Volatility Analysis of Boeing and the 737 Max Crashes

Shauna Fitzmaurice, Senior Sophister
Róise McSorley, Senior Sophister

Shauna Fitzmaurice and Róise McSorley analyse the impact of the two high-profile crashes of Boeing's 737 Max aircraft in October 2018 and March 2019 on the stock price of the company. They examine these crashes as exogenous shocks to Boeing's stock price and investigate whether the behaviour of Boeing's stock price was well captured by Autoregressive Conditional Heteroscedasticity (ARCH) models. Furthermore, they seek evidence of whether or not there was volatility clustering around the time of the shocks. The authors find that Boeing's stock price showed evidence of serial correlation following the second crash but not the first. The paper also illustrates how and why Boeing's stock price rapidly rebounded following both crashes, suggesting that Boeing recovered quickly due to the crashes occurring outside the EU or US and investor risk perceptions being largely unaffected.

I. Introduction

Despite 2017 being the safest year in the history of air travel, with zero crashes transpiring according to The Aviation Safety Network (2017), the aviation industry was hit with two fatal aircraft crashes within five months of each other in October 2018 and March 2019. The first of these crashes occurred with Lion Air on 29th October 2018 and the second crash was with Ethiopian Air on March 10th 2019, killing a combined total of 346 people. Notably, each crash involved one of Boeing's newly launched and highly anticipated 737 Max aircraft, and its non-disclosed software flaw in its Manoeuvring Characteristics Augmentation System (MCAS). These two crashes can be examined as exogenous shocks to Boeing. As conditional heteroskedasticity features in many financial time series, we inspect if this was accurate for Boeing and whether any potential volatility clustering was visible when the shocks occurred.

To obtain insight into the volatility and its persistence for Boeing stock in response to shocks, we first propose using the Capital Asset Pricing Model (CAPM) to calculate the beta (β). The calculated β will aid in indicating if Boeing provides returns greater than the market return. While βs < 1 are expected for income stocks similar to Boeing, the aviation industry is inherently riskier than other industries. Fluctuating fuel costs as well as airlines facing high safety standards require that Boeing is fulfilling strict aviation regulation. Any potential airworthiness issues injure both the airline and the aircraft manufacturer. Considering that commercial orders from airlines worldwide make up the majority of Boeing's order books and projected profits, as well as the near substitutability of the aircraft products (e.g. Boeing's 737 Max is substitutable with the A320neo from rival Airbus), competition against its primary competitor Airbus intensifies risk. These orders are low in volume but are high revenue generating over a long delivery period, therefore neither company can afford any gaps in their order books.

By using the covariance/variance formula as well as confirming this by running a regression, a β of 1.13 is found for Boeing stock over a long run period. This involved use of monthly Boeing return data from January 2010 to November 2019 i.e. a near ten-year period of analysis. As this β is marginally greater than one, it suggests that Boeing is slightly riskier than the market, as proxied by the New York Stock Exchange (NYSE index). Hence, it enjoys marginally better returns than the NYSE index when markets are bullish and marginally worse returns when markets are bearish. While we calculated Boeing's β over the long run, it has been contended that it is statistically inefficient to focus on volatility measures that assume constant variance over the same period, when the series moves through time (Campbell et al., 1997). We believe that this long run β has not sufficiently accounted for the exogenous shocks faced by Boeing in relation to the two major 737 Max crashes as well as the inherent riskiness of the aviation industry itself. We wish to examine if Boeing's returns around the period of the two shocks were serially correlated. Our main motivation is to investigate the effect on volatility of specific aviation crash shocks to Boeing. This required daily data for a short run window of 123 stock trading days. The results hinted that over this window period, Boeing's returns experienced increased autocorrelation, ministering investors an element of predictability.

II. Methodology

To examine the full extent of the dynamics of the volatility impact of the two exogenous shocks to Boeing, we obtained daily data of Boeing and market returns beginning October 2018 and ending March 2019. This analysis window covers 123 stock trading days from the month of the first crash until the end of the month containing the second crash. This window was selected because it was the chief period of effect of the two exogenous shocks, which significantly had a similar nature (i.e. same aircraft model and MCAS flaw causing the crash).

A CAPM analysis to obtain the relevant window's β, coupled with an accompanying ARCH model, permitted detecting any reaction in the volatility dynamics of the shocks. Nevertheless, there is room for concern since the short analysis window may not provide a sufficient duration for a precise conclusion on volatility persistence. This stems from aircraft crashes requiring lengthy investigations which forces a time lag before perceptions are modified and recommendations can be implemented; e.g. the difficulty in resolving and upgrading a design defect in aircraft located world-wide. Hence, a lag may arise before dynamics fully account for any shock.

III. Results of CAPM and ARCH

The CAPM analysis of returns as per *Figure 3* in the Appendix calculated a β for this 123-day period of 1.48. It is noteworthy that this β is equivalent to the β that can be calculated for the time period exactly between the two crashes. As the window is of a marginally longer duration, by including daily data from the full month of the exogenous shocks, this further emphasises the absence of expectation of the crashes and the concealment of the MCAS software error from the market, thereby ensuring exogeneity. This β denotes higher riskiness than the market and exceeds its long run β, which would be expected due to the crashes occurring.

Interestingly, the inclusion of time as an explanatory variable in the CAPM model is statistically significant at the 1% level and increases the R^2. Hence, Boeing's return is trending with time. Moreover, the small yet statistically significant negative coefficient associated with the trending variable accurately reflects the fact that Boeing's return is falling over the window period, as the impacts of the shock are realised and markets react. As the returns are of a relatively high frequency, often the daily changes can be small. Yet because of the shocks, this window period sees large variation in Boeing's return.

The window period focuses more on the bearings of the first crash, which occurred near the beginning of the window period (as opposed to the second crash which occurred towards the end of the window period) and led to increased daily volatility in returns. Much of this volatility forces downward pressure on Boeing's daily returns. Notably, the variation in returns reduces two months after the first crash marking the beginning of the 2019 market opening. From our calculation, Boeing's returns average slightly positive at 0.8% during this time.

With the occurrence of the second crash in early March, a dip in returns of -5.33% occurred, which is similar to, though smaller than the stock's reaction of -6.59% to the first crash. In contrast to the first crash, persistent high volatility is remarkably not induced after the second crash. This illustrates increased stability of the Boeing stock in response to a similar exogenous shock. Yet this stability occurs with the immediate global grounding of the 737 Max aircraft. The grounding would prevent further crashes and worsening financial implications.

Moreover, after the grounding occurred, the markets were expecting a rapid fixing of the MCAS error permitting the prompt return of the aircraft to the skies in a best-case scenario of a six to eight-week timeframe, according to Canaccord Genuity analysts (Barron's, 2019). Investors were not expecting the ensuing public relations crisis. Furthermore, Business Insider (2019) highlights the difficulty associated with an airline cancelling its 737 Max order (Boeing has 4,500 unfulfilled 737 Max orders) due to the duopoly nature of large commercial aircraft manufacturers as well as the financing/investment decisions undertaken by their multi-million dollar aircraft order and up to 30% prepayment. Thus, order revisions rather than pure cancellations are likely for Boeing, with increased orders for older aircraft models, thereby positively contributing to Boeing's stability and outlook. Correspondingly, Airbus faces a similar backlog for its nearest substitute aircraft causing any new order to be placed at the back of the queue taking at least three years, as reported by the Financial Times (2019a).

Nevertheless, the higher β of 1.48 over this window period (which mainly comprises the impact of the first crash) hints that the increased riskiness of Boeing could be reflected in conditional variance, which we examined using the ARCH model (*Figure 4* in Appendix). Lamoureux and Lastrapes (1990) suggest that conditional heteroskedasticity may be due to a time dependence in the rate in which information arrives to the market. The conditional variance for the window period rarely deviates from 3, relative to its long run conditional variance of 27. Using the Lagrange Multiplier test on our ARCH model, we cannot reject the presence of ARCH at the 5% significance level. This is in contrast to Boeing's long run period where we rejected the presence of ARCH in our data, in line with the resulting ARCH alpha's (α) lack of statistical significance at the 5% level as well as its smaller absolute value. Hence, higher errors for the long run occur as compared to the window period.

In addition, evidence from the autocorrelation plot for Boeing's stock for the window suggest that there is increased positive autocorrelation over daily time lags. Notably, post second crash the autocorrelation is statistically significant. Hence, the returns are correlated with each other, allowing a degree of predictability for investors. As window returns move to match those of a lagging time series, we established a positive time trend for April 2019. This supports the more stable return that is low but positive directly after the second crash. Boeing's long run return surmounts the severity of the shocks caused by the crashes and a degree of persistence in the short run periods, that may in the long-term net out.

IV. Results in a Dynamic Context

Our results highlight the absence of volatility clustering, which would have been expected due to the exogenous shocks faced by Boeing. Therefore, rejection of the assumption of a constant variance of the error term (i.e. the innovation) occurs. Hence, the tendency of large changes followed by further large changes and vice versa is surprisingly not apparent in our results. Generally, a shock ensues a continuous period of increased volatility which would be expected due to the severity of the nature of Boeing's shocks. Despite the peak in volatility to a conditional variance of 12 relative to 3 due to the first crash, our results find that this peak quickly wears off and returns to its average variance within two days.

By examining global volatility outlook through the Chicago Board Options Exchange (CBOE) Volatility Index (VIX index), we can confirm that there exists a detachment of Boeing's conditional variance plot from the market's volatility (proxied by the Standard & Poor's 500 index [S&P500]) as no co-movement is evident between their volatilities. Boeing's diverse portfolio, the duopoly nature of the market it operates in, and close relationship with the U.S. Administration and the U.S. Federal Aviation Administration (FAA), secures its position against adverse market changes. Therefore, the global volatility index was not pre-empting either shock to Boeing which fortifies the exogeneity of the shocks experienced.

Despite the large market capitalisation of Boeing ($194 billion), the impact of the exogenous shock of the 737 Max crashes did not result in increased global volatility (VIX fell by 8.4 in the week post-crash), further supporting the idea of the separation of Boeing and the market. Hence, this separation illustrates the idiosyncratic nature of the 737 Max crashes, with the shock of the 737 Max crash being inherent to the aviation industry rather than the wider market. However, our result contradicts the findings of Kaplanski and Levy (2010) who studied 39 American and European aviation disasters from 1990-2007. They revealed that on average, aviation accidents caused a spike in VIX, which contradicts our findings on Boeing. Our study may be an outlier possibly due to the rest-of-world locations (outside E.U. and U.S.) of the crashes as well as the recent timescale.

Dillon et al. (1999) highlight that out of the ten fatal aircraft accidents experienced by major US domestic airlines from 1990-97, only four experienced abnormal market responses. In the aviation industry, shareholder responses to an aircraft accident depend on its circumstances. Notably, shareholders will respond by altering their assessment of risk if the accident or the public response to it seems anomalous. This adjustment can originate from substantial problems with the firm's operating procedures and policies. Consequently, abnormal market responses will occur which can be defined as responses that are not consistent with the full-cost information of the accident.

This marginally abnormal response is supported by Boeing stock falling by 6% (amounting to $12 billion) which considerably exceeds the forecasted aggregated cost of the 737 Max accidents of under $5 billion according to the Wall Street Journal. Observing Boeing's market capitalisation of $194 billion, the effect of the small fall in its stock is marginal and not highly abnormal, highlighting that accident costs are usually small relative to market capitalisation. This is additionally supported by Kaplanski and Levy (2010) whose study featuring investor sentiment found that aviation disasters resulted in less than the average market loss (>$60 billion) for larger, less risky firms such as Boeing. In addition, their finding of the price reversal within two days holds for our results. Furthermore, they found that aviation disasters precede a rise in perceived volatility risk, with the implied volatility increasing after the disaster although actual volatility does not. Hence, investors are unlikely to have reached considerably different conclusions on Boeing's risk exposure than before the accident because of the lack of persistence of the Boeing stock response to shocks over the long run (e.g. re-evaluation of the probability of an accident occurring was unlikely after the first crash).

Remarkably, recent Boeing developments raise similarities to the Boeing 737 aircraft (an older model than the 737 Max) crashes with U.S. Air in 1991 and 1994, killing all passengers. These crashes resulted from a design flaw relating to the aircraft's rudders. No grounding ever occurred even when the lengthy FAA investigation was ongoing and this aircraft became one of Boeing's most successful, as reported by the Financial Times (2019b). Hence, many of the industry specialists believe that the 737 Max will survive its present problems once it gains recertification from regulators, as emphasized by the Financial Times (ibid.). This further relates to Boeing's quick recovery and increased stability seen post second crash. This has continued in the period after the window, with Boeing achieving a significant order of two-hundred 737 Max aircraft from International Airlines Group (parent company of British Airways), though at a discount, further marking a significant vote of confidence in the 737 Max aircraft (Financial Times, 2019c).

Moreover, owing to the fact that both 737 Max crashes occurred outside the U.S. and E.U., where less stringent safety regulation prevails, there is evidence that aviation crashes outside these territories have less of an impact on US investors (Kaplanski & Levy, 2010). This arises from the reduced relevance to the US investor, deflating the impact/severity of these fatal crashes (Kaplanski & Levy, 2010). Remarkably, Lion Air was prohibited from the EU up until the year prior to its 737 Max crash due to failing to meet safety standards (Reuters, 2016). Hence, this redirected focus away from Boeing and the possible fault in the aircraft's manufacture/design. This is strengthened by the small 6% fall in Boeing's stock and its subsequent quick rebound. Following aviation accidents, sophisticated investors exploit the low market prices contributing to a price reversal (Shleifer et al., 1991). This supports our results of a mean-reverting reversal effect two days after the crash.

V. Summary

Our study utilised monthly data taken from the first day of every month, from January 2010 to November 2019 (almost a decade of monthly data). However, the long run conditional variance plot (*Figure 2* in Appendix) did not display spikes when the two crashes occurred. This arises from the lack of persistence in volatility in the long run. Using the first date of each month signifies that the impact of each crash has worn off by the time our data was sampled (i.e. we included data on 1st November, but the Lion Air crash occurred on 29th October). This supports the finding that true effects of an aviation crash only last about two days, before the price reverts to its mean. Hence, in the long run, the complete impact on volatility is not visible as the data collected includes dates that demonstrate a stock price that reflects a rebounding stock, which acts to stabilise volatility. In contrast, as we used the daily return for our window period, this shows every change from marginal predictable changes, to impacts of exogenous shocks as they happen. Hence, spikes in volatility are evident on the days of the crashes (*Figure 4* in Appendix) with a small degree of volatility persistence occurring after the second crash.

VI. Conclusion

To conclude, it is apparent that Boeing's return exhibits a degree of persistence in the short run window period which covers the two exogenous shocks. Serial correlation occurs with returns after the second crash, as autocorrelation increases with daily time lags over the window period. We failed to reject the ARCH model for this short run window period. Boeing's stock rebounded quickly after both shocks, aided by the 737 Max crashes occurring outside E.U. or U.S. territories, risk perceptions staying relatively constant and no resultant increase in implied global volatility as measured by the VIX index. Our results hint towards the lack of volatility clustering, yet we cannot give a precise conclusion on this, due to the high frequency of data and analysis over the short window period. Notwithstanding, Boeing's 123- day window period contrasts to its near 10-year, long run period. Boeing's long run data rejected the ARCH model demonstrating that no persistence in volatility was evident. Therefore, in the long run, Boeing stock is unpredictable. This stems from the dynamic context of the aviation industry and reliance on consumer demand for flying and economic cycles.

VII. References

1. Aviation Safety Network (2017). ASN data show 2017 was safest year in aviation history. Available Online: https://news.aviation-safety.net/2017/12/30/preliminary-asn-data-show-2017-safest-year-aviation-history/ [Accessed 18th February 2020].
2. Barron's (2019). The Boeing 737 MAX Is Grounded. Wall Street's Next Question: How Much Will This Cost? Available Online: https://www.barrons.com/articles/boeing-737-max-grounding-cost-51552573977 [Accessed 18th February 2020].
3. Business Insider (2019). One airline has attempted to cancel its order for Boeing's 737 Max 8. Here's why it would be difficult for other airlines to do the same. Available Online: https://www.businessinsider.com/boeing-737-max-8-orders-unlikely-canceled-experts-2019-3?r=US&IR=T [Accessed 18th February 2020].
4. Campbell, J., Lo, A. and MacKinlay, A. (2012). Econometrics of Financial Markets. Princeton, NJ: Princeton University Press.

5. Dillon, R., Johnson, B. and Pate-Cornell, M. (1999). Risk Assessment Based on Financial Data: Market Response to Airline Accidents. Risk Analysis, 19(3), pp.473-486.
6. Financial Times (2019a). Airbus cannot build fast enough to replace Boeing's 737 Max. Available Online: https://www.ft.com/content/a495bc06-49a6-11e9-bbc9-6917dce3dc62 [Accessed 18th February 2020].
7. Financial Times (2019b). Boeing prepares for long haul to win back customers. Available Online: https://www.ft.com/content/832b5ef8-f681-11e9-9ef3-eca8fc8f2d65 [Accessed 18th February 2020].
8. Financial Times (2019c). BA parent orders 200 Boeing 737 Max aircraft despite grounding. Available Online: https://www.ft.com/content/e8e017f4-91d5-11e9-aea1-2b1d33ac3271 [Accessed 18th February 2020].
9. Kaplanski, G. and Levy, H. (2010). Sentiment and stock prices: The case of aviation disasters. Journal of Financial Economics, 95(2), pp.174-201.
10. Lamoureux, C. and Lastrapes, W. (1990). Heteroskedasticity in Stock Return Data: Volume versus GARCH Effects. The Journal of Finance, 45(1), p.221.
11. Reuters (2016). EU allows Iran's state carrier to resume flights in bloc. Available Online: https://www.reuters.com/article/us-indonesia-airlines-eu-idUSKCN0Z20XE [Accessed 18th February 2020].
12. Shleifer, A., Thaler, R. and Lee, C. (1991). Investor Sentiment and the Closed-End Fund Puzzle. The Journal of Finance, 46(1), pp.75-109.

VIII. Appendix

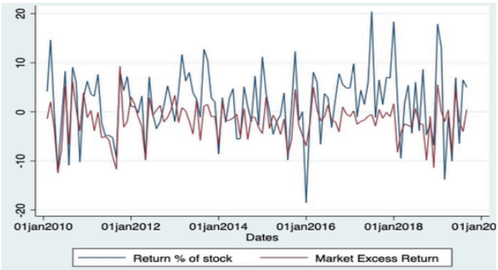

Figure 1: Boeing's % Monthly Return changes as compared with the NYSE Market % Monthly Return, illustrating Boeing's Long Run β of 1.13.

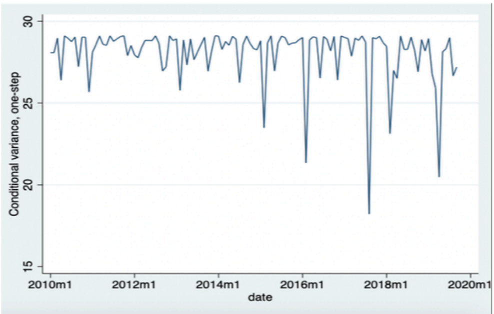

Figure 2: Boeing's long run ARCH plot. A Lagrange multiplier test rejects the presence of ARCH.

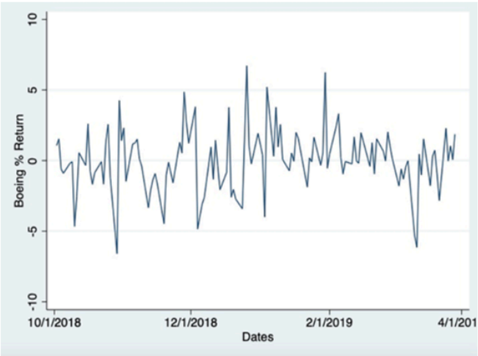

Figure 3: Boeing's % Daily Return over the short run window period of 123 stock trading days.*

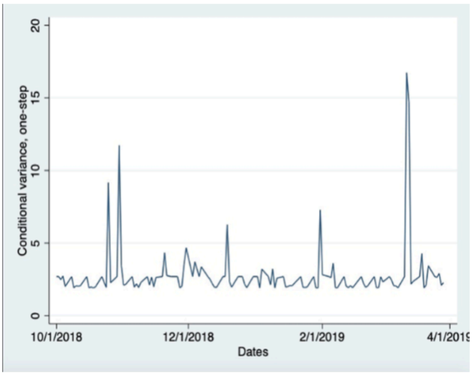

Figure 4*: Arch plot for the short-run (123-day) window. A Lagrange multiplier test fails to reject the presence of ARCH.

**Note: These dates are in the American date format of mm/dd/year.*