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Airline stock market reaction to CrowdStrike IT outage: An event study analysis

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ABSTRACT

This study investigates the short-term market effect of CrowdStrike IT outage in the airline industry. Using an event study methodology, we evidence that airline stocks respond significantly negatively to the technology disruption within two days before and after the event day. IT disruptions, by creating friction in daily operations, such as broken schedules, delayed or cancelled flights, negative externalities, and customer dissatisfaction, lead to loss of value for airlines. The results also show that the most affected airlines are those from main CrowdStrike customers 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.

1. Introduction

On July 19, 2024, CrowdStrike experienced an IT outage, the major IT outage in history,[1] that caused significant disruptions across various sectors. The airline industry was particularly hard hit, leading to widespread delays and cancellations and operational challenges worldwide, affecting airline operations, especially in Western countries. As a result, 3000 flights had been cancelled and more than 11,400 others were overdue in the US. Worldwide, more than 42,000 flights experienced delays in the first day.[2]

Globally, the aviation industry has seen an increase in passenger traffic, where the advancement of information technology (IT) has been a fundamental lever to sustain 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 due to technology failure or cyber-incidents can lead severe financial consequences, including loss of revenue, reputational damage, reduced productivity, and high recovery costs (Bharadwaj et al., 2009; Benaroch et al., 2012; Ramdas et al., 2013; Kamiya et al., 2021).

This study examines the short-term impacts caused by CrowdStrike IT outage on listed airlines. Two recent studies analyzed the

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[1] https://www.cnbc.com/2024/07/19/latest-live-updates-on-a-major-it-outage-spreading-worldwide.html.
[2] https://www.cbsnews.com/news/microsoft-internet-outages-reported-worldwide/.

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effects caused by CrowdStrike IT outage on tourism, airports, airline, and IT industries. Demir and Demir (2024) analyzed tourism-related news on websites and conducted interviews with tourism professionals to study the effects of CrowdStrike IT outage on the tourism industry. Applying an event study methodology, Grebe et al. (2024) show that the unexpected CrowdStrike IT outage caused negative short-term abnormal returns in airports, airlines, and IT industries. This study distinguishes from the previous studies because it only analyzes the effects of the CrowdStrike IT outage on the airline industry (the most affected by the event) and for extending 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. Thus, our research fills a crucial gap in understanding the short-term market impact of the CrowdStrike IT outage on airlines.

With an event study methodology applied to a dataset comprising 76 listed airlines, we find a statistically significant negative stock price response for airlines surrounding the CrowdStrike IT outage date, but only in the two days before and after the event date. This result is in line with the financial literature. Systematic literature reviews conducted by Spanos and Angelis (2016) and Ali et al. (2021) about the market's efficiency in processing public information related to information security events reveal a statistically negative reaction within two days before and after the event day. Our findings evidence a significant negative reaction in the stock market reaction for airlines located in CrowdStrike's main customer countries (mainly non-Asian countries) and an identical market impact for full and low-cost carriers, except for the time interval [-1; 1]. Finally, this paper offers insights into the airline characteristics that arise as value drivers during an IT disruption. This study shows that listed airlines with characteristics such as size, profitability, and cyber risk rating and lower leverage are more resilient to adverse effects caused by IT outages.

2. Link between technology failures and airlines' market value

Technology is crucial for the operations of airlines. Airlines have utilized IT systems for several purposes, including computerized airline reservation systems, flight operations, telecommunications, websites, and maintenance systems such as servers and check-in kiosks (Gokhale, 2018). The technology disruptions can lead to widespread problems in airlines (Kohl et al., 2007; Ramdas et al., 2013; Tae et al., 2020). According to the authors, these disruptions can introduce challenges in daily operations, potentially leading to several problems such as schedule interruptions, flight delays or cancellations, and customer dissatisfaction. These disruptions typically lead to two main categories of costs for 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, which reflects not only the loss of revenue but also the expenses associated with compensation and hotel accommodations each day over five days[3] and (*ii*) indirect costs associated with reputation damage and loss of revenue resulted from customers' lower willingness to pay and lower desire to fly with an airline after facing the CrowdStrike IT outage.

An expected decline in future cash flows caused by direct costs, reputational damage, and poor service quality will lead to a decrease in the airline's market value. This negative effect will intensify if the drop in future cash flows caused by current poor service becomes persistent over time (Ramdas et al., 2013). Additionally, Anderson et al. (2009) argue that flight overdue caused by airlines lead to greater dissatisfaction than those resulting from factors outside the airlines' control.

Finally, the stock market penalizes airlines more severely for unexpected delays or cancellations, especially those that operate a larger proportion of short-haul flights, where alternative modes of transportation are more accessible. Additionally, airlines that have a higher frequency of connecting passengers tend to experience greater financial impacts from missed connections, as these can lead to increased direct costs and higher levels of customer dissatisfaction. This, in turn, can negatively affect the airlines' future revenues (Ramdas et al., 2013).

Despite the importance of studying the stock market impact of technology disruptions, empirical studies that address this issue are scarce. Bharadwaj et al. (2009) investigate the effects of unexpected operating or implementation IT failures on firms' market value. Their results evidence that IT failures result in a decrease of 2 % in average cumulative abnormal returns (CARs) over a 2-day event windows. Benaroch et al. (2012) investigate the short-term market effects 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 focus has largely been on confidentiality events and empirical studies concerning the impact of availability IT operational risk events are practically non-existent. Based on an event study methodology, they evidence that firms facing availability IT operational risk events experience significantly more negative abnormal returns compared to firms facing integrity or confidentiality risk events. They also conclude that investor's view availability events as signalling the presence of more severe IT control weaknesses compared to those signalled by confidentiality and integrity events. Finally, Grebe et al. (2024) investigate the short-term market effect of the unexpected CrowdStrike IT outage in the IT, airports and aviation industries. They find abnormal negative returns around the event date, and a quick recovery within a week.

In the financial literature, there is, however, a broader set of empirical studies that analyze the effect caused by cyberattacks (largely focused on confidentiality events). According to the work of Kamiya et al. (2021), a reference in financial literature, cyberattacks that do not lead to the loss of personal financial information do not significantly reduce shareholder wealth. In turn, empirical studies of Johnson et al. (2018) and Arcuri et al. (2020) analyze the impacts of cyberattacks on the stock market within the hospitality industry and find negative abnormal returns during three-day intervals surrounding announcements of cyberattacks. These results align with the conclusions obtained by Spanos and Angelis (2016) and Ali et al. (2021) through their systematic literature review. Ali

[3] https://www.cnbc.com/2024/07/31/delta-ceo-crowdstrike-microsoft-outage-cost-the-airline-500-million.html.

Table 1
Listed airlines by business model and by country and benchmark indices.
This table shows the distribution of the 76 listed airlines by business model and by country. The table also presents the indices used to calculate the CARs. # is the number of listed airlines.

	Distribution by countries				
Country	**# Airlines**	**Benchmark Index**	**Country**	**# Airlines**	**Benchmark Index**
Australia	2	S&P/ASX 200	Kuwait	1	Kuwait Main Market 50
Brazil	2	BOVESPA	Malaysia	2	KLCI
Canada	4	TSX Composite	Mexico	1	S&P BMV IPC 50
Chile	1	S&P IPSA	New Zealand	1	NZX 50
China	7	Shanghai SE	Norway	2	Oslo All Shares Index
Finland	1	OMX Helsinki 25	Panama	1	
France	1	CAC 40	Philippines	1	PSEi Composite
Germany	1	DAX Index	Singapore	1	FTSE Straits Times Singapore
Greece	1	Athens General Composite	South Korea	6	KOSPI
Hong Kong	1	Hang Seng	Spain	1	IBEX 35
Hungary	1	Budapest SE	Taiwan	3	TWSE Index
Iceland	2	ICEX Main	Thailand	1	SET
India	2	Sensex-30	Turkey	2	BIST 100
Indonesia	1	IDX Composite	UAE	1	ADX General
Ireland	1	ISEQ All Share	UK	2	FTSE 100
Israel	1	TA-35	USA	16	Dow Jones Industrial Average
Japan	3	TOPIX	Vietnam	2	VN Index
	Distribution by Business Model				
Country	**# Airlines**		**Country**	**# Airlines**	
Full-Service Carrier	44		Low-Cost Carrier	32	

et al. (2021) highlighted that 75 % of studies show negative significant CARs associated with information security events, primarily occurring two days before and after the date of the event.

This work aims to analyze the short-term market effect of the largest technology disruption in history (CrowdStrike IT outage) on the airline industry. Thus, the research hypothesis follows bellow:

Null Hypothesis (H_0): The CrowdStrike IT outage has no effect on the short-term market value of airlines.

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 penalized by 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 UK with 197 (7.70 %) customers respectively.[4] Asian nations, like China, were less affected, given that have developed its own operating systems to reduce reliance on Windows and associated products.[5] 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 cybersecurity measures to enhance resilience and reduce vulnerability to future disruptions (*e.g.*, Demir et al., 2023). Lastly, regarding the impact of 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 from different sources to use in the event study. Airline's stock returns and country benchmark indices were obtained from Eikon Refinitiv. The control variables utilized in the cross-sectional analysis were sourced from ORBIS. Table 1 show the distribution of 76 listed airlines by business model and country, categorized as low-cost or full-service carriers. US, China, and South Korea have 16, 7 and 6 listed airlines, respectively, which are the most represented countries.

We employ the standard technique for calculating abnormal returns with the market model to test the previous section's research hypothesis.[6] We use the date of July 19, 2024, as the event date to figure abnormal returns (ARs), that are determined by taking the difference between observed returns of airline i on day t (R_{it}) and the expected return generated by the market model. The ARs is computed as follows:

[4] Main CrowdStrike Customers by geography are available here: https://6sense.com/tech/endpoint-protection/crowdstrike-market-share.
[5] https://www.abc.net.au/news/2024-07-23/why-asia-was-less-crippled-by-the-crowdstrike-outage/104126594.
[6] MacKinlay (1997) and Serra (2004) provide a detailed explanation.

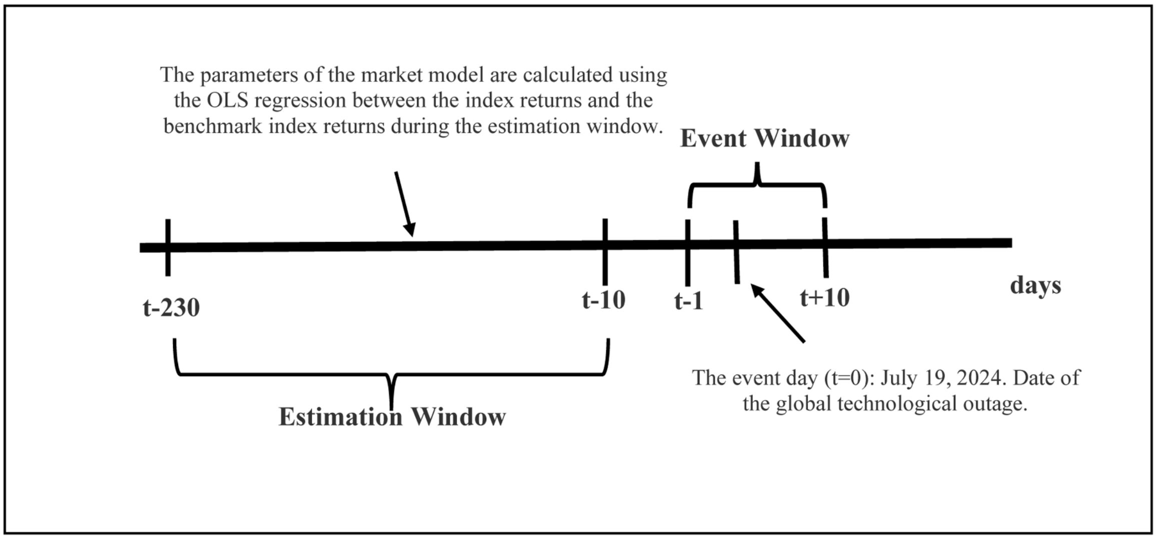

Fig. 1. Timeline of the event.
The figure demonstrates the timeline used to compute the ARs returns around the CrowdStrike IT outage, for the listed airlines.

Table 2
Determinants of cumulative abnormal returns (CARs): Variable definition and expected relationship.
This table shows the notation, measures and expected impact of Eq. (4) explanatory variables on the CARs of listed airlines. "**No**" means the absence of a statistically significant effect.

Variable	Notation	Measure	Author(s)	Expected Effect
Size	**SIZE**	Market capitalization 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); Boehmer and Kelley (2009); La Porta et al. (2002)	-/No
Low-cost dummy	**LCD**	Dummy variable that takes the value of one if the airline is a low-cost carrier, and 0 otherwise	Tang et al. (2006); 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 Customers 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)	+

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

where, AR_{it} means the abnormal return of airline i on the trading day t; R_{it} means the daily rate of return of airline i on the trading day t; R_{mt} means domestic index upon which each airline trades (benchmark index)[7]; a_i and b_i means the regression coefficients of the daily rate of return of airline i and the market rate of return, respectively. e_{it} means the error term.

To estimate a_i and b_i, we utilize a pre-event window of 220 trading days [-230; -10] for each airline and domestic index, like Kamiya et al. (2021). The event timeline in Fig. 1 explain how to compute the abnormal returns.

[7] Table 1 shows the benchmark indices used to calculate abnormal returns, which are based on the empirical study by Boubaker *et al.* (2022). In the case of Iceland, Panama and Vietnam, countries not analyzed by Boubaker et al. (2022), the indices used are based on the study by Martins (2024). Finally, in the case of Japan and Taiwan, the indexes used are based on a suggestion from a reviewer of the manuscript.

Table 3
Descriptive statistics of CARs and variables and abnormal returns tests.
This table shows descriptive statistics of CARs, explanatory variables and the results of abnormal returns tests. All figures of airline characteristics explanatory variables are computed from the previous year-end accounting figures. *SIZEi* is the market capitalization in USD (natural logarithm) for airline *i; LEVi* is the ratio of debt to total assets (%) for airline *i; LIQi* is the ratio of current assets to total assets (%) for airline *i; ROAi* is the ratio of operating income to total average assets (%) for airline *i; INSTi* is the percentage of stocks that are in possession of institutional investors (%) for airline *i*; LCD_i is a dummy variable that takes the value 1 if the airline is a low-cost carrier and 0 otherwise; *WESTi* is a dummy variable that assumes the value 1 if the airline *i* main markets are in Western countries, and 0 otherwise; *CYB_Ri* 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, that detailed explains). ***, ** and * means statistical significance at the 1 %, 5 % and 10 % level, respectively.

Variable	Mean	SD	25th perc.	Median	75th perc.	θ_1	τ_1
Panel 1: All Sample							
CAR [-1,1]	-1.595 %	5.179 %	-2.662 %	-1.196 %.	1.243 %	-2.164**	-2.054**
CAR [-1,5]	-0.991 %	7.792 %	-3.628 %	0.056 %	2.357 %	-0.873	-0.365
CAR [-2,2]	-2.042 %	6.997 %	-4.233 %	-0.554 %	1.799 %	-2.214**	-2.349**
CAR [-2,4]	-1.095 %	8.107 %	-3.684 %	0.495 %	2.866 %	-1.007	0.486
CAR [-3,3]	-1.559 %	8.219 %	-4.352 %	0.204 %	2.448 %	-1.428	1.330
CAR [-5,5]	-0.337 %	10.340 %	-4.105 %	0.516 %	5.167 %	-0.247	-0.928
CAR [0,2]	-1.406 %	5.882 %	-3.273 %	-0.664 %	1.838 %	-2.058**	-1.919*
CAR [0,3]	-1.872 %	6.338 %	-3.641 %	-0.864 %	1.461 %	-2.260**	-2.082**
CAR [0,4]	-0.460 %	7.347 %	-3.235 %	0.423 %	3.026 %	-0.493	-0.446
CAR [0,5]	-0.497 %	7.653 %	-3.202 %	0.340 %	3.279 %	-0.494	-0.589
Panel 2: Explanatory variables – All sample							
SIZE (ml)	$ 500,282	$ 426,425	$ 736	$ 4773	$ 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		

Then, we compute the cumulative abnormal returns (CARs) by cumulating the abnormal returns over a particular time period. For each airline *i*, the CAR for the time interval $[T_1; T_2]$ is computed as:

$$CAR[T_1, T_2] = \sum_{T_1}^{T_2} AR_t \tag{2}$$

Ten distinct 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]. Then, we compute the cumulative average abnormal returns (CAARs) for each time intervals using the specification below:

$$CAAR[T_1, T_2] = 1 \Big/ N \sum_{T_1}^{T_2} CAR_{[T1,T2]} \tag{3}$$

where, N is the 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 analyzed using a two-sample *z*-test for statistical significance.

Finally, we utilize Ordinary Least Squares (OLS) to examine if specific airline characteristics affect the variation of abnormal returns among different airlines, following the specified model:

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

where, CAR_i is the cumulative abnormal returns calculated above for airline *i* for time windows [-1;1], [0;2] and [0;3]. Table 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 main affect countries by CrowdStrike IT outage. Therefore, Eq. (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 crisis (*e.g.*, Wiklund et al.,

Table 4
Airline's CAARs by location and business model and difference test for CAARs.
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-value 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 two-sample *z*-test. ***, ** and * means statistical significance at the 1 %, 5 % and 10 % level, respectively.

			[-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	0.113 %	0.675 %	0.284 %	0.069 %
		θ_1	0.271	0.155	0.247	0.456
		τ_1	0.296	0.161	0.253	0.467
Difference		CAAR	-3.138 %	-5.146 %	-3.178 %	-3.654 %
		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	0.115 %	-1.274 %	-0.664 %	-0.416 %
		θ_1	0.889	0.125	0.245	0.352
		τ_1	0.846	0.128	0.250	0.357
Difference		CAAR	-2.275 %	-1.991 %	-1.501 %	-1.448 %
		z-test *(p-value)*	0.036**	0.040**	0.046**	0.047**
Panel 3: Business Model						
	# Airlines					
Low-Cost Airlines	32	CAAR	-2.523 %	-3.392 %	-2.388 %	-2.559 %
		θ_1	0.046**	0.044**	0.051*	0.092*
		τ_1	0.047**	0.046**	0.053*	0.093*
Full Carrier Airlines	44	CAAR	-0.836 %	-1.059 %	-0.680 %	-1.361 %
		θ_1	0.144	0.131	0.155	0.111
		τ_1	0.149	0.130	0.163	0.119
Difference		CAAR	-1.687 %	-2.333 %	-1.708 %	-1.198 %
		z-test *(p-value)*	0.075*	0.117	0.102	0.209

2010). According to the authors, leverage, liquidity, and profitability are among the most currently used indicators of firms' financial solidity. Following Boehmer and Kelley (2009) and La Porta et al. (2002), we include in the cross-sectional analysis a variable related with 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 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 in order to test the different repercussions of the IT outage at 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 firm 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 3.

4. Results

4.1. Abnormal return

Table 3 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. According to Ali et al. (2021), there are studies about information security events that evidence these events influence the firms' stock market performance, but for a short-term period, consistent with market efficiency theory.

Table 5
Cross-sectional analysis.
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: *SIZEi* is the market capitalization in USD (natural logarithm) for airline *i; LEVi* is the ratio of debt to total assets (%) for airline *i; LIQi* is the ratio of current assets to total assets (%) for airline *i; ROAi* is the ratio of operating income to total average assets (%) for airline *i; INSTi* is the percentage of stocks that are in possession of institutional investors (%) for airline *i; LCD_i* is a dummy variable that takes the value 1 if the airline is a low cost carrier and 0 otherwise; N*_ASIAi* is a dummy variable that assumes the value 1 if the airline *i* headquarters is in a non-Asia country, and 0 otherwise; M*_CUSTi* is a dummy variable that assumes the value 1 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_Ri* 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.

	CAR [-1;1]	CAR [0;2]	CAR [0;3]	CAR [-1;1]	CAR [0;2]	CAR [0;3]
Constant	0.354	0.280	0.106	0.276	0.239	0.315
	(0.970)	(0.672)	(0.209)	(0.899)	(0.474)	(0.491)
Ln(SIZE)	0.007***	0.009**	0.010**	0.007***	0.009**	0.010**
	(2.813)	(2.405)	(2.417)	(2.814)	(2.414)	(2.413)
LEV	-0.039*	-0.033*	-0.028*	-0.038*	-0.031*	-0.026*
	(-1.923)	(-1.899)	(-1.749)	(-1.936)	(-1.879)	(-1.714)
LIQ	0.015	0.020	0.017	0.014	0.016	0.015
	(0.904)	(1.291)	(1.037)	(0.810)	(1.072)	(0.994)
ROA	0.271***	0.249***	0.276***	0.266***	0.241***	0.260***
	(3.413)	(2.699)	(2.690)	(3.338)	(2.598)	(2.659)
INST	0.034	0.045	0.028	0.034	0.037	0.025
	(0.740)	(0.682)	(0.961)	(0.727)	(0.563)	(0.834)
LCD	-0.036*	-0.030	-0.012	-0.037*	-0.031	-0.014
	(-1.725)	(-1.405)	(-0.682)	(-1.746)	(-1.414)	(-0.711)
N_ASIA	-0.034**	-0.041**	-0.040**			
	(-2.291)	(-2.435)	(-2.271)			
M_CUST				-0.055***	-0.066***	-0.071***
				(-2.749)	(-2.833)	(3.025)
Ln(CYB_R)	0.138**	0.143**	0.175**	0.144**	0.156**	0.192**
	(2.011)	(2.036)	(2.228)	(2.089)	(2.240)	(2.391)
# Obs.	76	76	76	76	76	76
Adj. R^2	0.342	0.351	0.300	0.349	0.361	0.338

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 presents the results. Concerning the market reaction to the airlines headquarter location, Panel 1 of Table 4 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 CAARs. The results also evidence the existence of statistically significant regional differences. The main reason for Asian airlines has not been affected by 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 customers countries – US, UK, India, Australia, Canada, France and Brazil, and the 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 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 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).

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 5 shows 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.

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 outage/security crises more easily (Kamiya et al., 2021; Rasoulian et al., 2023). Regarding the airline's cybersecurity rating variable, the results indicate a strong negative stock market return for airlines with lower cybersecurity 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 airline 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 CrowdStrike IT outage in the airline industry, which is the largest IT outage in the world. 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 customers 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, and 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 cybersecurity investments to increase resilience and reduce vulnerabilities to future IT outages.

CRediT authorship contribution statement

João Costa: Investigation, Formal analysis, Data curation. **Susana Cró:** Writing – original draft, Investigation, Formal analysis, Data curation, Conceptualization. **Nuno Moutinho:** Writing – review & editing, Investigation, Funding acquisition, Formal analysis, Conceptualization. **António Miguel Martins:** Writing – original draft, Supervision, Project administration, Methodology.

Declaration of competing interest

None.

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Data availability

Data will be made available on request.

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