker:** Writing – review & editing, Supervision, Conceptualization.

Declarations of interest

none.

Appendix

In Table A1, we compare the mean and median of the number of accidents for a series of subsamples that are formed around the median of our independent variables (below-median vs. above-median).[23] For each subsample, we report the number of observations (N), as well as the mean and median of the number of accidents. We employ a series of t-tests and Wilcoxon tests to test for the equality of mean and median accidents between the subsample pairs.

Our univariate tests provide initial support for our main hypotheses, suggesting that both an airline's corporate governance as well as its home country's institutional environment affect its safety performance. The mean and median accidents for airlines with a low (below-median) *succession factor* are higher than the accident rates for the above-median subsample. The differences are statistically significant, indicating (as expected) that airlines with a higher risk of succession have more accidents than airlines with a lower risk of succession. Similarly, the mean and median accidents are significantly higher for airlines with undiversified boards (boards with a smaller *gender ratio*), airlines with larger boards (*board size* $>$ 11 members), boards whose directors are about to retire sooner (*average director time to retire* $\leq$ 10.5 years), and airlines with older CEOs (*CEO age* $>$ 60 years). Airlines with busier boards (*busy board* $>$ 2) and airlines with CEOs who also serve as chairmen of the board of directors (CEO duality = 1) also exhibit a higher number of accidents. The subsample differences for the latter two variables are only significant in the median (not the mean), however. Somewhat surprisingly, the subsample differences suggest that boards with a higher proportion of independent directors (*independent director ratio* $>$ 0.863) are associated with higher accident rates. The difference becomes insignificant in our subsequent multivariate analysis, however.

The subsample differences for other firm-level variables are also as expected: airlines with higher utilization factors (*average airline utilization factor* $>$ 7.1), less liquid assets (*current ratio* $\leq$ 0.905), lower asset turnover (*total asset turnover* $\leq$ 1.139), and lower Z scores (*Z score* $\leq$ 3.683) are more prone to accidents. The *maintenance ratio* also exhibits the expected differences: airlines with a lower maintenance ratio (*maintenance ratio* $\leq$ 0.106) have poorer safety performance, but the subsamples only differ in the mean, not the median.

Finally, on a country level, airlines appear to have poorer safety performance if they are headquartered in countries with a higher flight volume (Ln *(departures)* $>$ 12.335). Contrary to our expectations, however, airlines from countries with a lower-quality institutional environment and poorer enforcement of the law have fewer accidents. This contradiction may be because we do not control the number of departures in each country in our univariate analysis. When we do so in our multivariate analysis, these variables reverse their signs and support our initial expectations.

Table A2 presents the regression results from a series of Negative Binomial models as a robustness check for the Poisson regressions shown in Table 5. The dependent variable in these models is the airline's accident count, with controls for various firm-level corporate governance measures, financial attributes, and country-level factors.

The results indicate that all our findings in Table 5 remain consistent across both model specifications (Poisson vs. Negative Binomial), confirming the robustness of our initial analysis. Furthermore, a comparison of the Log Likelihood values between Models 1–4 in Table 5 and those in Table A2 reveals that the Poisson model provides a better fit for the data in Models 1, 3, and 4.

We also perform Likelihood Ratio Tests (LRT) between each model from Table 5 and its corresponding model in Table A2, with related p-values reported. These tests show that only for Model 2 does the Negative Binomial model better fit the data, whereas for Models 1, 3, and 4, the Poisson model (as shown in Table 5) remains the superior specification. Additionally, the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values are higher for the Negative Binomial models in Table A2, further supporting the suitability of the Poisson model.

Using these same goodness-of-fit metrics, we find similar results supporting the use of the Poisson model for the regressions performed in Table 6 (untabulated for brevity). Collectively, these findings affirm that the Poisson model provides a more parsimonious and effective fit for analyzing airline accidents.

[23] For binary variables, we define the subsamples based directly on the underlying variable values (zero or one).

Table A1

Univariate Test – The Number of Accidents for Subsamples Based on Different Firm- and Country-Level Characteristics.

This table forms subsamples around the median of each continuous or categorical independent variable and compares the accident rate (i.e., the number of accidents per $ billion in revenue) in the below-median vs. above-median subsamples. For continuous variables, p-values of t-tests of differences in means and Wilcoxon tests of differences in medians are reported. For categorical and binary variables, p-values of Chi-Square test are reported.

Subsample 1: Below Median	N, Mean, Median	Subsample 2: Above Median	N, Mean, Median	Tests of differences Means (p-Value) Medians (p-Value)	Chi-Square (p-Value)
Avg. Number of Qualifications ≤2	492 0.123 0	>2	437 0.116 0	 0.793 0.846	
Succession Factor ≤0.3	194 0.154 0	>0.3	403 0.066 0	 **0.006** **0.018**	
Gender Ratio ≤0.889	458 0.165 0	>0.889	445 0.083 0	 **0.004** **0.001**	
Board Size ≤11	470 0.072 0	>11	400 0.170 0		**0.000**
Nationality Mix ≤0.2	441 0.138 0	>0.2	360 0.097 0	 0.179 0.230	
Std. Dev. of Age of Directors ≤7.2	486 0.117 0	>7.2	484 0.115 0	 0.952 0.542	
Independent Director Ratio ≤0.863	485 0.078 0	>0.863	486 0.164 0	 **0.001** **0.000**	
Busy Board ≤2	468 0.091 0	>2	457 0.135 0	 0.106 **0.052**	
Std. Dev. of Busy Board ≤1.2	484 0.113 0	>1.2	410 0.102 0	 0.662 0.841	
Avg. Dir. Time to Retire ≤10.5 Years	502 0.173 0	>10.5	503 0.063 0	 **0.000** **0.000**	
CEO Tenure ≤4.5 Years	498 0.122 0	>4.5	485 0.115 0	 0.793 0.228	
CEO Age ≤60 Years	501 0.091 0	>60	504 0.114 0	 **0.044** **0.013**	
CEO Duality Dummy = 0	516 0.108 0	= 1	415 0.144 0		**0.002**
Avg. Airline Utilization Factor ≤7.1	1856 0.015 0	>7.1	1853 0.063 0	 **0.000** **0.000**	
Net Profit Margin ≤0.010	2741 0.050 0	>0.010	2662 0.055 0	 0.774 0.815	
Maintenance Ratio ≤0.106	3199 0.043 0	>0.106	3229 0.032 0	 **0.052** 0.156	
Current Ratio ≤0.905	3083 0.044 0	>0.905	3100 0.030 0	 **0.013** **0.001**	
Total Asset Turnover ≤1.139	3103 0.054 0	>1.139	3105 0.021 0	 **0.000** **0.000**	
Growth Ratio ≤0.018	2500 0.038 0	>0.018	2499 0.039 0	 0.947 0.933	
Z Score ≤3.683	2799 0.050 0	>3.683	2799 0.029 0	 **0.000** **0.002**	
Unemployment Rate ≤6.7%	3316 0.053 0	>6.7%	3223 0.044 0	 0.167 0.118	
Ln (Departures) ≤ 12.335	4204 0.019 0	>12.335	4201 0.055 0	 **0.000** **0.000**	
English Origin Dummy = 0	5117 0.026 0	= 1	3238 0.054 0		**0.001**

(*continued on next page*)

Table A1 (*continued*)

Subsample 1: Below Median	N, Mean, Median	Subsample 2: Above Median	N, Mean, Median	Tests of differences Means (p-Value) Medians (p-Value)	Chi-Square (p-Value)
Efficiency of the Judicial System ≤5.92	3982	>5.92	4374		
	0.031		0.042	**0.023**	
	0		0	**0.082**	
Corruption ≤6.32	3882	>6.32	4474		
	0.029		0.044	**0.002**	
	0		0	**0.004**	
Rule of Law ≤8.33	4653	>8.33	3702		
	0.029		0.047	**0.000**	
	0		0	**0.001**	
Quality of Air Tran. Infrastructure ≤7.85	4324	>7.85	4173		
	0.028		0.047	**0.000**	
	0		0	**0.000**	

Table A2

Negative Binomial Regression Results – Firm Level Analysis.

This table provides regression results for a series of Negative Binomial models in which an airline's number of accidents is regressed on various firm-level corporate governance measures, while controlling for financial and country-level attributes. Model 1 focuses on the board characteristics, Model 2 focuses on CEO characteristics, and Model 3 focuses on financial performance metrics. In the last column, Model 4, we include all variables together. For each variable, we report the coefficient and the corresponding p-value (in parentheses). *, **, and *** denote statistical significance at the 10%, 5%, and 1% level, respectively.

Dependent Variable: Number of Accidents	Model 1	Model 2	Model 3	Model 4
Avg. Number of Qualifications $_{t-1}$	−0.983**			−1.658***
	(0.018)			(0.006)
Succession Factor $_{t-1}$	−3.630*			−7.174**
	(0.063)			(0.038)
Gender Ratio $_{t-1}$	−1.634			−0.654
	(0.322)			(0.760)
Board Size $_{t-1}$	0.101*			0.240*
	(0.094)			(0.077)
Nationality Mix $_{t-1}$	0.351			−0.874
	(0.662)			(0.401)
Std. Dev. of Age of Directors $_{t-1}$	0.206			0.357**
	(0.132)			(0.015)
Independent Director Ratio $_{t-1}$	1.240			3.965*
	(0.475)			(0.093)
Busy Board $_{t-1}$	0.559*			0.401
	(0.059)			(0.224)
Std. Dev. of Busy Board $_{t-1}$	−0.633*			−1.007**
	(0.088)			(0.012)
Avg. Dir. Time to Retire $_{t-1}$	−0.052			−0.074
	(0.559)			(0.409)
Ln (CEO Tenure) $_{t-1}$		−0.363**		−0.296**
		(0.040)		(0.047)
Ln (CEO Age) $_{t-1}$		1.428		−0.688
		(0.275)		(0.678)
CEO Duality Dummy $_{t-1}$		0.032		0.035
		(0.926)		(0.943)
Net Profit Margin $_{t-1}$			−1.422**	−1.228
			(0.043)	(0.198)
Maintenance Ratio $_{t-1}$			−0.180***	−0.227***
			(0.001)	(0.001)
Current Ratio $_{t-1}$			0.001	−0.014
			(0.930)	(0.428)
Total Asset Turnover $_{t-1}$			−0.016***	−0.048*
			(0.008)	(0.058)
Growth Ratio $_{t-1}$			0.090	−0.041
			(0.224)	(0.833)
Z Score $_{t-1}$			0.027	−0.073**
			(0.214)	(0.044)
Operating Revenue $_{t-1}$			0.175***	0.298***
			(0.001)	(0.001)
Avg. Airline Utilization Factor $_{t-1}$	0.076**	0.027	0.013	0.054*
	(0.013)	(0.323)	(0.697)	(0.051)
Unemployment Rate $_{t-1}$	0.002	0.038	0.161	0.156*
	(0.976)	(0.605)	(0.105)	(0.090)
Ln (Departures) $_{t-1}$	0.306*	0.270	0.229	0.124
	(0.057)	(0.110)	(0.211)	(0.628)
English Origin Dummy $_{t-1}$	−0.436	−0.598	−1.263**	−0.784
	(0.485)	(0.352)	(0.044)	(0.259)
Rule of Law $_{t-1}$	−0.339	−0.030	−1.134**	−1.256***
	(0.481)	(0.940)	(0.011)	(0.007)

(*continued on next page*)

Table A2 (*continued*)

Dependent Variable: Number of Accidents	Model 1	Model 2	Model 3	Model 4
Constant	−2.510	−11.364*	6.678*	9.981
	(0.628)	(0.097)	(0.070)	(0.247)
Firm fixed-effects	YES	YES	YES	YES
Year fixed-effects	YES	YES	YES	YES
Observations	576	582	2350	489
$\chi2$ Test (p-value)	0.002	0.097	0.001	0.001
Pseudo R^2	0.069	0.021	0.098	0.174
Log likelihood	−181.599	−196.276	−417.292	−134.737
Likelihood Ratio Test (Poisson Vs. Negative Binomial)	0.124	0.001	0.218	0.877
Akaike Information Criterion	397.198	412.551	858.583	323.474
Bayesian Information Criterion	470.984	456.216	933.491	436.668

Data availability

Data will be made available on request.

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