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The Impact of the CrowdStrike Incident in the Stock Market

An Event Study Analysis for Airlines

MASTER DISSERTATION

João Francisco Maciel Costa
MASTER IN MANAGEMENT

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ABSTRACT AND KEY WORDS

This study investigates the short-term market effect of the CrowdStrike IT outage in the airline industry. Using an event study methodology, we provide evidence that airline stocks respond significantly negatively to the technology disruption within two days before and after the event day. IT disruptions create friction in daily operations—such as schedule disruptions, flight delays or cancellations, negative externalities, and customer dissatisfaction—ultimately leading to a loss of value for airlines. The results also show that the most affected airlines are those from main CrowdStrike customer's countries (mainly non-Asian countries) and an irrelevance of the business model. Finally, the extent of the stock market's response to the CrowdStrike IT outage is influenced by other airline characteristics such as profitability, size, leverage, and cyber risk rating.

Keywords: Airline industry; Market impact; Event Study; CrowdStrike IT outage.

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1. INTRODUCTION

CrowdStrike is among the leading global cyber security firms, therefore, the IT disruption of July 19, 2024, the largest IT outage in history[1], unsurprisingly caused extensive service disruptions. Originating from a faulty update to the Falcon security software[2], the failure impacted many sectors that use the CrowdStrike product, with the airline industry suffering the most significant repercussions. Despite the company discovering the problem rapidly and issuing a fix "merely" 78 minutes after the original update went out[2], the damage was irreversible, leading to widespread delays, cancellations, and operational challenges, especially in Western countries. As a result, 3,000 flights have been cancelled, and more than 11,400 others were delayed in the US. Globally, more than 42,000 flights were postponed on the first day[3].

In today´s world, almost every company depends on functioning and robust Information Technology (IT) systems to operate (Franke, 2020), and the airline industry is no different. IT drives modern technological progress and globalisation, serving as a key catalyst for economic and technological growth (Ejiaku, 2014). For airlines, IT systems are used for many operations, such as computerised airline reservation systems, flight operations, telecommunications, websites, and maintenance systems, including servers and check-in kiosks (Gokhale, 2018).

Globally, the aviation industry has experienced growing passenger traffic, with advancements in IT playing a key role in sustaining this acceleration. However, the high investments in IT in the airline industry mean that one of the threats the airline industry is exposed to is technological disruptions (Gokhale, 2018). According to the financial literature, business interruptions caused by technology failure or cyber-incidents can have severe financial repercussions, including revenue loss, decreased productivity, reputational damage, and significant recovery costs (e.g., Bharadwaj et al., 2009; Benaroch et al., 2012; Kamiya et al., 2021), plus the negative impact on airlines will be larger if the reduction in future cash flows induced by current poor service is more long-lasting (Ramdas et al., 2013).

In this study, we examine the short-term effects caused by the CrowdStrike IT outage on listed airlines, therefore our research question is the following: What was the short-term impact of the CrowdStrike incident on airline stock prices?

Two recent studies analysed the effects caused by the CrowdStrike IT outage on tourism, airports, airlines, and IT industries. Demir and Demir (2024) analysed tourism-related news on websites and conducted interviews with tourism professionals to study the impact of the

CrowdStrike IT outage on the tourism industry. Using an event study methodology, Grebe et al. (2024) showed that the unexpected CrowdStrike IT outage led to short-term negative abnormal returns in airports, airlines, and IT industries. This study distinguishes itself from previous studies because it only analyses the impact of the CrowdStrike IT outage on the airline industry (the most affected by the event) and extends the literature through the addition of new determinants of abnormal returns, such as location, cyber risk rating, and business model, not covered in previous studies. By doing so, our research addresses a critical gap in the understanding of the short-term market impact of the CrowdStrike IT outage on airlines, while also contributing to the limited literature on the financial effects of IT failures—particularly operational IT failures, such as the CrowdStrike case, which remain significantly underexplored (Bharadwaj et al., 2009).

The remainder of the dissertation is structured as follows: the next chapter aims to provide an overview of the existing research on the topic to better understand the latter. The third chapter focuses on the explanation of the data collected as well as the methodology used to obtain the results. The fourth chapter is set to expose and explain the results obtained from the dissertation, followed by the fifth chapter, which aims to conclude the work.

2. LITERATURE REVIEW

2.1. EVENT STUDY METHODOLOGY

The event study methodology is quantitative in nature, as it applies statistical techniques to historical stock data. It serves as a tool to determine whether unexpected events cause significant deviations in stock returns, thereby assessing their market impact (MacKinlay, 1997; McWilliams & Siegel, 1997). The latter is valid if, according to McWilliams and Siegel (1997), the methodology meets three key assumptions: (i) markets are efficient, (ii) the event is unanticipated, and (iii) no confounding occurrences take place during the event window. This approach relies on the semi-strong form of the Efficient Market Hypothesis (EMH), which assumes that stock prices fully and rapidly reflect all publicly available information (Fama, 1970).

As reviewed by Corrado (2011), the event study methodology was initially developed as a statistical tool for empirical research in accounting and finance. Since then, it has expanded into many other fields, including marketing (e.g., Sood & Tellis, 2009; Mazodier & Rezaee, 2013;

Wiles et al., 2010), sports (e.g., Zawadzki & Potrykus, 2023; Bradbury, 2024), healthcare (e.g., Salokangas, 2021; Dobkin et al., 2018), or political science (e.g., Perez-Truglia, 2018; Boyd et al., 2005), demonstrating its wide applicability across disciplines.

The first event study documented is believed to be by Dolley (1933), where the latter analysed the changes in nominal stock prices during stock splits (MacKinlay, 1997), even though the influential articles by Ball and Brown (1968) and Fama et al. (1969) were the ones that started the modern era of the event study methodology (Corrado, 2011). While much time has passed, and the event study methodology has evolved and is still evolving, the fundamentals that characterised the modern era of event studies remain relevant (Ding, 2018; Corrado, 2011), making the event study methodology the standard approach for assessing how security prices respond to an announcement or event (Binder, 1998).

2.2. CYBER SECURITY

Cyber security has become a global concern, with incidents potentially compromising the confidentiality, integrity, or availability of information (Von Solms & Van Niekerk, 2013). As cybercrime's economic impact on businesses is projected to reach $10.5 trillion by 2025[4], all areas of business face an urgent need for constant vigilance and proactive measures against cyber-attacks. In the air transport industry, safety and cyber security remain top priorities, where the adoption of disruptive technologies must not jeopardise operational or commercial activities (Florido-Benítez, 2024). With aviation systems increasingly digitised and interconnected, and many communications relying on wireless technology, maintaining robust cyber security has become critical to ensure the sector's resilience (Dave et al., 2022).

In the financial literature, there is a substantial set of empirical studies that analyse the effect caused by cyber-attacks (largely focused on confidentiality events[5]). As a reference in financial literature, the study of Kamiya et al. (2021) concludes that cyber-attacks that do not involve the loss of personal financial information do not cause a significant shareholder wealth loss.

In turn, Garg et al. (2003) found that security breaches lead to an average 2.7% to 4.5% abnormal decline in share price within three days of the incident, which, according to the authors, could translate to a loss of $17–28 million per incident for the average company. Tosun (2021) analysed the impact of corporate cyber-attacks on stock markets, showing short-term drops in returns, increased trading volumes, and sell pressure due to investor attention despite market value and performance remaining unaffected in the long run. Cavusoglu et al. (2004)

discovered that, on average, firms announcing a security breach lose 2.1% of their market value within two days, translating to a $1.65 billion loss of market capitalisation per breach. Finally, Goel and Shawky (2009) found that, on average, security breach announcements result in a 1% decline in a firm's market value in the days surrounding the event.

In the hospitality industry, empirical studies by Johnson et al. (2018) and Arcuri et al. (2020) that examine the stock market's impact of cyber-attacks found negative abnormal returns in the three-day time intervals around cyber-attack announcements.

These results are in line with the conclusions obtained by Spanos and Angelis (2016) and Ali et al. (2021) through their systematic literature review. Ali et al. (2021) highlighted that 75% of the information security events studies show negative significant CARs and that such effects are exhibited mainly two days before and after the event date.

Even though cyber-attacks can harm stock prices, Huang and Madnick (2020) discuss that the damage caused by cyber incidents can often be managed with a well-executed response. Rather than resorting to secrecy or excuses, companies should communicate openly about their cybersecurity measures and planned improvements. Effective responses—such as increasing security investment and offering customer protections—can mitigate damage, minimise short-term stock declines, and even enhance long-term resilience. This insight is echoed by Akyildirim et al. (2024), who noted that since market reactions tend to remain consistent regardless of an incident's severity, businesses should prioritise cyber resilience and transparency over focusing on the magnitude of the breach.

2.3. TECHNOLOGY DISRUPTIONS

IT is more than just a collection of hardware and software components, it represents the integrated use of computer hardware, software, telecommunications, and related infrastructure that enables organisations to create, store, process, and transmit information (Brynjolfsson & Hitt, 2000).

In today's world, almost every business enterprise utilises some aspect of IT—whether through computers, telecommunications, or even the Internet (Palvia et al., 2021), being considered by Brynjolfsson and Hitt (2000) and Jovanovic and Rousseau (2005) as a "General Purpose Technology", suggesting that investments in IT will be linked to more productivity, organisational transformation and acceleration of the innovation process. This integration provides a foundation for automation and significantly improves operational efficiency (Chen et al., 2017). With the rapid technological growth over the years and the constant concern of losing competitive advantage, IT has emerged as a cornerstone of modern business operations (Palvia et al., 2021).

In the aviation sector, the importance of IT is overwhelming, with many operations being heavily impacted by the quality of the systems to ensure efficiency, safety, and a seamless experience for passengers. Any failure in these systems can lead to significant disruptions resulting in frictions in day-to-day operations and lead to several problems such as breakdown of schedules, delay or cancellation of flights, negative externalities, and customer dissatisfaction (e.g., Kohl et al., 2007; Ramdas et al., 2013). These disruptions tend to result in two broad categories of cost to the airlines (Ramdas et al., 2013; Tae et al., 2020): (i) direct out-of-pocket costs – according to the news, the massive CrowdStrike IT outage will cost airlines $500 million. The figure includes not just loss of revenue but the millions of dollars per day in compensation and hotels over five days[6], and (ii) indirect costs associated with reputation and lost revenue due to customers' reduced willingness to pay and reduced inclination to fly on an airline after experiencing the CrowdStrike IT outage.

After assessing the importance of IT, it's crucial to point out that breaches, failures, or outages in IT systems can be prejudicial and even lethal to companies. As explained by Triche and Walden (2018), IT failures typically fall into three broad categories: developmental (arising during the design and planning stages), implementational (emerging during system deployment), and operational (occurring during everyday use). Whether the issue stems from the technology itself or human action, these failures can happen at any stage, and even the most prepared companies can get tangled.

In the financial literature, studies focusing on the market impact of technology disruptions are scarce. Bharadwaj et al. (2009) investigated the effects of unforeseen operating or implementation-related IT failures on firms' market value. Their findings show that IT failures decrease by 2% in average cumulative abnormal returns (CARs) over a 2-day event window. Benaroch et al. (2012) investigated the short-term market impact of IT operational risks. As explained by the authors, "IT operational risk is any threat to the integrity, confidentiality, or availability of data of IT assets" (p. 360). According to the authors, the literature has largely focused on confidentiality events and empirical studies on the consequences of the availability of IT operational risk events are practically non-existent. Using an event study methodology, the authors found that firms experiencing availability IT operational risk events suffer substantially more negative abnormal returns than firms experiencing integrity or confidentiality events. They concluded that investors view availability events as signalling the presence of more severe IT control weaknesses than those signalled by confidentiality and integrity events.

Additionally, to the financial losses incurred by IT disruptions, these events profoundly affect customer perceptions and satisfaction in the airline industry. Research by Tsohou et al. (2020) reveals that customers undergo a series of distinct behavioural stages when a technological failure occurs. Initially, they attempt to identify the source of the problem and seek temporary workarounds to continue their service experience. As the disruption persists, they endure the diminished service quality while waiting for a resolution. Over time, if the situation remains unsatisfactory, customers explore alternative providers and eventually decide whether to remain with the current service or switch to a competitor. This behavioural progression is influenced by factors such as the duration of the disruption, the overall value derived from the service, and the level of trust in the provider's ability to rectify the issue. Complementing the latter, Bejou and Palmer (1998) observed that the effect of service failures on airline customer loyalty depends on how long the customer has been with the airline and the severity of the failure. Early-stage customers tend to be forgiving, mid-stage customers are very sensitive, and long-term customers often stick with the airline due to inertia. Major failures damage trust more than minor ones, especially in newer relationships. Therefore, effective recovery strategies during key periods are crucial for rebuilding trust and commitment.

In addition, Anderson et al. (2009) examined the impact of service failures on overall customer satisfaction, specifically in the context of airlines. Their study indicates that when delays are attributed to internal technological problems, customer satisfaction declines sharply. In these cases, the typical recovery actions—such as proactive and positive interactions from employees—lose their effectiveness, leading customers to focus instead on more tangible service aspects, like the physical quality of the service environment or the speed of issue resolution. Together, the author's findings emphasise that robust and reliable IT infrastructures are critical not only for maintaining operational efficiency and financial stability but also for preserving customer trust and loyalty in a highly competitive industry.

2.4. RESEARCH HYPOTHESIS

This dissertation aims to analyse the short-term market impact of the largest technology disruption in history (CrowdStrike IT outage) on the airline industry. Consequently, our research hypothesis is the following:

Null Hypothesis (H0) = The CrowdStrike IT outage does not affect the short-term market value of airlines.

2.5. AIRLINE CHARACTERISTICS

Lastly, we investigate which specific airline characteristics arise as value drivers during a technology disruption. Among the various airline-specific characteristics, we are particularly interested in studying the impact caused by the location of airlines' main markets, the airline's cyber risk rating, and business model. We expect a greater negative impact for airlines operating outside of Asia. According to Mugu et al. (2024), the airlines most penalised by the CrowdStrike IT outage were those located in North America and Europe. It is important to bear in mind that the top two geographies of CrowdStrike for endpoint protection are the US with 1819 (71.14%) and the UK with 197 (7.70%) customers, respectively[7]. Asian nations, like China, were less affected, given that they have developed their operating systems to reduce reliance on Windows and associated products[8]. Regarding airline's cyber risk rating, Aldasoro et al. (2022) argue that higher investments in IT lead to lower future costs from cyber incidents. Additionally, airlines with a good cyber risk rating tend to have robust contingency plans and cyber security measures to enhance resilience and reduce vulnerability to future disruptions (e.g., Demir et al., 2023). Lastly, regarding the impact of the business model (low-cost vs full carriers) on the market value of airlines, it is not easy to predict. On the one hand, full-service carriers have a greater capacity and access to additional resources through their networks/alliances compared to low-cost carriers (Tang, 2006). As a result, they are expected to manage disruptions' effect on operational activities more effectively than low-cost airlines. On the other hand, the literature shows that an unplanned event disrupting a network airline would have a significant impact on full-service carriers due to the presence of more densely populated nodes within the network airline (Craighead et al., 2007; Kohl et al., 2007).

3. DATA AND METHODOLOGY

We collect the data used in this event study from different sources. The airline's stock returns and country benchmark indices were obtained from Eikon Refinitiv. Control variables used in the cross-section analysis were obtained from ORBIS. Table 3.1 presents the distribution of the

76 listed airlines by country and business model (low-cost vs full carriers). The US, China, and South Korea, with 16, 7, and 6 listed airlines, respectively, are the most represented.

Table 3.1-Distribution of Listed Airlines by Country and by Business Model

Distribution by Countries			
Country	**#Airlines**	**Country**	**#Airlines**
Australia	2	Kuwait	1
Brazil	2	Malaysia	2
Canada	4	Mexico	1
Chile	1	New Zealand	1
China	7	Norway	2
Finland	1	Panama	1
France	1	Philippines	1
Germany	1	Singapore	1
Greece	1	South Korea	6
Hong Kong	1	Spain	1
Hungary	1	Taiwan	3
Iceland	2	Thailand	1
India	2	Turkey	2
Indonesia	1	UAE	1
Ireland	1	UK	2
Israel	1	USA	16
Japan	3	Vietnam	2
Distribution by Business Model			
Business Model	**#Airlines**	**Business Model**	**#Airlines**
Full-Service Carrier	44	Low-Cost Carrier	32

This table shows the distribution of the 76 listed airlines by business model and country.

To test the research hypothesis presented in the previous section, we use the standard abnormal returns technique based on the market model[9]. We use the date of July 19, 2024, as the event date to compute abnormal returns (ARs), which are obtained by the difference between observed returns of airline i on day t (R_{it}) and the expected return generated by the market model, as follows:

$$AR_{it} = R_{it} - a_i - b_i(R_{mt}) \quad (1)$$

where AR_{it} is the abnormal return of airline *i* on the trading day *t*; R_{it} is the daily rate of return of airline *i* on the trading day *t*; (R_{mt}) is the domestic index upon which each airline trades (benchmark index); a_i and b_i are the regression coefficients of the daily rate of return of airline *i* and the market rate of return, respectively.

To estimate a_i and b_i, like Kamiya et al. (2021), we use a pre-event window of 220 trading days [-230; -10] for each airline and domestic index. The event timeline in Figure 3.1 explains how to compute the abnormal returns.

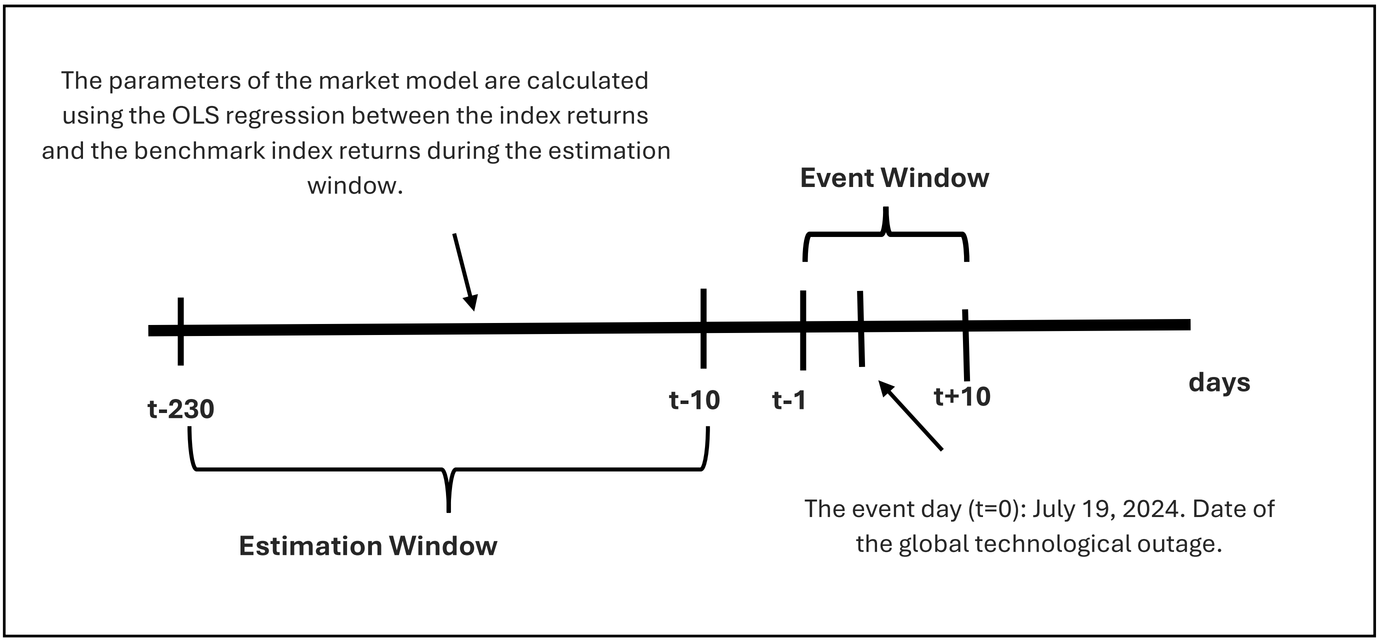

Figure 3.1-Timeline of the event[10]

We then calculate the cumulative abnormal returns (CARs) by cumulating the Ars over a particular time interval. For each airline *i*, the CAR for the time interval [T_1;T_2] is computed as:

$$CAR[T_1; T_2] = \sum_{T_1}^{T_2} AR_t \quad (2)$$

Ten different time intervals for the CARs around the event date were considered: [-1,1], [-1,5], [-2,2], [-2,4], [-3,3], [-5,5], [0,2], [0,3], [0,4] and [0,5]. Finally, we calculate the cumulative average abnormal returns (CAARs) for each time interval as follows:

$$CAAR[T_1; T_2] = 1/N \sum_{T_1}^{T_2} CAR_{[T_1;T_2]} \tag{3}$$

where *N* is the sample size of the sample (in this case, *N*=76).

Regarding the analysis of the differences in abnormal returns between airlines based on the location of its headquarters (Asia vs non-Asia), main CrowdStrike customers by geography, and the airline's business model, we compute the CAARs and their differences for each subsample. The differences observed in the portfolios are analysed using a two-sample z-test for statistical significance.

Finally, we use Ordinary Least Squares (OLS) to analyse how airline-specific characteristics impact the variation of abnormal returns across different airlines, following the specified model:

$$CAR_i = \beta_0 + \beta_1 \ln(SIZE_i) + \beta_2\, LEV_i + \beta_3\, LIQ_i + \beta_4\, ROA_i + \beta_5\, INST_i + \beta_6\, LCD_i + \beta_7 N\_ASIA_i + \beta_8 \ln(CYB\_R_i) + \varepsilon_i \tag{4}$$

where CAR_i is the cumulative abnormal returns calculated above for airline *i* for time windows [-1;1], [0;2], and [0;3]. Table 3.2 presents the control variables employed in the cross-sectional analysis. We conduct an additional robustness check to assess the sensitivity of our findings to an alternative dummy variable of the main affected countries by the CrowdStrike IT outage. Therefore, Equation (4) is also estimated using the dummy variable M_CUST.

According to Murphy et al. (2009) and Rasoulian et al. (2023), the size of airline (*SIZE*), by capturing the effects of economies of scale and reputation, proves to be important in the recovery of airlines after a crisis event. Larger firms can allocate more tangible resources and employees to resolve the crisis. Furthermore, from a reputational perspective, larger airlines with solid brand names may more easily counter the percentual damage of a crisis compared to smaller airlines (Rasoulian et al., 2023). *LEV*, *LIQ,* and *ROA* variables are proxies for airlines' accessibility to financial resources that allow them to fulfil their short and long-term obligations. In the context of a crisis, the possession of solid financial resources and profitability can buffer the pressure of a crisis (Wiklund et al., 2010). According to the authors, leverage, liquidity, and profitability are among the most currently used indicators of a firm's financial solidity. Following Boehmer and Kelley (2009) and La Porta et al. (2002), we include in the cross-sectional analysis a variable related to institutional ownership (*INST*). Institutional investors tend to be better informed than other market participants, and they may interpret the IT outage as a high-risk event, reducing the weight of their investment in this industry. *LCD* variable measures the impact of the business model on the market value of airlines, and as explained at the end of section 2, it is not easy to predict. *N_ASIA* and *M_CUST* are included to test the different repercussions of the IT outage at a regional level. As highlighted by Mugu et al. (2024), airlines operating outside Asia (*N_ASIA*) are those that tend to be most affected by the IT disruption. Furthermore, the countries most affected by the CrowdStrike IT outage (*M_CUST*) are also expected to be those where CrowdStrike has a high market share. Finally, according to Aldasoro et al. (2022), higher levels of IT spending are effective at protecting firms from negative repercussions of IT disasters. For this reason, the variable *CYB_R* was included in the analysis. Descriptive statistics are shown in Panel 2 of Table 4.1.

Table 3.2- Determinants of Cumulative Abnormal Returns (CARs): Variable Definition and Expected Relationship

Variable	Measure	Author(s)	Exp. Effect
Size (SIZE)	Market capitalisation in USD (natural logarithm)	Kamiya et al. (2021); Rasoulian et al. (2023)	+/-/No
Leverage (LEV)	Ratio of total liabilities to total assets (%)	Kamiya et al. (2021); Rasoulian et al. (2023)	-/No
Liquidity (LIQ)	Ratio of current assets to total assets (%)	Kamiya et al. (2021); Rasoulian et al. (2023)	+/No
Profitability (ROA)	Ratio of operating income to total average assets (%)	Kamiya et al. (2021); Rasoulian et al. (2023)	+/No
Institutional Ownership (INST)	Percentage of stocks that are owned by institutional investors (%)	Kamiya et al. (2021)	-/No
Low-Cost Dummy (LCD)	Dummy variable that takes the value of one for low-cost carriers and 0 otherwise	Craighead et al. (2007); Kohl et al. (2007)	-/+/No

Airline Headquarters Dummy (N_ASIA)	Dummy variable that takes the value of one if the airline headquarters is in a non-Asian country and 0 otherwise		-
Main CrowdStrike Costumers Dummy (M_CUST)	Dummy variable that takes the value of one if the airline headquarters is in one of CrowdStrike's main customer countries (US, UK, India, Australia, Canada, France, or Brazil), and 0 otherwise		-
Cyber Risk Rating (CYB_R)	Cyber risk rating for each airline based on the cyber risk model defined by ORBIS (natural logarithm). Cyber risk categories range from 250 (basic) to 900 (advanced)	Aldasoro et al. (2022); Demir et al. (2023)	+

This table presents the definitions, notation, and the expected effect of the explanatory variables of Equation (4) on CARs of listed airlines. No = denotes the absence of a statistically significant impact.

This study adopts a positivist epistemology and objectivist ontology approach to examine the CrowdStrike incident. From a positivist standpoint, the incident is regarded as an observable and independent phenomenon suitable for hypothesis development and verification through data-driven statistical testing grounded in the existing literature. (Maruster, 2013; Al-Saadi, 2014). The objectivist ontology further assumes that reality, such as the CrowdStrike IT outage, constitutes an external reality that exists independently of human interpretation, with the resulting market reactions viewed as objectively observable and quantifiable (Bryman, 2016; Al-Saadi, 2014). Clarifying these assumptions ensures methodological coherence and reinforces the validity of the study's empirical approach and findings.

4. RESULTS

4.1. ABNORMAL RETURN

Table 4.1 displays the airline's CARs around the CrowdStrike IT outage. The findings demonstrate a significant negative stock price response following the announcement of the IT outage during some time intervals [-1;1], [-2;2], [0,2], and [0,3]. For other time intervals further away from the date of the event, there are no statistically significant abnormal returns. These results provide valuable insights, leading us to reject the research hypothesis about the non-existence of abnormal returns, being in line with prior empirical studies that reveal the existence of negative abnormal returns around IT operational risk events within two days before and after the event day.

Table 4.1- Descriptive Statistics of CARs and Variables and Abnormal Returns Tests

Variable	Mean	SD	25th perc.	Median	75th perc.	θ_1	τ_1
Panel 1: All Sample							
CAR [-1,1]	-1.592%	5.175%	-2.662%	-1.194%.	1.240%	-2.162**	-2.052**
CAR [-1,5]	-0.987%	7.790%	-3.628%	0.054%	2.355%	-0.872	-0.364
CAR [-2,2]	-2.040%	6.999%	-4.233%	-0.552%	1.798%	-2.211**	-2.348**
CAR [-2,4]	-1.097%	8.102%	-3.684%	0.494%	2.864%	-1.005	-0.484
CAR [-3,3]	-1.555%	8.214%	-4.352%	0.203%	2.446%	-1.425	-1.328
CAR [-5,5]	-0.333%	10.335%	-4.105%	0.515%	5.165%	-0.244	-0.926
CAR [0,2]	-1.401%	5.879%	-3.273%	-0.662%	1.836%	-2.055**	-1.917*
CAR [0,3]	-1.869%	6.334%	-3.641%	-0.862%	1.459%	-2.258**	-2.082**
CAR [0,4]	-0.456%	7.344%	-3.235%	0.421%	3.024%	-0.492	-0.445
CAR [0,5]	-0.494%	7.649%	-3.202%	0.339%	3.277%	-0.491	-0.588
Panel 2: Explanatory Variables – All Sample							
SIZE (ml)	$ 500,282	$ 426,425	$ 736	$ 4,773	$ 35,106		
LEV	87.82%	29.77%	71.08%	83.10%	96.48%		
LIQ	25.74%	11.59%	17.26%	24.48%	33.29%		
ROA	3.81%	6.97%	1.41%	4.80%	7.43%		
INST	32.69%	29.86%	8.58%	20.45%	50.51%		
LCD	42.11%	49.37%	0	0	1		
N_ASIA	57.90%	49.37%	0	1	1		
M_CUST	38.16%	48.58%	0	0	1		
CYB_R	674.61	70.89	610	690	732.5		

This table presents descriptive statistics of CARs and control variables and the results of abnormal returns tests. All figures of airline-specific control variables are calculated from the previous year-end accounting figures. *SIZE* is the market capitalisation in USD (natural logarithm) for airline *i*; *LEV* is the ratio of debt to total assets (%) for airline *i*; *LIQ* is the ratio of current assets to total assets (%) for airline *i*; *ROA* is the ratio of operating income to total average assets (%) for airline *i*; *INST* is the percentage of stock that is owned by institutional investors (%) for airline *i*; *LCD* is a dummy variable that takes the value of one for low-cost carriers and 0 otherwise; *N_ASIA* is a dummy variable that assumes the value of one if the airline *i* headquarters is in a non-Asia country, and 0 otherwise; *M_CUST* is a dummy variable that assumes the value of one if the airline *i* headquarters is in one of CrowdStrike's main customer countries (US, UK, India, Australia, Canada, France, or Brazil), and 0 otherwise; CYB_R is the cyber risk rating for airline *i* (natural logarithm). θ_1 and τ_1 are the t-test statistics and Corrado rank test statistics, respectively, of Brown and Warner (1980) and Corrado (1989) (see Serra, 2004, for more details). *, ** and *** denote statistical significance at the 10%, 5% and 1% level, respectively.

We also examine the stock market returns differences between different regions, Asia vs non-Asian countries, and main CrowdStrike customers by geography and according to the airline's business model (full carriers vs low-cost). Table 4.2 presents the results. Concerning the market reaction to the airline's headquarters location, Panel 1 of Table 4.2 shows the existence of two distinct patterns in terms of CAARs behaviour. In the case of airlines whose headquarters are in Asia, the CAARs are not statistically significant. On the contrary, for airlines whose headquarters are located outside of Asia, the CAARs are negative and statistically significant. The results also evidence the existence of statistically significant regional differences. The main reason why Asian airlines have not been affected by the IT outage is because few businesses in the region are CrowdStrike customers. In Panel 2, the same analysis is performed but dividing the sample between CrowdStrike's main customer countries – US, UK, India, Australia, Canada, France, and Brazil – and other countries. Airlines located in CrowdStrike's main customer countries show negative and statistically significant CAARs. For the other airlines, the abnormal returns are not statistically significant. The two-sample test for the differences shows statistical significance.

Lastly, the results in Panel 3 of Table 4.2 evidence negative abnormal returns for low-cost and full carriers, but only the low-cost CAARs' are statistically significant. The two-sample test results indicate non-significant differences between the two subsamples of airlines, except for the time interval [-1,1]. Although full carriers have access to more resources that allow them to better manage the impact of IT disruptions on their operational activities (Tang, 2006), an unplanned event that disrupts a network airline, like the CrowdStrike IT outage, can have a more severe effect compared to a low-cost airline due to the presence of more densely populated nodes within the network airline (Craighead et al., 2007; Kohl et al., 2007).

Table 4.2- Airline's CAARs by Location and Business Model and Difference Test for CAARs

			[-1;1]	[-2;2]	[0;2]	[0;3]
Panel 1: Airline's Location (Asia vs Non-Asia)						
	#Airlines					
Non-Asia	44	CAAR	-3.025%	-4.471%	-2.894%	-3.585%
		θ_1	0.019**	0.008***	0.014**	0.011**
		τ_1	0.022**	0.008***	0.017**	0.012**
Asia	32	CAAR	0.111%	0.671%	0.280%	0.065%
		θ_1	0.270	0.154	0.245	0.454
		τ_1	0.295	0.160	0.251	0.465
Difference		CAAR	-3.136%	-5.142%	-3.174%	-3.650%
		z-test (p-value)	0.026**	0.006***	0.028**	0.027**
Panel 2: Main CrowdStrike Customers by Geography						
	#Airlines					
Main Customers Countries	29	CAAR	-2.160%	-3.265%	-2.165%	-1.864%
		θ_1	0.013**	0.004***	0.016**	0.011**
		τ_1	0.014**	0.005***	0.017**	0.012**
Other Countries	47	CAAR	0.112%	-1.270%	-0.660%	-0.411%
		θ_1	0.888	0.123	0.242	0.349
		τ_1	0.844	0.125	0.248	0.354
Difference		CAAR	-2.272%	-1.995%	-1.505%	-1.453%
		z-test (p-value)	0.036**	0.041**	0.045**	0.047**
Panel 3: Business Model						
	#Airlines					
Low-Cost Airlines	32	CAAR	-2.516%	-3.382%	-2.378%	-2.549%
		θ_1	0.045**	0.044**	0.052*	0.092*
		τ_1	0.048**	0.046**	0.055*	0.095*

Full Carrier Airlines	44	CAAR	-0.827%	-1.053%	-0.674%	-1.353%
		θ_1	0.145	0.134	0.156	0.112
		τ_1	0.151	0.130	0.163	0.121
Difference		CAAR	-1.689%	-2.329%	-1.705%	-1.196%
		z-test (p-value)	0.075*	0.120	0.104	0.206

This table shows the airline's cumulative average abnormal returns (CAARs) around the CrowdStrike IT outage and the differences in the CAARs for two subsamples of airlines: (i) airlines whose headquarters are in Asia versus airlines whose headquarters are in non-Asia Countries (Panel 1); (ii) airlines whose headquarters are in one of CrowdStrike's main customer countries (US, UK, India, Australia, Canada, France, or Brazil) versus other Countries (Panel 2) and (iii) low-cost airlines versus full carrier airlines (Panel 3). The CAARs were estimated using the market model (MM) and daily returns for four different time windows [-1;+1]; [-2; +2]; [0; +2] and [0; +3] around the CrowdStrike IT outage. θ_1 and τ_1 are the p-values of t-test statistics and Corrado rank test statistics, respectively of Brown and Warner (1980) and Corrado (1989) (see Serra, 2004, that detailed explains). The significance of the differences in CAARs is determined via a two-sample z-test. ***, ** and * means statistical significance at the 1%, 5% and 10% level, respectively.

4.2. CROSS-SECTIONAL ANALYSIS

We also examine the cross-section impact of airline-specific characteristics variables on CARs around the CrowdStrike IT outage date. The results in Table 4.3 show that airlines with characteristics of larger size, profitability, and cyber risk rating and lower leverage from Asia (non-core CrowdStrike customer countries) are more resilient to adverse effects caused by IT outages.

Table 4.3- Cross-Sectional Analysis

	CAR [-1;1]	CAR [0;2]	CAR [0;3]	CAR [-1;1]	CAR [0;2]	CAR [0;3]
Constant	0.352 (0.972)	0.276 (0.669)	0.101 (0.202)	0.272 (0.897)	0.236 (0.471)	0.311 (0.489)
Ln (SIZE)	0.007*** (2.813)	0.009** (2.402)	0.010** (2.414)	0.007*** (2.811)	0.009** (2.411)	0.010** (2.411)
LEV	-0.039* (-1.922)	-0.033* (-1.897)	-0.028* (-1.745)	-0.038* (-1.934)	-0.031* (-1.877)	-0.026* (-1.712)
LIQ	0.015 (0.901)	0.020 (1.289)	0.017 (1.034)	0.014 (0.809)	0.016 (1.072)	0.015 (0.991)
ROA	0.270*** (3.411)	0.248*** (2.697)	0.277*** (2.694)	0.267*** (3.341)	0.242*** (2.600)	0.259*** (2.656)
INST	0.035 (0.743)	0.043 (0.679)	0.028 (0.965)	0.034 (0.724)	0.037 (0.565)	0.024 (0.829)
LCD	-0.036* (-1.723)	-0.030 (-1.401)	-0.011 (-0.679)	-0.037* (-1.744)	-0.031 (-1.411)	-0.013 (-0.705)
N_ASIA	-0.033** (-2.289)	-0.040** (-2.431)	-0.040** (-2.269)			
M_CUST				-0.055*** (-2.745)	-0.066*** (-2.832)	-0.071*** (3.023)
Ln (CYB_R)	0.138** (2.009)	0.143** (2.034)	0.174** (2.225)	0.143** (2.087)	0.157** (2.242)	0.192** (2.389)
# Obs.	76	76	76	76	76	76
Adj. R^2	0.341	0.351	0.298	0.348	0.362	0.337

This table shows the cross-sectional estimation for the airline-listed CARs around the CrowdStrike IT outage. The dependent variables are the airline's CARs for three different time windows: [-1;+1], [0;+2], and [0;+3], computed with the market model (MM). The airline characteristics variables are the following: *SIZE* is the market capitalisation in USD (natural logarithm) for airline *i*; *LEV* is the ratio of debt to total assets (%) for airline *i*; *LIQ* is the ratio of current assets to total assets (%) for airline *i*; *ROA* is the ratio of operating income to total average assets (%) for airline *i*; *INST* is the percentage of stocks that are owned by institutional investors (%) for airline *i*; *LCD* is a dummy variable that takes the value of one if the airline is a low-cost carrier and 0 otherwise; *N_ASIA* is a dummy variable that assumes the value of one if the airline *i* headquarters is in a non-Asia country, and 0 otherwise; *M_CUST* is a dummy variable that assumes the value of one if the airline *i* headquarters is in one of CrowdStrike's main customer countries (US, UK, India, Australia, Canada, France, or Brazil), and 0 otherwise; *CYB_R* is the cyber risk rating for airline *i* (natural logarithm). ***, ** and * denote statistical significance at the 1%, 5% and 10% level, respectively. Standard errors adjusted for heteroskedasticity and clustering at the country level are reported in parentheses. # Obs. means the number of observations.

From a reputational perspective, major airlines with strong brand names and resources tend to recover more easily from an IT outage. The reputational advantage of large airlines should help mitigate the impact of their losses (Murphy et al., 2009; Rasoulian et al., 2023). Additionally, the literature reveals that firms with low levels of debt and a high capacity to generate profits tend to have the financial resources to recover from the negative effects caused by IT outages/security crises more easily (Kamiya et al., 2021; Rasoulian et al., 2023). Regarding the airline's cyber security rating variable, the results indicate a strong negative stock market return for airlines with lower cyber security ratings. This pattern of market price behaviour is in accordance with the financial literature, which reveals that increased spending on IT is linked to a future reduction in costs related to cyber incidents (e.g., Aldasoro et al., 2022). Finally, the cross-section analysis corroborates that airlines with headquarters outside of Asia or in one of CrowdStrike's main customer countries experience more negative CARs.

5. CONCLUSION

This study investigates the short-term market effect of the CrowdStrike IT outage in the airline industry, which was the largest IT outage in history. According to the financial literature, IT outage announcements seem to impact the market value of airlines because they create friction in daily operations, such as broken schedules, delayed or cancelled flights, negative externalities, and customer dissatisfaction.

Based on an event study involving 76 listed airlines, we show a statistically significant negative stock price reaction to the CrowdStrike IT outage two days before and after the event date. Our findings also show that the most affected airlines are those from main CrowdStrike customer's countries (mainly non-Asian countries) and an irrelevance of the business model. Finally, this study offers insights into airline-specific characteristics that drive firm value during an IT disruption. The study shows that Asian-listed airlines with characteristics of larger size, profitability, high cyber risk rating, and lower leverage are more resilient to adverse effects caused by IT outages.

These results reveal that airlines must balance their investments in IT technology and digital transformation with the need for robust contingency planning and cyber security investments to increase resilience and reduce vulnerabilities to future IT outages.

6. NOTES

1. https://www.cnbc.com/2024/07/19/latest-live-updates-on-a-major-it-outage-spreading-worldwide.html
2. https://www.theverge.com/2024/7/23/24204196/crowdstrike-windows-bsod-faulty-update-microsoft-responses
3. https://www.cbsnews.com/news/microsoft-internet-outages-reported-worldwide/
4. https://cybersecurityventures.com/hackerpocalypse-cybercrime-report-2016/
5. Amir et al. (2018) explains confidentiality events as "Breaches that allow unauthorized users access to confidential information, such as bank account credentials, credit card data, medical records, insurance history, usernames, or passwords" (p. 1183).
6. https://www.cnbc.com/2024/07/31/delta-ceo-crowdstrike-microsoft-outage-cost-the-airline-500-million.html
7. Main CrowdStrike Customers by geography are available here: https://6sense.com/tech/endpoint-protection/crowdstrike-market-share
8. https://www.abc.net.au/news/2024-07-23/why-asia-was-less-crippled-by-the-crowdstrike-outage/104126594
9. For more details, please see MacKinlay (1997) and Serra (2004).
10. The figure demonstrates the timeline used to compute the ARs returns around the CrowdStrike IT outage for the listed airlines.

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