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Research on the Dynamic Correlation Between COVID-19 Pandemic and Boeing Stock

Ziang Shi[1,*,†], Jinyan Wang[2,†], Shuwen Yang[3,†]

[1] Pen State University
[2] Southwestern University of Finance and Economics
[3] Boston University
[*]Jinyan Wang. Email: jinyan@bu.edu
[†]These authors contributed equally

ABSTRACT

Over the past two years, the COVID-19 outbreak has affected industries and changed People's Daily lives. Due to social distancing and airlines ' shutdown, businesses sensitive to the Covid-19 pandemic, such as aerospace industry players, have been devastated. This leads us to be interested in how the COVID-19 pandemic is changing the stock price dynamics of companies in the sector, such as Boeing. Then, we came to explore the relationship between the evolvement of Covid-19 cases and changes in Boeing's stock price so that businesses in this industry can react more promptly to future pandemic events and take some precaution measures. To explore, we used time series models, including ARMAX and GARCH models, and regression analysis, including the VAR model, to explore how U.S. and World Covid-19 cases have impacted Boeing's stock price returns. As a result of our modeling analysis, we find out that the impact of both the U.S. and world COVID-19 outbreak on Boeing's log stock return over a long-term scope is fairly weak, and the impact of COVID-19 on stock returns is more of a temporary shock than a long-term impact. Moreover, Boeing's stock return is positively impacted by one standard deviation unit of the number of new additions to COVID-19 cases in the United States. Over time, the impact of the number of new COVID-19 topics in the US on Boeing's stock returns tends to zero.

Keywords: *COVID-19 Pandemic, Boeing's Stock, Dynamic Correlation.*

1. INTRODUCTION

1.1. Background

As the COVID-19 pandemic has stalled activities worldwide, the global economic landscape has transformed dramatically over the past two years. The shock it created had a ripple effect across all sectors of the worldwide economy, triggering a significant decline in global GDP, disruption of the supply chain, and decimation of various industries. United States Census Bureau showed that the pandemic had reduced global economic growth by an annual rate of around 3.2% in 2020, and global unemployment is predicted to reach 200 million people before 2022 [1]. The unemployment rate in the United States has also earned the highest at 14.8% since data collection began in 1948 [2].

Manufacturing, one of the main pillars of U.S. industrial development, has been hit hard by COVID-19. Before the pandemic, the manufacturing industry contributed $2.17 trillion to the U.S. economy, nearly 12% of the US GDP [3]. Advanced manufacturing and technology accounted for 90% of private-sector research and development and employed 80% of the nation's engineers [3]. However, as the pandemic invades the economy, business processes in the manufacturing industry are constrained, raw material prices are unstable, and the distribution of raw materials and manufactured goods are all disrupted. According to a Bureau of Labor Statistics report in 2021, manufacturing industries suffered a great depression with a decline of output growth in 2021 by 3.8% due to pandemic shock [1].

Among all manufacturing businesses, the aerospace industry, as a world leader in advancing science and technology, not only plays a critical role in U.S. economic growth but also reflects a nation's defense technology and economic strength. The impact of COVID-19 on the aerospace industry, therefore, requires special attention. Before the pandemic, the sector contributed $151 billion in sales to the U.S. economy in 2018 [4]. International Trade Admission has shown that its positive trade balance of $88 billion was the largest trade surplus of any manufacturing industry, supporting high-wage jobs for thousands of American workers [5].

However, the COVID-19 crisis brought into sharp relief the critical importance of aerospace to the global economy. Due to general health concerns and travel restrictions, airline companies first come to a virtual standstill with a 92% loss in passengers from 2019 and an estimated $157 billion loss in revenue [6]. Airlines have reduced sharply by 30% in international and domestic travel [6].

The extent of the impact on the aerospace industry and how the pandemic will affect the technology behind it has gone largely unnoticed. According to one of the manufacturing giants, the airplane manufacturers, including those that make engines, avionics, composite structures, and most everything else that goes into an airplane, needs access liquidity of at least $60 billion in the form of grants and loans to compensate for reduced cash flow [7]. The changes being brought about by the COVID-19 will undoubtedly stay with the aerospace industry in the long term.

Boeing is the world's largest aerospace company and the world's leading manufacturer of civil and military aircraft. Boeing also provides numerous military and civilian support services to customers in 150 countries and territories around the world. Boeing is one of the largest U.S. exporters in terms of sales. However, in the first half of 2020, sales of the giant Boeing fell 26%, and its commercial aircraft deliveries plummeted by nearly $29 billion [8]. It has also slashed its 10-year forecast for new aircraft demand by 11% [8]. Therefore, the aerospace giant's problems are complex and widespread, so further research is needed to investigate its economic importance.

1.2. Date Source

Data for Covid-19 cases in this paper are derived from www.OurWorldinDathistory.org, an authoritative scientific online publication that portrays the economic and environmental history of our world up to the present day in data visualizations. They sourced raw data on confirmed cases and deaths for all countries from COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at the Johns Hopkins University.

Data for Boeing’s stock price are derived from Yahoo Finance, a platform that provides financial news, data, and commentary including stock quotes, press releases, and financial reports.

1.3. Literature Review

Most existing literature on the economic impacts of COVID-19 on the aerospace industry only focuses on its macroeconomic influences, but few provided perspectives on its impacts on a specific company [5]. Intuitively, the outburst of the pandemic disrupts airplane operations and consumers' demand and dramatically constrain individual corporations' cash flows [9]. Previous studies have not fully considered the pandemic's disturbance on a particular aerospace company. As one of the leading companies, Boeing has experienced a stock price crash, and its stock performance has been closely related to the spread of COVID-19 cases [10]. Therefore, we will choose Boeing as our research subject and utilize different statistical models to explore how the changing number of COVID-19 cases affects its share price dynamism.

Our motivation is to discover how the outburst of an unexpected natural event, such as COVID-19, would change a company's stock price that has a close bearing on this event. We are also devoted to providing a robust theoretical basis for the government to launch more useful fiscal subsidy policies and react more promptly next time to recover the aerospace industry economy, which is critical to people's everyday lives.

Our paper contributes to several aspects. First of all, the existing research on the economic crash brought by COVID-19 is primarily based on macroeconomic and microeconomic data, such as GDP growth rate and unemployment rate. Until this point, only research teams from aerospace companies, such as Boeing and Airbus, have studied the impact COVID-19 has on aerospace businesses [11]. This paper fills the void by looking into the impact of COVID-19 on a specific company and giving attention to how a company's stock price interacts with the change of COVID-19 cases. Our findings add to the literature on the relationship between COVID-19 infections and stock price changes. Second, we will perform a Maximum Likelihood Estimation (MLE) and VAR linear regression analysis to explore a relationship between Boeing's stock price and the number of COVID-19 infections. Then, we will leverage VAR Time Series Modelling to investigate whether the past number of COVID-19 cases influenced Boeing's future stock prices.

The following parts of the paper are organized: Section 2 provides background information and data that support it. Section 3 contains model specification, which briefly introduces what mathematical models we will use in our research. Section 4 includes an estimation of the future impacts that COVID-19 will have on Boeing's stock price. Section 5 presents empirical results we generated from conducting ARIMA and VAR modeling. Section 6 is the conclusion that includes how the variation of the number of COVID-19 cases influences

Boeing's share price volatility and how Boeing's stock price will look in the upcoming two years.

2. MATH AND EQUATIONS

2.1. Model Specification

2.1.1. Unit Root Test

Unit root tests are tests for stationarity in a time series. A time series has stationarity if its mean and variance remain constant. Unit roots are one cause for non-stationarity. These tests are known for having low distribution. Many tests exist because non stand out as having the most power. These tests include: (1) Augmented Dickey-Fuller Test, which is based on linear regression; (2) The Elliott-Rothenberg-Stock Test; (3) The Schmidt-Phillips Test which includes the coefficients of the deterministic variables in the null and alternate hypothesis; (4) The Zivot-Andrews test that allows a break at an unknown point the intercept or linear trend

Therefore, to test the stationarity of our US and world COVID-19 cases and stock price data, we conducted unit root test. In our unit root hypothesis test, our null hypothesis is that the logarithm-transformed Boeing's stock price has a unit root and is not stationary. The alternative hypothesis is that the logarithm-transformed Boeing's stock price does not have a unit toot and is nonstationary. After conducting Augmented Dickey-Fuller as shown in table 1, we get the ADF test statistic -3.0151, with a p-value of 0.0342, smaller than the significance level of 0.05. Therefore, we reject the null hypothesis and conclude that logarithm-transformed Boeing's stock prices do not have a unit root and are nonstationary.

Table 1 ADF-test, a statistical test used to verify whether a given time series is stationary.

Variables	ADF Statistic	Prob*
Log Boeing stock return	-3.0151	0.0342
Log world covid-19 data	-3.6360	0.0054
Log US Covid-19 data	-3.6069	0.0060
Test critical values:		
1% level	-3.4445	
2% level	-2.8677	
3% level	-2.5701	

Note: ADF statistic is used to test the null hypothesis.
log means taking the logarithm of the variable

Then, we conducted an ADF test for logarithm-transformed world Covid-19 data. The ADF test statistic is -3.6360 with a p-value of 0.0054, smaller than our significance level of 0.05. Therefore, we reject the null and conclude that the logarithm-transformed world COVID-19 data do not have a unit root and are nonstationary.

Next, we conducted an ADF test for logarithm-transformed US Covid-19 data. The ADF test statistic is -8.1758 with a p-value of 0.0000, smaller than our significance level of 0.05. Therefore, we reject the null and conclude that logarithm-transformed US Covid-19 data have a unit root and are non-stationary.

2.1.2. ARIMA Model

ARMAX model is a model that incorporates other explanatory variables based on the ARMA model. It uses past time series values and past disturbances to predict the future while examining the contributions of other explanatory variables to dependent variables.

Therefore, in our research, Boeing's stock price is the dependent variable, and US and world COVID-19 data are explanatory variables. We are intended to use Boeing's past stock prices to predict its future stock price while examining the contributions of US and world Covid-19 cases and their data disturbance to Boeing's stock prices. To investigate whether Boeing's stock price has a long-term relationship with world and US Covid-19 data, we resort to the ARMAX model. The ARMAX model is designed as follows:

$$x_t = \varphi_0 + \sum_{i=1}^{p} \varphi_i x_{t-i} + a_t - \sum_{i=1}^{q} \theta_i a_{t-i} + \gamma_{11} x_{1,t-1} + \ldots + \gamma_{1q_1} x_{1,t-q_1}$$
$$+ \gamma_{k1} x_{k,t-1} + \ldots + \gamma_{kq_k} x_{k,t-q_k} \tag{1}$$

Where φ_0 is a constant; φ_1 is a coefficient for x_{t-i} which represents Boeing's stock return for i_{th} lag; θ_1 is the coefficient for a_{t-1} which is the model residual. X is the exogeneous variable that we will use to replace with US and world Covid-19 data. Since the logarithmic stock return, US and world data are all stationary, so we use logarithmic Boeing's stock return as response variance and use logarithmic world and US Covid-19 data as independent variables and try to fit them in an ARMAX time series model.

2.1.3. VAR Model

Vector autoregressive model is abbreviated as VAR model, which uses all current variables in the model to regress several lagged variables of all variables. The VAR model is used to estimate the dynamic relationship of joint endogenous variables without any prior constraints. The structural relationship between economic variables is sometimes difficult to define. Using the VAR model can circumvent this problem. The VAR model is as follows:

$$Y_t = c + \sum_{i=1}^{p} \alpha_i Y_{t-i} + \sum_{i=1}^{q} \beta_i X_{t-i} + e_t \quad (2)$$

Where c is a constant; a_i is a coefficient for Y_{t-i} which represents Boeing's yield of the stock price for t-i lag; β_i is a coefficient for X_{t-i} which represents new additions to COVID-19 cases in the United States. e_t represents the error of the model. Since logarithmic stock price, US and world data are all stationary, so we use logarithmic Boeing's yield of stock price and the logarithmic world and US Covid-19 data as variance and try to fit them in a VAR model.

2.1.4. ARMA-GARCH Model

The ARMA model with GARCH specification will be helpful to examine the mean and the volatility of Boeing's stock price with the covariate of the COVID-19 data of the United States and the world. Mathematically, the ARMA is the model aiming to find the conditional mean and the GARCH model is the process to determine the conditional variance of the process. The ARMA-GARCH Model with its terms' specifications is as follows:

$$Y_t = \mu + \sum_{i=1}^{p} \alpha_i Y_{t-i} + \sum_{i=1}^{q} \beta_i \varepsilon_{t-i} + \varepsilon_t$$
$$\varepsilon_t = \sqrt{\sigma_t} z_t, \quad \sigma^2 = \omega + \sum_{i=1}^{p} \alpha_i \varepsilon^2{}_{t-i} + \sum_{i=1}^{q} \beta_i \sigma^2{}_{t-i} \quad (3)$$

Where the μ is the mean of Boeing's yield of the stock price for t lag. The a_i is the coefficient for Y_{t-i} which represents new COVID-19 cases and the β_i is the coefficient for the error term ε_{t-i} of the model for t-i lag. Since logarithmic stock price, US and world data are all stationary, so we use logarithmic Boeing's stock price as response variance and use logarithmic world and US Covid-19 data as independent variables and try to fit them in an ARMA-GARCH time series model.

3. EXPERIMENTAL RESULTS AND ANALYSIS

3.1. ARIMAX Model Experimental Results

First of all, we run a PACF test to find the lag order for the Auto-regression model (AR) and run an ACF test to find the lad order for the Moving Average model (MA).The AR model believes that the current time point can be predicted by the linear combination of the past time points of the time series plus white noise and MA model is a linear combination of past white noise. we found that the lag order for the AR model is 2 and the lag order for a MA model is 2, as is shown below.

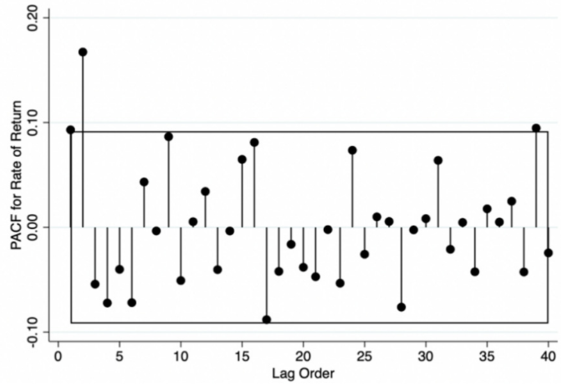

Figure 1 PACF for Boeing's Stock Return for AR Model

Note: The Y-axis is a partial autocorrelation function of the log of stock return with its own lagged values. The X-axis is the lag order.

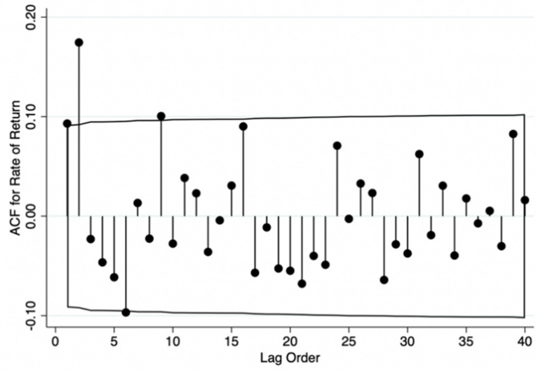

Figure 2 ACF for Boeing's Stock Return for MA Model

Note: The Y-axis is the autocorrelation function of the log of stock return with its own lagged values. The X-axis is the lag order.

Then we fit an ARMAX model with the exogenous variable being logged US Covid-19 data and log world Covid-19 data respectively, then we generated the following printout:

Table 2. ARMAX Summary Statistics

Variables	(1)		(2)	
	Coef.	Std. err	Coef.	Std. err
The US	0.0012*	0.0007		
Worldwide			0.0027*	0.00168
AR (-2)	-0.0574	0.1793	-0.0591	0.1805
MA (-2)	0.2356	0.1854	0.2351	0.1867
Constant	-0.0193**	0.0095	-0.0352*	0.0191

Note: In this table, *Coef* and *Std. err* stand for the coefficients and standard deviation of AR(2) and MA(2) models. The calculation results are rounded up to 4 digits after the decimal point.

As is shown, the impact of both the US and world COVID-19 outbreak on Boeing's logarithmic stock return over a long-term scope is fairly weak, which is reflected both from the magnitude of the coefficients and their corresponding significance level. Combined with some common facts about the spread of COVID-19 and the trend of the US stock market, it can be inferred that the impact of COVID-19 on stock returns is more of a temporary shock than a long-term impact.

3.2. VAR Model Experimental Results

3.2.1. determine optimal lag

First of all, we are going to determine the optimal lag of the VAR model

Table 3. Lag-order selection criteria

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-359.955				.017504	1.63043	1.6377	1.64888
1	1293.06	3306	4	0.000	.00001	-5.79758	-5.77575	-5.74223
2	1335.86	85.589	4	0.000	8.7e-06	-5.97233	-5.93595	-5.88008
3	1367.12	62.524	4	0.000	7.7e-06	-6.09513	-6.0442	-5.96598
4	1384.45	34.669	4	0.000	7.3e-06	-6.15519	-6.08971	-5.98914
5	1396.91	24.907	4	0.000	7.0e-06	-6.19327	-6.11324	-5.99032
6	1505.43	217.05	4	0.000	4.4e-06	-6.6641	-6.56952	-6.42426
7	1511.67	12.483	4	0.014	4.3e-06	-6.6742	-6.56506	-6.39745
8	1537.13	50.906	4	0.000	3.9e-06	-6.77083	-6.64715	-6.45719
9	1538.78	3.3127	4	0.507	4.0e-06	-6.76028	-6.62204	-6.40973
10	1548.41	19.249	4	0.001	3.9e-06	-6.78561	-6.63282	-6.39817
11	1576.8	56.798	4	0.000	3.5e-06	-6.89552	-6.72818	-6.47117*
12	1587.08	20.541*	4	0.000	3.4e-06*	-6.92376*	-6.92376*	-6.46252

Note: Lag means lag order
The number marked with * corresponds to optimal lag

This article is based on the two major information criteria of AIC and HQ, LR statistics, and FPE's determination of the lag order. From the above figure, the LR statistics and the final prediction error FPE and AIC criteria, and HQ criteria all indicate that the model has a lag period of 12.

3.2.2. VAR Stability

we are going to ensure the stability of the VAR model. Stability means that when a pulsating shock is applied to the innovation process of a certain equation in the VAR model. With time passing, if the shock disappears gradually, the system is stable; otherwise, the system is unstable. The necessary and sufficient condition for judging whether the VAR model is stable is that all the characteristic values of the var model must be within the unit circle. As shown in the figure, the characteristic roots are all in the unit circle, so the var model is stable.

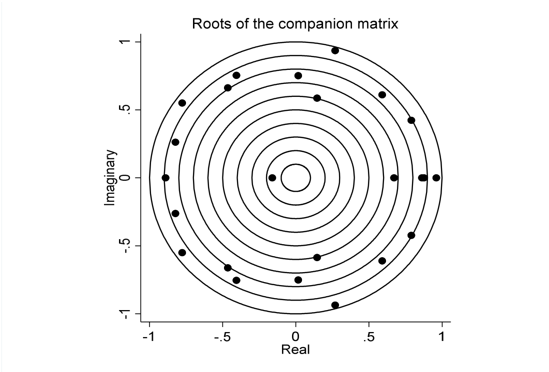

Figure 3 Characteristic Values of the VAR Model in Unit Circle

3.2.3. Impulse response analysis

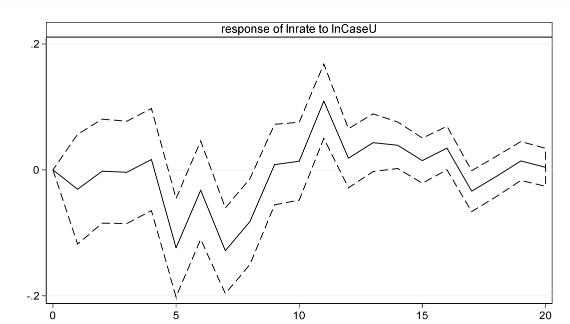

Figure 4 Response of late to lnCaseU

An impulse response is when a variable in the model is impacted, the impact effect is tested, and it is found whether the impact effect can have an impact on the other variables. As shown in the figure, when the BA yield is positively impacted by one standard deviation unit of the number of new additions to COVID-19 cases in the United States, the BA yield has an obvious negative reaction in the first 10 periods, and the fifth period suffered the most negative impact. In the 12th period, the BA yield received a slight positive impact. Finally, as time went on, after the 15th period, the impact of the number of new additions to COVID-19 cases in the United States on the BA yield tended to zero.

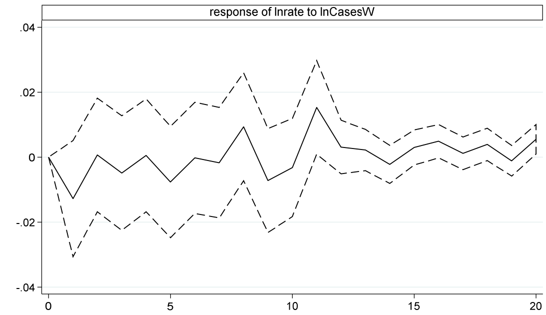

Figure 5 Response of late to lnCasesW

At the same time, the impact of the positive impact of one standard deviation unit of new additions to COVID-19 cases in the world on BA yield is roughly the same as the impact of the positive impact of one standard deviation unit of new additions to COVID-19 cases in the United States on BA yield.

3.3. ARMA-GARCH Model Experimental Results

Lastly, to examine the volatility, we perform the ARMA-GARCH process to examine the conditional variance and the conditional mean of Boeing's stock price concerning the COVID-19 data. With the previous result showed in the ACF and the PACF plot, we determine ARMA (2,2) with ARCH (1) and GARCH (1) processes for the model. To fit the model, we use the logarithmic new daily US COVID 19 cases and the new daily World COVID 19 cases as exogenous variables. We generate the following table of coefficients:

Table 4. ARMA-GARCH Summary Statistics

Variables	(1)		(2)	
	Coef.	Std. err	Coef.	Std. err
The US	-0.0735	0.0468		
Worldwide			-0.2118**	0.0993
ARCH	0.1667***	0.0309	0.1606***	0.0311
GARCH	0.8064***	0.0268	0.8093***	0.0272
Constant(mean)	-0.0001	0.0013	-0.0000	0.0014
Constant(variance)	-9.002***	0.8022	-7.4771***	1.2910

By examining the estimation of the constant of the variance function, we can still conclude that the COVID-19 outbreak does not increase the volatility of the rate of return of Boeing's stock price in long term.

4. DISCUSSION

Based on the statistical results from the ARMAX, VAR, and the ARMA-GARCH model, we have the confidence to make inferences that the spread of COVID-

19 will not explicitly impact Boeing's stock price in the long term. The spread of COVID-19 on the stock price will be considered temporary.

The research "Stock Market reaction to COVID-19: Evidence from U.S Firms' International exposure", conducted by Huw Hwa Au Yong and Elaine Laing [12], explains that multinational firms are more resilient to economic shocks caused by COVID-19 due to the benefits of geographical diversification. This is also helpful to explain the minimal impact on the volatility of Boeing's stock price rate, as Boeing is a multinational corporation. Another factor contributing to this fact is the Boeing company's international exposure; a portion of the revenue, approximately 70%, comes from the selling of commercial airplanes outside the United States. The finding from this research proposed the statement that the firms with international exposure are more robust against economic shocks due to COVID-19 in the long run. This statement also supports our findings by using Boeing's stock price as evidence.

With many positive macroeconomic and microeconomic features that the Boeing corporation contains, the volatility of its stock prices is not affected by the long-term pandemic. We want to propose a further investigation on the company's characteristics with the stock price that does not receive abnormal impact by the pandemic of COVID 19 as a long-term effect. The research would be helpful to advise the owner of the company to modify its plan to confront the effect brought by the pandemic.

5. CONCLUSION

Although the COVID-19 pandemic has caused great losses to the global manufacturing industry, especially in the aviation sector, major companies face a lack of cash flow. Boeing's sales have fallen by 26%, and its commercial aircraft deliveries have fallen by nearly $29 billion. However, from the models of ARMAX and ARMA-GARCH, we can see that Boeing's stock price has only suffered a short-term impact. Boeing's overall stock price will not be affected in the long run. The pulse analysis diagram of the VAR model also verifies this phenomenon. By reading this article, people who own Boeing stock need not worry too much about the impact of the COVID-19 pandemic. Price fluctuations will not last long. At the same time, there is no need to be overly pessimistic about their industry for airlines. Boeing itself has a certain ability to withstand risks due to its vast international market and advanced manufacturing technology.

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