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Mathematical Modeling of the Financial Impact of Air Crashes on Airlines and Involved Manufacturers

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Abstract: Despite air transport being the safest way to travel, accidents still happen, which incur massive costs and many consequences for industry and society. The main objective of this research is to determine the financial impact of air crashes by distinguishing between fatal and non-fatal events and their effect on the market stock price of the involved companies of airlines and manufacturers. This study also aims to contribute to the literature about the Event Study Methodology by determining which model of the two most employed in this methodology (Market model or Fama-French model) provides more accurate results. The results reveal that the companies harmed when an air crash occurs include the involved airline, regardless of the causes of the crash if it was a fatal event. However, with non-fatal events, the impact on airlines differs depending on the event's outcome. In any case, effects are immediate, especially on the same day the event occurred. Nevertheless, manufacturing firms show no negative abnormal returns after an air crash. Finally, the Market model is more accurate in this study. These results are important for investors since they show mistrust in air transport and losses only occur in the airline involved, especially if the accident is fatal. In turn, our results provide reassurance to investors in manufacturing companies in the event of such an occurrence. In any case, this study has shown that both airlines and manufacturers must continue to promote and improve safety.

Keywords: airline industry; safety; event study methodology; stock markets; shares price; stock returns; air crashes; market model

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1. Introduction

The commercial airline industry is that which deals with any activity related to air transport, including those performed by airlines and airplane manufacturers. The airline sector is known worldwide as the safest way to travel [1,2]. Of the factors contributing to this, we find technological ones, but also improvements to certain legal, institutional, and cultural factors. Despite being the safest way to travel, accidents still happen and incur massive costs to not only airlines [3], but also to aeronautical manufacturers, industry, and, above all, society. Although human loss can never be compensated, the financial impact of these devastating events on the commercial airline industry has captured the interest of many economists and lawmakers. For this reason, a large body of literature can be found about this matter and to also understand the risks associated with the industry being vital to efficiently administer business.

Nonetheless, when stock markets react to air crashes, in most cases information is not completely available on markets because the cause of the crash remains unknown. This is generally because the National Transportation Safety Board (NTSB) takes months, or even years, to issue a probable cause report [4]. However, investors expect airlines' future cash flow to decrease, probably because of consumers' possible reaction to decide not to fly due to panic, uncertainty and lack of knowledge of the true level of airlines' safety [5,6].

This is why it is vital for the companies themselves and investors to verify whether there is a negative effect on the companies involved after the aviation events and quantify the expected loss.

Thus, this research work has two priority objectives. First, its main objective is to estimate the financial impact of events that have involved airlines and international manufacturers by distinguishing between fatal and non-fatal accidents (according to the National Transportation Safety Board (NTSB), fatal accidents involve mortal victims and complete airplane damage, which is no longer useful; non-fatal events imply serious harm to the passengers onboard, and personal and/or substantial damage to the plane). That is, this study focuses on analyzing the impact of air crashes on the financial value for both airlines and the involved manufacturers. To do so, the financial value will form part of the stock exchange listing because the economic theory indicates that the shares value represents shareholders' credit side and their willingness to provide a company with capital and, thus, considers that it is a good indicator of a firms' financial value.

A priori, it seems logical to expect an adverse reaction to the financial value of both airlines and the involved manufacturers when events occur. However, if the market states that failure is attributed to the airline, then no abnormal returns (AR) in the yields of manufacturers' shares might be found. In light of this, the present research work considers the causes of a crash to seek the relation between the factor that triggered the crash and the market's reaction.

To this end, a sample of international companies is studied, airlines and manufacturers involved in air accidents are analyzed jointly, and the events are classified into fatal and non-fatal accidents, depending on whether or not there are human losses. These aspects add value to the present work, distinguishing it from previous studies.

Second, this study also aims to contribute to the literature about the Event Study Methodology, and to determine which model of the two most employed in this methodology (Market or capital asset pricing model (CAPM) model or the Fama-French model) provides more accurate results in the air industry domain; more specifically, about the short-term impact of both the fatal and non-fatal events that have recently occurred in the sector. This methodology has been applied to study other types of adverse and unexpected events (the so-called black swans) [5] affecting the airline industry, such as the 11 September terror attacks in 2001 [7], the European Ash Crisis generated by the eruption of the Icelandic Volcano Eyjafjallajokull in 2010 [8], Brexit in 2018 [9], and, more recently, the COVID-19 pandemic declared in March 2020, [10].

In other words, this work updates and expands the existing results on the event methodology in the airline industry, verifying its application in the industry worldwide, and pioneering the application of two models (CAPM and Fama-French), being able to show which one provides more accurate results in this sector.

The article is arranged as follows: Section 2 presents background evidence and the hypothesis. Section 3 explains the data and methodology. Section 4 offers empirical results. Section 5 provides the discussion and the main conclusions.

2. Background Evidence and Hypothesis

Common sense tells us that an air crash should significantly impact the involved firms' financial yields. A large body of literature exists about the relation between these events and companies' financial value, and the vast majority have centered on the US airline industry where the Event Study Methodology predominates.

The literature shows that many authors focus on studying the impact of an aggregate set of fatal air crashes [11–19]. They all reveal that the listings of the involved air companies, and those of rival firms, quickly react to events. For instance, Borenstein and Zimmerman [18] indicate that shareholders of airlines with a crash history lose about one percent of their wealth. Consequently, air crashes negatively affect the prices of these firms' shares during and after aviation disasters. On competition, these studies generally conclude that the most fatal accidents can negatively impact rival airlines, while less serious ones can positively influence competing airlines because they will fly more passengers. About the involved company, we find that the more mortal victims there are, the more drastic the drop in profits is [11]. This work is the only one that classifies accidents according to the degree of fatality as low, medium, or high. However, the classification used differs from the one used in our study and does not include accidents without fatalities, only investigates a set of U.S. carriers, analyzing average data for the whole sample, and does not distinguish the effects caused to the airlines and manufacturers involved. On the other hand, Nethercutt and Pruitt [20] center on studying the effect of one crash, the US ValueJet Flight 592, on both the airline itself and its competitors with an event-time analysis. These authors report marked losses for the company's shareholders and other "low-cost" airlines, but significant earnings for the owners of major airline stocks.

Once the effect of fatal accidents on air companies and their rivals is known, it is worth considering the existence of factors whose influence may actually favor such an impact. One of them is the media's presence because it affects the feelings of investors on the stock exchange because the media's activity has been seen to impact investors' decisions, whose concerns are reflected in the lower-demand of risk assets [3]. Another influential factor is the involved companies losing their reputation [21,22]. Even today, operational safety is extremely relevant when evaluating the quality of the product offered by the commercial air sector.

Most authors have focused on studying responses of the financial value of the airline companies involved in accidents, and very few have investigated the effect on the manufacturers of these airlines. Chance and Ferris [23] analyze the price of the participating firms' shares to study the financial impact as a result of the event. According to these authors, the share value is negatively affected on the day that the event takes place and a few days after the event; in other words, the effect is immediate, which falls in line with other authors. Although these authors also study the effect of the airline manufacturers' listings, they indicate investors do not foresee significant financial implications for them. In the same year, Chalk [24] looked more closely at a sample of air crashes to determine if the cause of the aviation disaster is related to the airplane's manufacturer. If such events are related to the manufacturer, the author reports almost immediate negative ARs of 0.97%, 2.80%, and 4.84% on the first day, and 3 days and 8 days after the crash, respectively. However, accidents not related to the manufacturer do not practically involve a negative AR. According to Rose [25], there is evidence to suggest that airlines pay penalties on the market as a consequence of air crashes. Not only does the share value drop, but sales lower considerably. In contrast, airplane manufacturers' are not significantly affected. Thus, they demonstrate that passengers do not tend to modify their behavior toward the plane involved in an accident.

More recently, Walker et al. [26], and Krieger and Chen [27], consider the impact of these events on airline manufacturers' stocks. The first authors do so by determining the link between the hypotheses of mechanical failures put forward in the media and the effect on listings. The second cited authors observe that when the media place blame upon manufacturers, despite the frequent ambiguity of the circumstances of the accident, the initial reactions in these firms are significantly negative, but the impact is insignificant if this is not the case.

Other studies related to this industry study the accident rate and industry's safety. For example, Golbe [28] investigates the accident rates of US airlines and their financial records to seek the correspondence between both, and finds no statistically significant relation. More recently, Kalemba and Campa-Planas [29] examine the relation between safety and other financial indicators to find no significant effect between safety and air companies' profitability. However, they report a significant effect between safety and these companies' income. There are other ways to interpret the effect of air crashes. For example, Raghavan [30] study the relation between the accident and airlines' financial value by dividing between national and regional airlines. This author concludes that only a significant negative relation exists for small regional airlines. Another possible analysis is that of Barnett [31], who evaluates the impact of air traffic fatalities by distinguishing three country categories: developed, developing countries, and less developed countries. This work concludes that airlines from developed countries are much safer than those from the other countries.

As demonstrated, the literature that evidences the impact of air crashes on these firms' financial value is considerable. The main conclusions reached with all these studies state that the impact of an air crash is relevant for the involved firms' stock exchange listings, especially those of airlines, but specially for the aircraft manufacturers barely affects their income. This literature also compellingly evidences that it is quite unlikely that the impact lasts more than a couple of days [23].

Therefore, to fulfill our objectives of analyzing the impact of air crashes on the financial value of both airlines and involved manufacturers, and of determining which model followed to evaluate financial assets is more accurate in this study within the Event Study Methodology; we intend to answer three research questions (RQ), which are built based on three hypotheses (H) as follows.

Hypotheses 1. *There are significant short-term differences among the two models applied in the event methodology, the market model, and the Fama-French model, to determine the profitability of financial assets*.

The literature has observed that there are numerous studies dealing with the short-term effects of air crashes on the financial value of companies, and practically all of them use the event study methodology, applying the CAPM financial asset valuation model which is the simplest one. However, three models calculate the event methodology [32]. This paper aims to test whether there are significant differences between the models to determine the profitability of financial assets in the short term. Starting from this hypothesis, the first RQ is:

1. Within the Event Study Methodology, which method applied to value financial assets provides more accurate results: The Market model or the Fama-French model? The model offering determination coefficients closer to 1 will obtain more accurate results within the Event Study Methodology to study the short-term effect of air crashes on the financial value of the involved firms.

Hypotheses 2. *Air accidents do not equally affect the airlines' financial value and the manufacturers involved.*

The literature has studied on many occasions and from different perspectives the effect of air accidents on the share price of the airlines involved, with unanimous results indicating that the effect is negative and immediate. However, most of the literature considers the airlines as the only ones responsible for the accidents and, therefore, the only ones affected. Very few authors analyze the effect of the manufacturers involved in such accidents on their share price, and they reach divergent conclusions. This is why it is necessary to provide clarity on this issue and a greater amount of recent evidence; in addition, previous studies do not analyze the reaction in airlines and manufacturers together; so, the second RQ to study is:

2. Is there a relationship between an air crash happening and the financial value of the involved firm regardless of it being the airline and the manufacturer?

Hypotheses 3. *Air accidents do not affect the financial value of companies (airlines and manufacturers) equally depending on the nature or severity of the accident.*

Previous studies only focus on analyzing fatal airline events, and there is no evidence in the study of non-fatal airline accidents. Only one study [11] classifies accidents according to their severity. Still, it does not study accidents without loss of life, nor the manufacturers' reaction and the classification used does not follow the NTSB. Even so, its results link the number of fatalities with the losses for the airline. This is why it is essential to expand this line of research because depending on the nature or severity of the accident, the reaction in the financial markets of the different companies involved may not be the same. These results are vital for investors, stockholders, and the companies involved since their investment decisions will be closely linked to these events in the short-term. Although it may seem logical, there is no reason to assume that the reaction in airlines and manufacturers will be similar depending on the type of accident. Therefore, the third RQ is:

3. By distinguishing between fatal and non-fatal events, is there a relationship between an air crash happening and the financial value of the involved firm regardless of it being the airline and/or the manufacturer?

The financial response of the airline and the involved manufacturer to fatal events and, finally, to non-fatal events, is separately studied.

According to the research questions, it is worth stressing that the main contributions made by the present study are to: First, contribute and update the literature about the theme by including much more recent pieces of evidence from the 21st century (from 2000 to 2018); second, the selection of the accidents was based in the following criteria: Study the accidents involving international airlines from three different continents, namely Europe, Asia, and America, rather than only those from America, on which all the previous literature centers; as well as relevant and different pieces of evidence corresponding to market segments (flag carriers and low-cost companies), third, also study the impact on the financial value of the involved manufacturers for which not so many previous pieces of evidence are available; fourth, analyze a set of recent events separately, and not in an aggregate manner as other studies have done, and classify events as fatal and non-fatal; fifth, attempt to closely examine the causes of the accident when abnormal results exist to investigate the relation between the the factor that triggered the accident and the market's reaction; sixth, focus on verifying our results with the Event Study Methodology by means of both the Market and Fama-French models to observe which one provides the most accurate results.

3. Materials and Methods

3.1. Sample and Data

The studied accidents making up our sample were taken from the Aviation Herald [33], a source of information about aviation incidents and novelties. First of all, the accidents of international airlines that took place in the 21st century from 2000 to 2018 were selected from the companies of Full-Service Carriers (FSC) and Low-Cost Carriers (LCC). In the end, the final sample included eight accidents, mainly because the complete daily data about them were not available (data about: companies' financial value at the time of the accident; the market index of the respective markets where the event occurred; the value of the assets of the companies comprising these rates when the accident happened; the treasury bonds of the governments from the countries where the stock market where the studied companies traded at the time of the accident) to obtain a sample with the same number of fatal and non-fatal events, events with many different causes, and airlines from several geographical areas and categories. Moreover, an attempt was made to avoid two accidents or more overlapping that could make the analysis of firms' financial performance difficult and could confound effects.

Table 1 shows the eight accidents making up our sample in chronological order and classified as fatal and non-fatal events. It also includes the date when the accident happened, the place, the analyzed firm (airline (A), manufacturer (M), or both), the studied stock exchange, the aeroplane model, the causes, and the number of victims.

Table 1. The main data about the eight accidents making up the sample.

Seriousness of the Event	Accident	Analyzed Company	Analyzed Market Index	Event Day (t = 0)	Place	Aeroplane Model	Causes	Victims Onboard (on Land)
Fatal	(1) American Airline flight 587	1. Airbus (M)	Paris/CAC 40	12 November 2001	Belle Harbor, New York	A300-605R	Pilot's structural failure	260 (5)
	(2) Spanair flight 5022	2. Spanair, SAS group (A)	Spain/Ibex 35	20 August 2008	Madrid, Spain	MD-82	Incorrect take off configuration, pilot's mistake	148 (0)
	(3) Air France flight 447	3.1. Air France (A) 3.2. Airbus (M)	Paris/CAC 40 Germany/DAC 40	1 June 2009	Atlantic Ocean	A330-203	Stalled, pilot's mistake	228 (0)
	(4) Germanwings flight 9525	4.1. Germanwings (A) 4.2. Airbus (M)	Germany/DAX 30	24 March 2015	French Alps	A320-211	Pilot's deliberate mistake: Suicide	150 (0)
Non-fatal	(5) Southwest Airline flight 1248	5. Boeing (M)	New York/Dow 30	8 December 2005	Midway Airport Chicago	B737-7H4	Runway overrun, pilot's mistake	0 (1)
	(6) Ryanair flight 4102	6.1. Ryanair (A) 6.2. Boeing (M)	London/FTSE 100 New York/Nasdaq 100	10 November 2008	Ciampino Airport, Rome	B737-800	Multiple bird strikes; failed engines	0 (0)
	(7) Asiana Airlines flight 214	7. Asiana Airlines (A)	S. Korea/Kospi	17 June 2013	San Francisco Airport, USA	B777-200ER	Manual final approach mismanagement	3 (0)
	(8) British Airways flight 2276	8.1. British Airways, IAG Group (A) 8.2. Boeing (M)	London/FTSE 100	8 September 2015	McCarran Airport, Las Vegas	B777-236ER	Engine failure upon takeoff	0 (0)

Source: Authors from The Aviation Herald and available reports.

Table 1 shows that four fatal and four non-fatal events are analyzed, and they all happened between 2001 and 2015. The involved companies are American (Boeing), European (British Airways, Air France, Spanair, Ryanair, Germanwings, Airbus), and Asian (Asiana Airlines). Three airlines and three manufacturers involved in fatal events, with the same number for non-fatal ones, are studied; that is, this work studies the effect of air crashes on the stock exchange value of 12 involved companies.

The employed data include prices taken when the stock exchange closes of the airlines and manufacturers involved in accidents, the average yield obtained with their respective stock exchange rates, and the yields of the 10-year bond issued by the French, Spanish, German, American, English, and South Korean governments are used as risk-free assets of each country according to where the involved company trades. This last piece of information includes the yields of both the bonds issued by the governments of the countries where trading markets are found, and of the shares of the main firms comprising these markets' indices at the time of the accident and their market capitalization volume. All these data were obtained daily from: Eurostat, Yahoo Finance, Google Finance, the Economista, Financial Times, and Investing.com [34–39].

3.2. Methodology

First, a descriptive data analysis was carried out. Then, the following assumptions of regressions were verified: linearity, multicollinearity, homoscedasticity, and normality.

This study followed the Event Study Methodology [40] to measure how the stock market price of both the airlines and manufacturers reacted when the air crash occurred, and how time influenced financial market reactions. This methodology estimates what should have been the expected returns ($E(R_{it})$) of the airline and/or the involved manufacturer when no accident took place during the estimated windows. Once the expected returns are known, they are compared to the real returns (R_{it}) to estimate the so-called ARs (AR_{it}) attributed to the accident occurring.

For our study objective, for all eight events (the air crashes selected according to Table 1), the date when the event took place is defined as the event day ($t = 0$) (Table 1). If the crash occurred on a non-trading day, then the following trading day was used as the event day.

The daily listings were obtained for all eight events to know the real returns of each firm (airline and/or manufacturer) participating in every event. In other words, for each firm, we first calculate the daily stock returns as:

$$R_{it} = \frac{P_{it} - P_{it-1}}{P_{it-1}} \times 100 \tag{1}$$

where: R_{it} represents the daily profitability of the shares of a firm i on day t belonging to the estimation window; P_{it} represents prices of the shares of a firm i on day t belonging to the estimation window.

Then, we calculate the *aRs* (AR_{it}) for each firm i on day t as:

$$AR_{it} = R_{it} - E(R_{it}) \tag{2}$$

To estimate models, we use data from 255 to 46 days before each event [10,20].

Basically, three models exist to make the short-term calculation $E(R_{it})$ [40]: the market model [41], the market-adjusted model [32], the Fama-French model [42]. The seminal reference for short-term event studies is Brown and Warner [32], who conduct tests on the first two asset pricing models, and conclude that the results of these models are similar over a short-term window. This is why the present study selects the Market model, which has been widely used in the literature and, as an alternative method, to assess short-term financial assets and to check if it provides more accurate results for our objectives. We also employ the Fama-French model. It has been previously demonstrated that the cumulative aRs (*CARs*) obtained with both models are highly correlated [40]. This means that all the 12 companies herein studied are analyzed with both the Market and Fama-French models.

According to the Market model, the profitability of an asset at a given time (R_{it}) is a function of the profitability of a risk-free asset, the market's profitability and of a factor β known as the risk factor; that is, $E(R_{it})$ is:

$$E(R_{it}) = rf_t + \beta_i \times [E(R_{mt}) - rf_t] \quad (3)$$

where: R_{mt} is the average rate of return of all the stocks trading on the stock market at time t, rf_t is the risk-free rate of return at time t, and β is the risk factor estimated from regression.

This can also be explained according to Equation (4). Accordingly, the risk premium of an asset is proportional to the risk premium of the market where trade is performed according to risk factor β.

$$(R_{it}) = \beta_i \times (R_{mt}) \quad (4)$$

where:

$$(R_{it}) = E(R_{it}) - rf_t \quad (5)$$

$$(R_{mt}) = E(R_{mt}) - rf_i \quad (6)$$

By applying Equation (4), risk factor β is obtained by OLS regression, where the dependent variable is the risk premium of the asset calculated with the yields made with the asset and a risk-free asset (5), and the independent variable is the risk premium of the market, which is calculated with the yields of the market index and a risk-free asset (6). The market risk premium represents the systematic, non-diversifiable market risk: it is the risk of the market in which the particular asset operates. This is captured in (5), and (6).

The employed risk-free assets are calculated by applying an arithmetical rate according to Equation (1). To calculate the market's yield, the rate defined by Equation (7) is applied.

$$E(R_{mt}) = \frac{M_{it} - M_{it-1}}{M_{it-1}} \times 100 \quad (7)$$

where M_{it} refers to the market index value at time t.

According to the Fama-French model, this adds two additional variables to the Market model to reestimate the profitability of shares: Small Minus Big (SMB) and High Minus Low (*HML*) and $E(R_{it})$, defined as:

$$E(R_{it}) = rf_t + \beta_{i1} \times [E(R_{mt}) - rf_t] + \beta_{i2} \times SMB + \beta_{i3} \times HML \quad (8)$$

As with the Market model (Equation (4)), this model is also expressed in accordance with Equation (9), according to which the risk premium of an asset is proportional to the risk premium of the market being traded on according to risk factor β_{i1}, proportional to factor SMB according to β_{i2} and to factor HML according to β_{i3}.

$$(R_{it}) = \beta_{i1} \times (R_{mt}) + \beta_{i2} \times SMB + \beta_{i3} \times HML \quad (9)$$

The three risk factors (β_{i1}, β_{i2}, β_{i3}) are obtained by OLS regression. The two new variables, SMB and HML, are obtained with the data from the market where the studied company trades, and as indicated in Section 3.1. SMB represents the risk-size and is calculated as the daily difference of the mean of the yields of the three companies with less market capitalization and the mean of the three companies with more capitalization. Factor HML represents the risk-value and is estimated as the daily difference of the mean of the yields of the three firms with a high listing price and the mean of the three firms with a low listing price [38].

Both the Market and Fama-French models estimate the expected returns ($E(R_{it})$) of the airline and/or involved manufacturer when no accident occurs.

Having obtained the aRs (AR_{it}), we then calculate the *CARs* (CAR_{ie}) for each firm *i* and for each event window as follows:

$$CAR_{ie} = \sum_{t=t_1}^{t_2} AR_{it} \tag{10}$$

where t_1 and t_2, respectively represent the start and end of the event window.

For our study, we define five different event windows from 5 days before each event to the event day (t = 0), and 1, 2, 5, and 10 days after events [20]; that is, the five event windows are: $t \in \{-5{,}0\}$, $t \in \{-5{,}1\}$, $t \in \{-5{,}2\}$, $t \in \{-5{,}5\}$, and $t \in \{-5{,}10\}$.

Finally, to test the significance of the impact, that is, if the effect on the listings of the involved firms is strong, a significance test is used (T-Test) [27,43] according to Equation (11):

$$\text{T-Test} = \frac{AR_{it}}{SE} \tag{11}$$

where *SE* is the standard error or standard deviation of all the collected daily data. The hypothesis that no relation exists between an accident happening and companies' stock market listing is rejected if the absolute T-Test value is higher than 1.96 (p-value 0.05) [44–46]. In addition, the Sign Test [1,47] is also employed to account for the possible tail risk, or probability of unexpected losses associated with the studied air crashes, as previous research [27,48] has argued that daily stock returns have distributions that are more fat-tailed (exhibit greater skewness or kurtosis) than normal distributions, suggesting the use of non-parametric tests. (p-value 0.05).

4. Results

4.1. R.Q.1. Within the Event Study Methodology, Which Model Followed to Value Financial Assets Provides More Accurate Results: The Market Model or the Fama-French Model?

To select the model that values financial assets (the Market or the Fama-French model) within the Event Study Methodology with more accurate results, that is, with determination coefficients closer to 1 [49], and to answer the first research question, we take the results of the regression analyses performed for all 12 studied companies, as shown in Tables 2 and 3 and classified as fatal and non-fatal events, respectively.

From the determination coefficients and the significance of the variables in each model, apparently both models offer a similar fit. Moreover, making decisions according to R^2 values is complicated because, for fatal events, in three cases the Market model presents a higher determination coefficient than the Fama-French model, while the exact opposite occurs in the other three cases. A similar situation appears with non-fatal events because in three of the six cases, the R^2 values of the Market models are higher than in the Fama-French models, and the opposite occurs in the other three cases. Nevertheless, according to the significance of the variables, e.g., variables SMB and HML of the Fama-French model are not significant. Introducing these variables into the regression analyses may lead to an additional error in the model that reduces its goodness-of-fit. Therefore, we conclude that, in most cases the multivariable Market model offers results that come closer to reality. Therefore, the Market model offers closer determination coefficients to 1 and, hence, more accurate results.

4.2. R.Q.2. Is There a Relation between an Air Crash Happening and the Financial Value of the Involved Firm Regardless of It Being an Airline and/or the Manufacturer?

Using the *Ars* and *CARs*, we estimate the magnitude, nature and duration of each impact on the financial value of the airline and/or manufacturer to answer the second research question of this research work. The results are found in Table 4, and are classified according to the seriousness of the event as fatal and non-fatal. According to this classification, the results are discussed in Section 4.3 because they answer the third research question herein posed.

Table 2. Regression results of fatal events.

	American Airlines Flight 587		Spanair Flight 5022		Airfrance Flight 447				Germangwings Flight 9525			
	Airbus (M)		SAS Group, Spanair (A)		Airfrance (A)		Airbus (M)		Lufthansa (A)		Airbus (M)	
Variables	**Market Model**	**Fama-French Model**	**Market Model**	**Fama-French Model**	**Market Model**	**Fama-French Model**	**Market Model**	**Fama-French Model**	**Market Model**	**Fama-French Model**	**Market Model**	**Fama-French Model**
Cte.	−0.0004	−0.007	0.00	0.008	0.009	0.00	−0.003	−0.03	−0.000	−0.0002	0.001	0.0002
RCAC40	1.633 ***	−1.949 ***			0.54 *	0.491 **						
RIbex35			1.89 **	1.963 ***								
RDAX							1.01 **	1.016 *	0.99 **	0.974 **	1.01 **	0.92 **
SMB		0.011		−0.79		−1.007		0.180		0.438		−0.53
HML				0.318		−0.806		0.128		0.282		0.32
R^2	60.3%	68.1%	66.67%	69.4%	32.6%	53.9%	79.59%	77.70%	83.88%	82.13%	81.7%	80.6%

RCAC40, Ribex35, RDAX are the yields of market index CAC 40, Ibex 35 and DAX, respectively. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 3. Regression results of non-fatal events.

	Southwest Airlines Flight 1248		Ryanair Flight 4106				Asiana Airlines Flight 214		British Airways Flight 2276			
	Boeing (M)		Ryanair (A)		Boeing (F)		Asiana Airlines (A)		British Airways (A)		Boeing (M)	
Variables	**Market Model**	**Fama-French Model**	**Market Model**	**Fama-French Model**	**Market Model**	**Fama-French Model**	**Market Model**	**Fama-French Model**	**Market Model**	**Fama-French Model**	**Market Model**	**Fama-French Model**
Cte.	0.0016	0.0011	−0.011	−0.0107	0.003	−0.0006	−0.002	−0.0029	0.008	0.0077	−0.0012	0.003
Rdow30	1.072 **	1.071 *										
RFTSE100			1.179 *	1.156 **					0.963 ***	1.132 ***	−0.995 **	1.196 ***
Rnasdaq100					1.104 **	1.161 **						
Rkospi							0.859 **	0.733 ***				
SMB		0.369		−0.043		0.119		0.589		−0.287		−0.360
HML		−0.256		−0.063		0.181		0.153		−0.493		1.953 *
R^2	56.04%	53.29%	81.09%	77.72%	63.8%	60.6%	56.63%	66.16%	65.5%	71.6%	58.06%	89.79%

Rdow30, RFTSE100, Rnasdaq100, Rkospi are the yields of market index DOW 30, FTSE 100, Nasdaq 100 and Kospi, respectively. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 4. Abnormal returns (Ars) and cumulative abnormal returns (CARs).

Seriousness of the Event	Accident	Analyzed Firm	Date (*t* = 0)	Valuation Model	AR (*t* = 0)	CAR (−5, 0)	CAR (−5, 1)	CAR (−5, 2)	CAR (−5, 5)	CAR (−5, 10)
Fatal	American Airlines flight 587	Airbus (F)	12 November 2001	MM	−4.79%	−4.79%	−1.28%	1%	4.57%	4.37%
				T-Test		−2.375 *	1.743	1.126	0.437	0.707
				Sign T.		2.000 *	2.050 *	1.750	0.687	0.507
				FFM	−7.16%	3.14%	12.76%	16.80%	10.35%	14.91%
				T-Test		−3.961 *	5.321 *	2.234 *	−0.773	−0.333
				Sign T.		2.030 *	2.005 *	1.750	0.685	0.179
	Spanair flight 5022	Spanair (A)	20 August 2008	MM	−8.94%	-8.94%	−9.78%	−4.08%	−7.42%	−8.75%
				T-Test		-3.598 *	−0.335	2.293 *	−1.830	0.921
				Sign T.		1.005	2.033 *	2.001 *	1.781	1.996 *
				FFM	−11.13%	−11.13%	−10.84%	−5.46%	−10.28%	−11.34%
				T-Test		−4.495 *	0.118	2.179 *	−2.144 *	0.802
				Sign T.		2.011 *	1.998 *	2.036 *	2.002 *	2.009 *
	Air France flight 447	Air France (A)	1 June 2009	MM	−3.48%	−6.40%	−2.58%	−7.71%	−27.24%	−34.04%
				T-Test		−1.042	1.144	−1.535	−1.684	−0.889
				Sign T.		2.013 *	1.998 *	1.987 *	2.054 *	1.960 *
				FFM	−6.09%	−14.51%	−8.36%	−11.92%	−37.70%	−39.53%
				T-Test		−2.261 *	2.283 *	−1.321	−2.146*	−0.986
				Sign T.		1.999 *	2.062 *	2.100 *	1.984 *	2.000 *
		Airbus (F)		MM	−2.05%	−2.05%	−3.92%	−2.73%	−0.09%	5.06%
				T-Test		-0.809	-0.741	0.473	−0.22	0.043
				Sign T.		2.018 *	1.898	2.100 *	1.968 *	1.960 *
				FFM	−2.17%	−2.17%	−3.93%	−3.12%	−1.70%	3.96%
				T-Test		−0.820	−0.665	0.307	−0.562	0.18
				Sign T.		2.005 *	2.103 *	2.058 *	1.968 *	1.996 *

Table 4. *Cont.*

Seriousness of the Event	Accident	Analyzed Firm	Date (t = 0)	Valuation Model	AR (t = 0)	CAR (−5, 0)	CAR (−5, 1)	CAR (−5, 2)	CAR (−5, 5)	CAR (−5, 10)
	Germanwings flight 9525	Lufthansa (A)	24 March 2015	MM	−4.22%	14.30%	5.02%	9.53%	9.47%	7.39%
				T-Test		−2.488 *	−5.463 *	2.653 *	−4.004 *	0.079
				Sign T.		2.301*	2.064 *	1.998 *	2.005 *	1.954
				FFM	−2.05%	−2.05%	−4.87%	−7.86%	−8.24%	−10.59%
				T-Test		−1.145	−1.568	−1.669	0.213	−1.452
				Sign T.		2.000 *	1.879	2.105 *	2.2060 *	1.992
		Airbus (F)		MM	−0.74%	−0.74%	−3.30%	−2.17%	−2.75%	−3.10%
				T-Test		−0.390	-1.360	0.598	0.104	−0.149
				Sign T.		1.968 *	2.056 *	2.130 *	2.047 *	1.972*
				FFM	−0.85%	−0.85%	−4.72%	−2.79%	−3.38%	−3.32%
				T-Test		−0.435	−1.992 *	0.99	−0.208	0.151
				Sign T.		2.008 *	1.968 *	2.019 *	2.109 *	1.993 *
	Southwest Airline flight 1248	Boeing (F)	8 December 2005	MM	0.92%	0.92%	−0.01%	0.75%	0.96%	−0.29%
				T-Test		0.895	−0.909	0.745	0.387	−0.160
				Sign T.		1.001	0.502	0.251	0.218	0.039
				FFM	1.15%	1.15%	0.30%	1.10%	1.17%	−0.30%
				T-Test		1.080	1.080	0.745	0.289	−0.300
				Sign T.		0.998	0.507	0.255	0.031	0.039
	Ryanair flight 4102	Ryanair (A)	10 November 2008	MM	0.51%	0.51%	2.08%	−2.16%	7.31%	10.23%
				T-Test		0.259	0.80	−2.174 *	−1.996 *	2.283 *
				Sign T.		1.021	1.507	1.750	0.687	0.040
				FFM	0.54%	0.54%	1.96%	−1.98%	7.86%	10.94%
				T-Test		0.254	0.672	−1.866	−1.687	2.163 *
				Sign T.		1.056	1.509	1.754	0.687	0.179
		Boeing (F)		MM	0.00%	0.00%	−2.59%	−7.90%	−10.85%	−8.27%
				T-Test		0.001	−0.700	−1.428	−1.385	0.397
				Sign T.		2.001*	2.059 *	1.998 *	2.102 *	1.999 *
				FFM	−0.53%	−0.53%	−3.66%	−8.30%	−13.95%	−13.78%
				T-Test		−0.136	−0.808	−1.19	−1.605	0.674
				Sign T.		1.998 *	2.050 *	2.001 *	2.106 *	1.978 *

Table 4. *Cont.*

Seriousness of the Event	Accident	Analyzed Firm	Date (t = 0)	Valuation Model	AR (t = 0)	CAR (−5, 0)	CAR (−5, 1)	CAR (−5, 2)	CAR (−5, 5)	CAR (−5, 10)
Non-fatal	Asiana Airlines flight 214	Asiana Airlines (A)	06 July 2013	MM	−4.53%		−4.53%	−3.85%	−5.82%	−6.05%
				T-Test			−2.954 *	0.44	0.579	0.140
				Sign T.			2.100 *	1.877	2.064 *	2.000 *
				FFM	−4.21%		−4.21%	−4.26%	−4.05%	−3.62%
				T-Test			−3.111 *	−0.03	0.930	0.268
				Sign T.			1.998 *	2.036 *	2.140 *	2.001 *
	British Airways flight 2276	British Airways (A)	8 September 2015	MM	−0.7%	−0.7%	−1.34%	−1.39%	−0.02%	−2.26%
				T-Test		−0.322	−0.296	-0.022	0.41	0.329
				Sign T.		2.015	1.998 *	2.033 *	1.968 *	1.960 *
				FFM	−4.69%	−7.35%	−11.10%	−13.14%	−14.39%	−15.42%
				T-Test		−2.383 *	−1.90	−1.040	0.834	1.202
				Sign T.		2.105 *	2.036 *	1.981 *	2.011 *	1.996 *
		Boeing (F)		MM	2.63%	2.63%	1.89%	2.60%	4.01%	4.60%
				T-Test		0.957	−0.270	0.256	0.513	−0.658
				Sign T.		2.066 *	1.875	1.991 *	2.055 *	0.039
				FFM	1.52%	1.52%	3.46%	3.49%	9.37%	8.77%
				T-Test		1.119	1.426	0.024	0.807	−0.443
				Sign T.		2.000 *	1.989 *	2.113 *	2.066 *	0.041

MM: Market model; FFM: Fama-French Model. M: Manufacturer. A: Airline. * Significant T-Test and Sign Test.

According to the obtained *CARs*, we conclude that an accident generally has an immediate effect on the involved airline's listing, regardless of the cause of the accident. So we confirm that a negative relationship exists between an air crash and the involved airline's financial value. Two of the six cases studied about airlines show a significant effect between the event and this company's financial value on the event day according to the Market model, and on three of the six companies according to the Fama-French model. At 1-day after the event, we find that the effect is significant on two airlines in each model. For 2-days after the event, it is significant on three companies in the Market model and on one company with the Fama-French model. For 5-days after the event, it is significant only on two airlines for the Market model, and on one for the Fama-French model. Finally, 10-days after the event, it is significant only for one company, and both models confirm this result. Therefore, the most significant effects are short-term, and they almost immediately appear either on the event day or 1 or 2 days later. However, the more days following the event, the milder the effect on airlines' financial value.

When analyzing the effect on the manufacturing companies of the involved aeroplanes, the event's effect on these firms' listing is not generally significant. A significant effect on manufacturing companies appears on the event day in only one of the six studied cases according to the Market model, and on the event day and the following 1 and 2 days according to the Fama-French model, and both for American Airlines flight 587. Nonetheless, the significant *CAR* value might more likely be due to the fear felt throughout the aircraft industry after the attacks on New York on 11 September 2001, which took place only 2 months before this event. Another significant effect is seen on the manufacturing company Airbus (Germanwings flight 9525), but only according to the Fama-French model. So it cannot be confirmed with the Market model and it only appears 1 day after the event. All the other values for this event are similar between models and present no significance.

4.3. R.Q.3. By Distinguishing between Fatal and Non Fatal Events, Is There a Relation between an Air Crash Happening and the Financial Value of the Involved Firm Regardless of It Being the Airline and/or the Manufacturer?

To answer research question 3, the seriousness of each event in the sample is first studied to classify it as a fatal or non-fatal event. Then, the short-term ARs and CARs of each impact on the financial value of the airline and/or the manufacturer are studied similarly to the way indicated in *R.Q.2* but, in this case, by applying the cited classification. The obtained results are shown in Table 4.

First of all, we observe that three airlines and three manufacturers are studied in the four analyzed non-fatal events. Of these results we find that, according to the obtained *CARs*, a significant effect of the event on two of the three airlines appears on their financial value according to the Market value. However, in one model, the effect appears only 1 day after the event, and on days 2, 5, and 10 after the event in the other model. Perhaps this difference among events is due to the outcome of the accident. For the two significant cases, accidents caused major damage to airplanes, and human damage included the death of three passengers onboard in one. Moreover, the accident whose effect was not significant was Ryanair flight 4102, which performed a successful emergency landing after multiple bird strikes on its route. So for non-fatal events we can state that the financial impact on airlines, for at least the studied cases, depends on the event's outcome. Therefore, a significant effect generally appears on the listing of the airlines with non-fatal events.

As to whether a significant impact of non-fatal air crashes exists on the manufacturers' financial value, we verify that in none of the three cases studied in these circumstances does the accident significantly influence the listing of the involved manufacturers regardless of the causes and consequences of the event.

Second, three airlines and three manufacturers are studied in the four analyzed fatal events. According to the results in Table 4, two of the three studied airlines with fatal events present significant *CARs* on the event day, one also does 2 days later, while the other airline (the Germanwings flight) still has significant *CARs* 1, 2, and 5 days after the event. This demonstrates a statistically significant impact of fatal events on the airlines' stock exchange value.

For the impact of fatal air events on manufacturers' financial value, according to the Market model, only a significant *CAR* on the event day is found for one of the studied cases, which is American Airlines flight 587. As pointed out in Section 4.2, this impact is accounted for mainly by this event taking place shortly after the terrorist attacks of 11 September 2001. Therefore, we can state that no relation exists between manufacturers' financial value and fatal air crashes.

5. Discussion and Conclusions

A large body of literature exists about air crashes and their effects on the financial yields of the involved firms. According to this literature, a negative correlation appears between adverse events and firms' financial value [7–10,50], and this correlation tends to be statistically significant when considering brief periods of time after an air crash [23], or when only fatal events are studied [3,11]. Nevertheless, these studies have focused on US airline accidents and show aggregate results from a large set of events. So it is impossible for them to detail if their results depend on the causes and consequences of these events.

The present document analyzes the financial impact of both fatal and non-fatal air crashes on airlines and the involved manufacturers for the period 2000–2018. Given our aim to work with a wide-ranging sample, we selected a set of eight accidents involving six airlines (both FSC and LCC) and six manufacturers, all from three continents: America, Europe, and Asia. All the events took place in the 21st century. To evaluate the immediacy and magnitude of the financial consequences, this short-term study evaluates the ARs for each financial day by presenting the CARs from 20 days prior to the event to 10 days following it with five time windows.

According to the Event Study Methodology followed for this study, the results are calculated using two different models: Market or CAPM and Fama-French. The first research question attempts to answer which of these two models better fits the data employed for the analysis to a greater extent. The optimum model for our study is the Market model, whose results come closer to reality. Therefore, in the airline industry, and more specifically when applying the Event Study Methodology to evaluate the short-term impact of events on the involved firms' returns, the Market model is the more suitable. This finding coincides with other more generic studies [40].

For research question 2, that of a relation between air crashes and the financial value of the involved firms, we see that a negative relation exists between air crashes and the involved airlines, which is verified by both the models that value financial assets, and it also agrees with most of the literature works about this theme [3,30]. However, no significant relation exists for the involved manufacturers, which contradicts Nancy L. Rose [25] and coincides with Chance and Ferris [23]. The effect is immediate for both company types (A and M): for manufacturers, only one of the six studied companies shows a significant relation on the event day; for airlines, between 2 and 3 of the six analyzed firms obtain significant results on the event day, and 1, 2, and 5 days later, but only one of the six does 10 days after the event. In these cases, we find that the relation exists independently of the causes of the event. Our results confirm other studies into the immediacy of the response of securities markets to knowledge of such events generally on the event day, or 1 or 2 days after the event [3,11,23].

On research question 3, which asks whether the relation studied in research question 2 is validated when classifying air crashes into fatal and non-fatal events, we conclude that this classification confirms our previous results. This means that a negative relation exists between airlines' listings and air crashes regardless of events being fatal or not. In both cases, two of the three studied firms present this significant relation. However, with non-fatal cases, this relation depends on the outcome and causes of the event. For manufacturers, we confirm that no relation exists between their financial value and impacts regardless of events being fatal or not. Moreover, these results are independent of both the causes and consequences of events.

In light of all this, we conclude that the involved airlines harmed when an air crash occurs and regardless of the causes of the event being fatal or not. However, this relation depends on the outcome of an event if the crash is not fatal. Nevertheless, Airbus and Boeing, the manufacturers considered in this study, obtain no negative ARs after an air crash.

This work also reveals the media impact noted on the days immediately after an air crash. Regardless of news being confirmed or not because the true causes and responsible parties of an accident frequently remain unknown until much later, we see immediate negative returns for airlines, which barely affect manufacturers.

Nowadays, operational safety is a very much debated matter, and this study demonstrates that both airlines and manufacturers must continue to promote and improve it. An air crash implies major losses of reputation, [51,52] and, consequently, passenger infidelity, who may no longer trust air transport or the involved airline in particular.

Given the importance of aviation safety for society, aviation companies, and investors, it is vital to understand market reactions to aviation accidents better. Undoubtlessly, as Taleb [5] argues air accidents are difficult to predict, and rather than trying to predict them, we should accept our limitations but also accept the existence of black swan events [5] and focus on prevention. Therefore, in the future, we intend to apply the Sliding Window Analysis to confirm the impact of such kinds of events [53,54] but also expand the number of events of different nature to be studied (accidents but also the effect of the COVID-19 pandemic on the airline industry and on manufacturers) to make our results more reliable and update them to take into account technological developments in the sector in addition to other aspects, such as the consumer reaction.

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