Volkswagen Price Analysis: 2009-2016

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Objectives

The purpose of this paper will be to analyze the volatility and movement of Volkswagen stock price following the announcement of the Porsche buyout. This paper will then further analyze how Volkswagen's volatility changed after the Dieselgate scandal in 2015.

Background

On December 12, 2009, Volkswagen officially announced they would buy 49.9% shares of Porsche. The merger of the two German car manufacturers was finally completed on July 5, 2012. The buyout accelerated Volkswagen growth, making it become one of the largest car manufacturers in the world.[1]

On September 20, Volkswagen admitted to cheating on EPA emissions tests, marking the beginning of the Dieselgate scandal. This caused a 20% drop in Volkswagen's share price the following day. The economic fallout of the scandal continued to hamper the firm's growth and has cost them tens of billions of dollars in penalty fees.[2]

Method

This paper recorded data from on the closing equity prices of Volkswagen, Porsche, and BMW from April 5, 2009, to October 20, 2016. In the first half of this paper, I will examine the price correlation between Volkswagen and Porsche throughout the buyout and compare it to the market benchmark (BMW). In the second half of the paper, I will examine how this correlation changes after the Dieselgate scandal in 2015.

The models in this paper consist of five different time periods:

- Period 1: The pre-buyout announcement period from April 5, 2009, to December 9, 2009
- Period 2: The intermediate period between the first announcement and the second announcement that finalized the merger, from December 12, 2009, to July 5, 2012.
- Period 3: The post-buyout period from July 5, 2012, to January 1, 2015.
- Period 4: The pre-Dieselgate period from January 1, 2015, to September 20, 2015
- Period 5: The post-Dieselgate period from September 20, 2015, to September 20, 2016

Lastly, we will build a SARIMAX model for every period we examine and test its forecasts against the actual price.

Price Correlation

In the pre-buyout period, we see the share valuation between Volkswagen, Porsche, and BMW similar in size and movement. After Volkswagen's first announcement where they bought 49.9% of Porsche shares, their stock price begins to soar relative to the other manufacturers. This gap is widened further after the second announcement in 2012.

Figure 1: Closing Price by Announcement Period

Source: Yahoo Finance

```
Correlation among manufacturers from 2009-04-05 to 2015-01-01

 Volkswagen and Porsche correlation:  0.886308503147584
Volkswagen and BMW correlation:      0.9713561403514728
Porsche correlation and BMW:         0.8880729994890912
```

The correlation over this entire time period suggests that all three prices follow each other closely. The aggregated values, however, fails to capture the seismic shift in correlation between Volkswagen and Porsche over the buyout.

In the first time period, the *r* coefficient between Volkswagen and Porsche is .66. After the first announcement, the correlation between the two firms increases by 11%. After the second announcement, the firms are highly correlated with an r-value of .94.

The acquisition of Porsche also led to a strong correlation between Porsche's price movements with BMW. Despite both companies being weakly correlated before the first announcement, BMW did have a

strong correlation with Volkswagen who grew as a market trendsetter after the first period. Since the buyout caused Volkswagen share value to directly affect Porsches', this allowed the latter and BMW to follow each other's price more closely.

```
      Correlation among manufacturers in Period 1

Volkswagen and Porsche correlation: 0.6633400817761245
 Volkswagen and BMW correlation:     0.842835347467531
Porsche and BMW correlation:        0.6095045685009073

      Correlation among manufacturers in Period 2

Volkswagen and Porsche correlation: 0.7422114347356785
Volkswagen and BMW correlation:     0.9795942993967812
Porsche and BMW correlation:        0.7035985449323023

      Correlation among manufacturers in Period 3

Volkswagen and Porsche correlation: 0.9465576185566056
Volkswagen and BMW correlation:     0.8472303914511872
Porsche and BMW Correlation:        0.9132323189838413
```

Modeling

Using the data, I constructed an ARIMAX price model for Volkswagen in each time period using the other two firms' share prices as exogenous variables.

SARIMAX Results

Dep. Variable:	y	**No. Observations:**	17
Model:	SARIMAX(1, 0, 0)	**Log Likelihood**	-329.60
Date:	Sun, 19 Jul 2020	**AIC**	669.21
Time:	22:06:03	**BIC**	685.11
Sample:	04-06-2009	**HQIC**	675.66
	- 12-09-2009		
Covariance Type:	opg		

	coef	std err	z	P>|z|	[0.025	0.975]
intercept	0.7502	0.464	1.618	0.106	-0.159	1.659
por	0.4141	0.099	4.169	0.000	0.219	0.609
bmw	0.6858	0.325	2.108	0.035	0.048	1.324
ar.L1	0.9634	0.020	48.676	0.000	0.925	1.002
sigma2	2.3414	0.159	14.719	0.000	2.030	2.653

Ljung-Box (Q):	38.25	**Jarque-Bera (JB):**	166.09
Prob(Q):	0.55	**Prob(JB):**	0.00
Heteroskedasticity (H):	1.61	**Skew:**	-0.52
Prob(H) (two-sided):	0.07	**Kurtosis:**	7.62

Figure 2: ARIMAX for Volkswagen in Period 1

Before the first announcement, the best fitting model for Volkswagen was a simple AR model with a single lag and two exogenous variables. All coefficients except the intercept are significant at the 5% level. Unexpectedly, the highest coefficient was the lagged variable. This was expected as prices do not repeatedly fluctuate randomly. Interestingly enough, prices are stationary enough to model using an ARIMAX.

SARIMAX Results

Dep. Variable:	y	**No. Observations:**	672
Model:	SARIMAX(1, 1, 1)x(1, 0, 1, 5)	**Log Likelihood**	-1095.678
Date:	Sun, 19 Jul 2020	**AIC**	2207.356
Time:	22:06:03	**BIC**	2243.426
Sample:	12-09-2009	**HQIC**	2221.326
	- 07-05-2012		
Covariance Type:	opg		

	coef	std err	z	P>|z|	[0.025	0.975]
intercept	0.0040	0.001	3.649	0.000	0.002	0.006
por	0.8131	0.064	12.738	0.000	0.688	0.938
bmw	1.5496	0.072	21.477	0.000	1.408	1.691
ar.L1	0.9419	0.015	63.278	0.000	0.913	0.971
ma.L1	-0.9996	0.078	-12.878	0.000	-1.152	-0.847
ar.S.L5	-0.9946	0.059	-16.974	0.000	-1.109	-0.880
ma.S.L5	0.9907	0.073	13.603	0.000	0.848	1.133
sigma2	1.5264	0.146	10.468	0.000	1.241	1.812

Ljung-Box (Q):	25.56	**Jarque-Bera (JB):**	89.47
Prob(Q):	0.96	**Prob(JB):**	0.00
Heteroskedasticity (H):	1.66	**Skew:**	0.35
Prob(H) (two-sided):	0.00	**Kurtosis:**	4.65

Figure 3: ARIMAX Model for Volkswagen in Period 2

In period 2, after Volkswagen purchases 49.9% of Porsche, the best fitting model is an ARIMAX (1,1,1) that is seasonally adjusted by 5 days. Unlike the previous model, this model is integrated so it is modeling returns rather than prices. The model also finds past residuals to have significant explanatory power. This suggests that the buyout announcement did change the trend of Volkswagen's share prices.

Lastly, even though our model suggests there is seasonality, there is not much economic explanation for this as price trends are more effected by current events rather than pre-existing patterns.

SARIMAX Results

Dep. Variable:	y	**No. Observations:**	651
Model:	SARIMAX(0, 1, 0)	**Log Likelihood**	-1001.321
Date:	Sun, 19 Jul 2020	**AIC**	2008.642
Time:	22:06:03	**BIC**	2022.072
Sample:	07-05-2012	**HQIC**	2013.851
	- 01-01-2015		
Covariance Type:	opg		

	coef	std err	z	P>|z|	[0.025	0.975]
por	1.8862	0.042	44.721	0.000	1.804	1.969
bmw	0.6922	0.061	11.395	0.000	0.573	0.811
sigma2	1.2752	0.049	26.116	0.000	1.179	1.371

Ljung-Box (Q):	30.15	**Jarque-Bera (JB):**	160.05
Prob(Q):	0.87	**Prob(JB):**	0.00
Heteroskedasticity (H):	0.51	**Skew:**	-0.36
Prob(H) (two-sided):	0.00	**Kurtosis:**	5.32

Figure 4: ARIMAX Model for Volkswagen in Period 3

After the complete purchase of Porsche, we see that the best-fitting model for Volkswagen is a simple integrated model with two exogenous variables. Notably, Porsche is the most economically significant model with a coefficient much higher than any of the variables in the previous model. This model is no longer reliant on past values since after the second announcement, Volkswagen and Porsche have become effectively one entity and most of the explanation of its price can best be captured by the other firms' price today than its own price yesterday.

Throughout all three models, Porsche became an increasingly larger variable as we moved from one period to the next. Modeling ARIMAX models for Porsche ought to lead to similar results where Volkswagen becomes increasingly more significant variable than the rest.

SARIMAX Results

Dep. Variable:	y	**No. Observations:**	178
Model:	SARIMAX(2, 0, 0)	**Log Likelihood**	-226.231
Date:	Sun, 19 Jul 2020	**AIC**	464.462
Time:	22:06:19	**BIC**	483.553
Sample:	04-06-2009	**HQIC**	472.204
	- 12-09-2009		
Covariance Type:	opg		

	coef	std err	z	P>|z|	[0.025	0.975]
intercept	0.5770	0.376	1.533	0.125	-0.161	1.315
vol	0.1111	0.051	2.157	0.031	0.010	0.212
bmw	0.8440	0.152	5.557	0.000	0.546	1.142
ar.L1	1.0747	0.059	18.193	0.000	0.959	1.191
ar.L2	-0.1589	0.059	-2.716	0.007	-0.274	-0.044
sigma2	0.7354	0.052	14.098	0.000	0.633	0.838

Ljung-Box (Q):	26.01	**Jarque-Bera (JB):**	559.41
Prob(Q):	0.96	**Prob(JB):**	0.00
Heteroskedasticity (H):	0.21	**Skew:**	-0.96
Prob(H) (two-sided):	0.00	**Kurtosis:**	11.47

Figure 5: ARIMAX Model for Porsche in Period 1

In the pre-announcement model for Porsche, the best fitting model is very similar to that of Volkswagen. The model is a simple AR(2) model with two exogenous variables where all coefficients except the intercept are statistically significant. Volkswagen is relatively small suggesting that it had a weak influence on Porsche's stock price.

SARIMAX Results

Dep. Variable:	y	**No. Observations:**	672
Model:	SARIMAX(1, 1, 0)	**Log Likelihood**	-581.705
Date:	Sun, 19 Jul 2020	**AIC**	1173.410
Time:	22:06:19	**BIC**	1195.954
Sample:	12-09-2009	**HQIC**	1182.142
	- 07-05-2012		
Covariance Type:	opg		

	coef	std err	z	P>|z|	[0.025	0.975]
intercept	-0.0210	0.022	-0.937	0.349	-0.065	0.023
vol	0.1740	0.016	11.219	0.000	0.144	0.204
bmw	0.3099	0.044	7.022	0.000	0.223	0.396
ar.L1	0.0712	0.030	2.343	0.019	0.012	0.131
sigma2	0.3315	0.010	32.515	0.000	0.312	0.352

Ljung-Box (Q):	35.66	**Jarque-Bera (JB):**	1072.22
Prob(Q):	0.67	**Prob(JB):**	0.00
Heteroskedasticity (H):	1.40	**Skew:**	0.07
Prob(H) (two-sided):	0.01	**Kurtosis:**	9.19

Figure 6: ARIMAX Model for Porsche in Period 2

In the second period model, we see that the coefficient of the first lagged value has dropped immensely. While the size of all the coefficients has been reduced in size due to the model estimating integrated values, the first lag coefficient is no longer the largest as in the previous model. The decrease in its size can be explained by the 57% increase in the Volkswagen coefficient.

SARIMAX Results

Dep. Variable:	y	**No. Observations:**	651
Model:	SARIMAX(0, 1, 0)	**Log Likelihood**	-335.182
Date:	Sun, 19 Jul 2020	**AIC**	676.363
Time:	22:06:19	**BIC**	689.794
Sample:	07-05-2012	**HQIC**	681.573
	- 01-01-2015		
Covariance Type:	opg		

	coef	std err	z	P>|z|	[0.025	0.975]
vol	0.2429	0.008	28.916	0.000	0.226	0.259
bmw	0.1509	0.019	8.022	0.000	0.114	0.188
sigma2	0.1642	0.005	31.677	0.000	0.154	0.174

Ljung-Box (Q):	41.89	**Jarque-Bera (JB):**	526.88
Prob(Q):	0.39	**Prob(JB):**	0.00
Heteroskedasticity (H):	0.62	**Skew:**	0.47
Prob(H) (two-sided):	0.00	**Kurtosis:**	7.31

Figure 7: ARIMAX Model for Porsche in Period 3

As expected, the ARIMAX model for Porsche in period 3 mirrors that of Volkswagen. Just as Porsche was the most significant variable in the Volkswagen, the reverse is true here. In every period, both coefficients became larger in each successive time period.

Predictive Power

Using our estimated best-fitting models, we will test how their forecasts line up with the actual values. More specifically, we will test whether adding Porsche as an exogenous variable will improve the model's forecast. In each case, we will compare an estimated ARIMAX model with only our market benchmark as an exogenous variable versus an ARIMAX model with Porsche as a second exogenous variable.

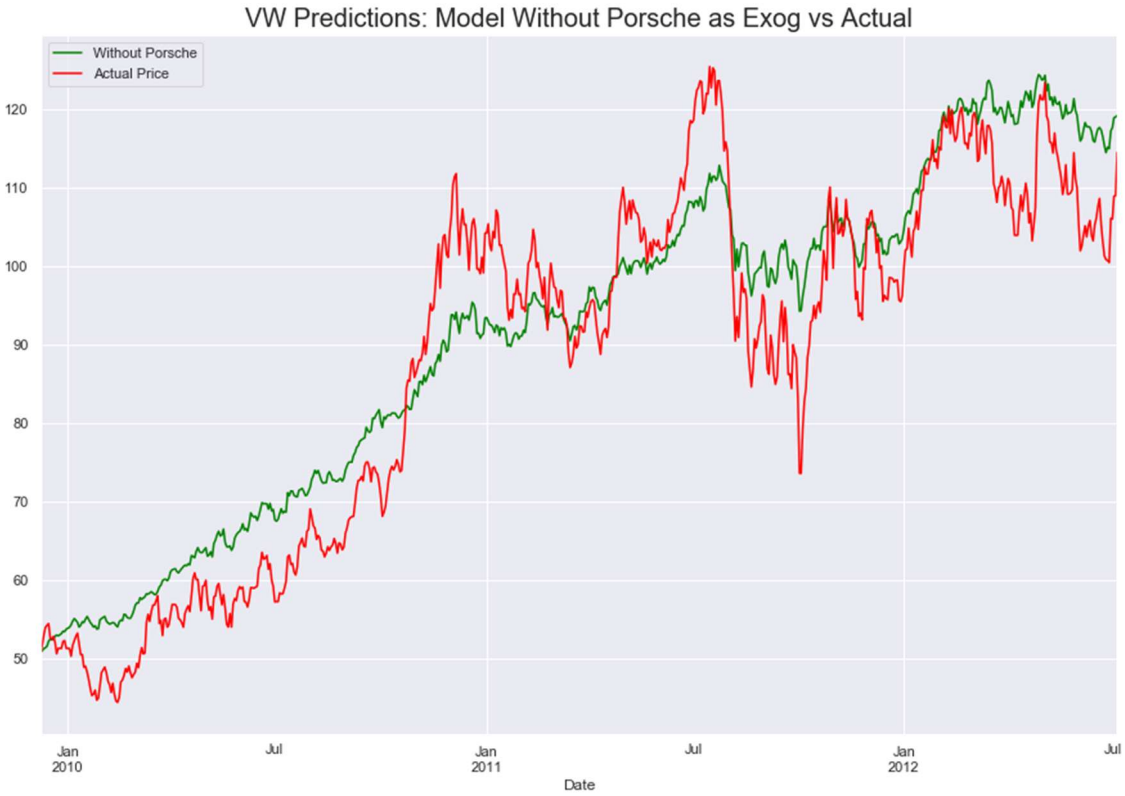

Figure 7: Volkswagen forecast in Period 2 Without Porsche

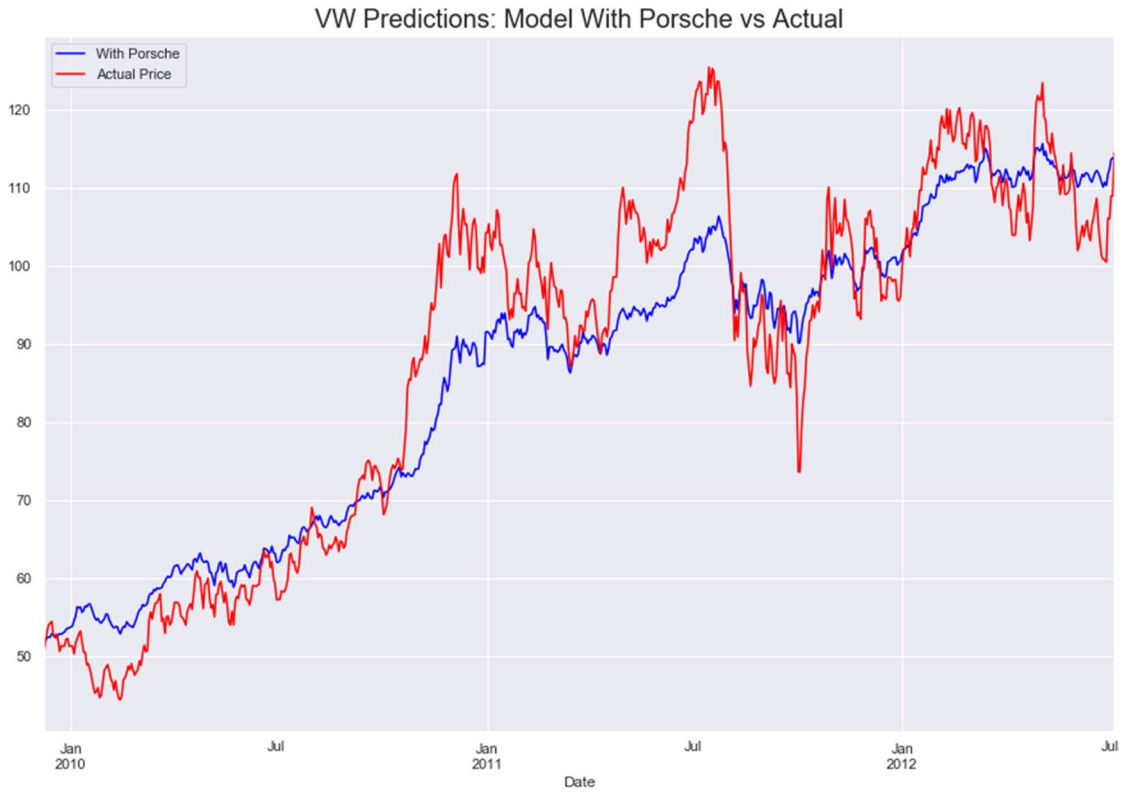

Figure 8: Volkswagen Forecast in Period 2 With Porsche

When using only the market benchmark as an exogenous variable, the forecasts conservatively estimate rises and falls in Volkswagen prices. Some intervals fail to adjust to major shocks, leading to prolonged overestimations in major decreases and underestimation in major increases.

When adding Volkswagen prices as an exogenous variable, the forecasts capture the magnitude of Volkswagen prices much more accurately. The model matches the smaller shifts more accurately and adjusts to sudden spikes faster.

Volatility of Each Time Period

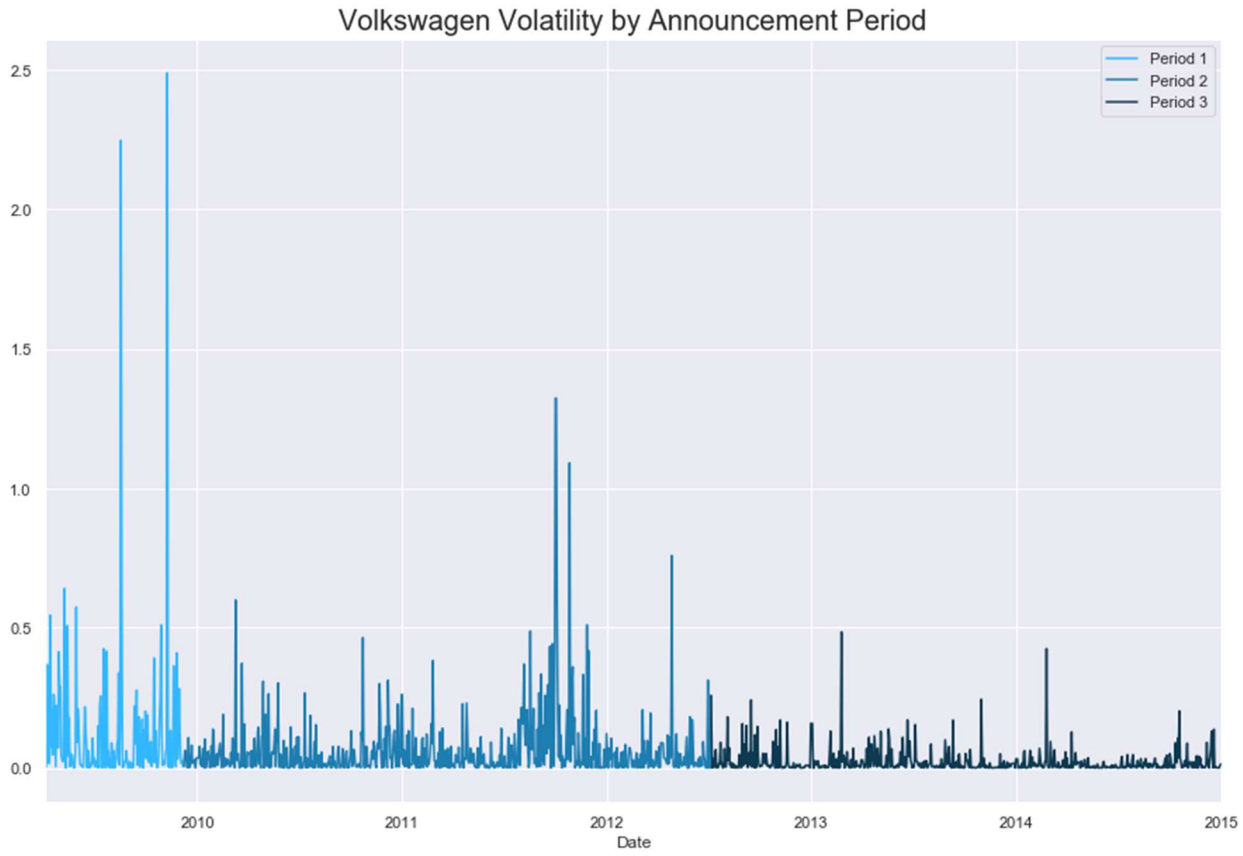

Figure 9: Volkswagen Volatility by Announcement Period

A look at Volkswagen's price volatility shows that prices become volatile before each announcement but begin stabilizing immediately after. Porsche also behaves in a similar manner.

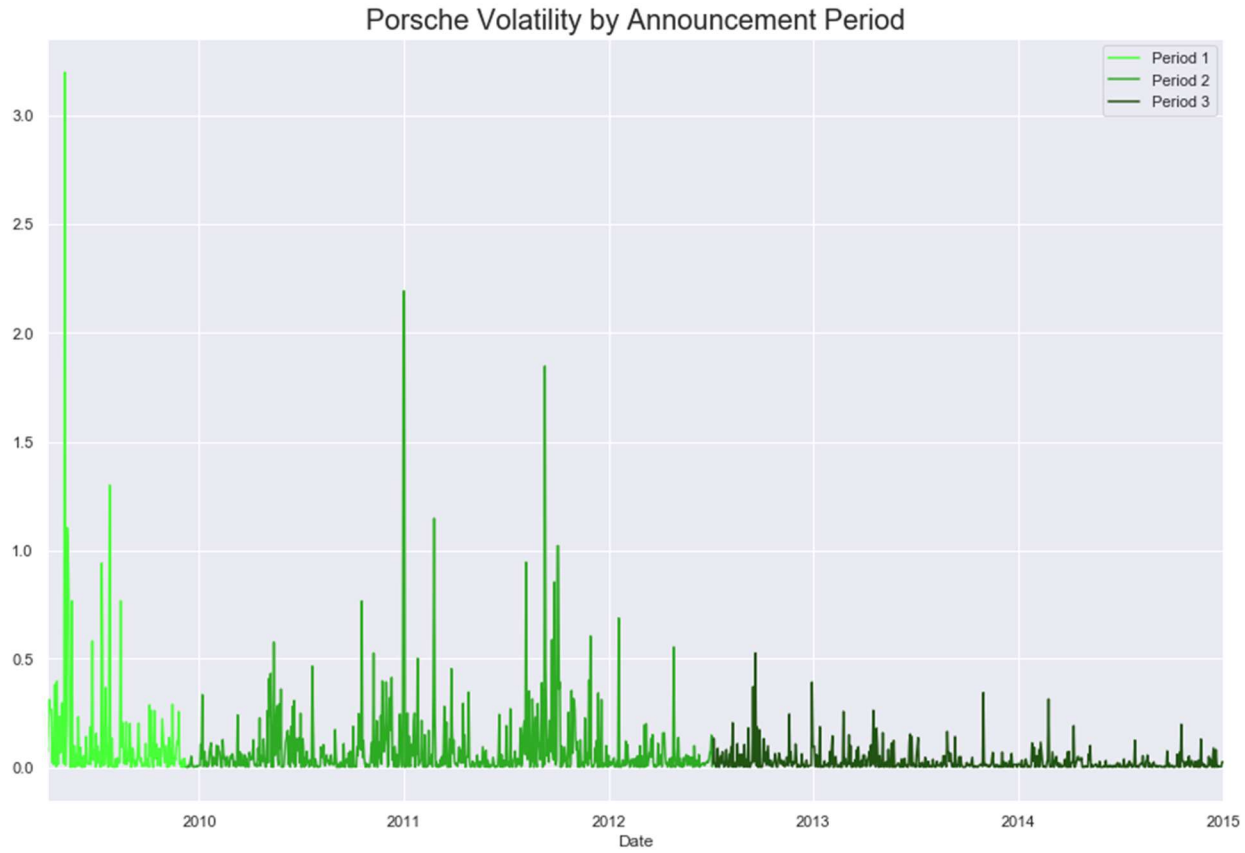

Figure 10: Porsche Volatility by Announcement Period

Dieselgate

From 2009 to 2015, the share value of all three firms were strongly correlated. However, when looking at the correlation between the manufacturers from 2015 to today, we see that they have become significantly less correlated than before.

```
Correlation among manufacturers from 2015-01-01 to 2020-07-23 00:00:00

        Volkswagen and Porsche correlation:  0.9450390759186332
        Volkswagen and BMW correlation:      0.5691199659404435
        Porsche and BMW correlation:         0.5130311337531018
```

This is largely because of the Volkswagen Emissions scandal that occurred in mid-2015. The cost of the scandal has been immense for Volkswagen and it still negatively impacts them today. Before, Dieselgate Volkswagen and Porsche's stock prices closely followed the market price. However, after Dieselgate the price movements became practically unrelated.

```
    Correlation among manufacturers from 2015-01-01 to 2015-09-20

        Volkswagen and Porsche correlation:  0.9923676020666576
         Volkswagen and BMW correlation:      0.961382135210234
        Porsche and BMW correlation:         0.9631012462830851
```

```
Correlation among manufacturers from 2015-09-20 to 2016-10-20

 Volkswagen and Porsche correlation:  0.9486407176234668
  Volkswagen and BMW correlation:      0.11365626776463127
 Porsche and BMW Correlation:         -0.006428802213832843
```

When graphing the stock prices and volatility for Volkswagen and Porsche, we see both stock prices experience a huge drop on September 20, 2015. From thereon, both firms experience a greater increase in volatility in the following year after the scandal than before.

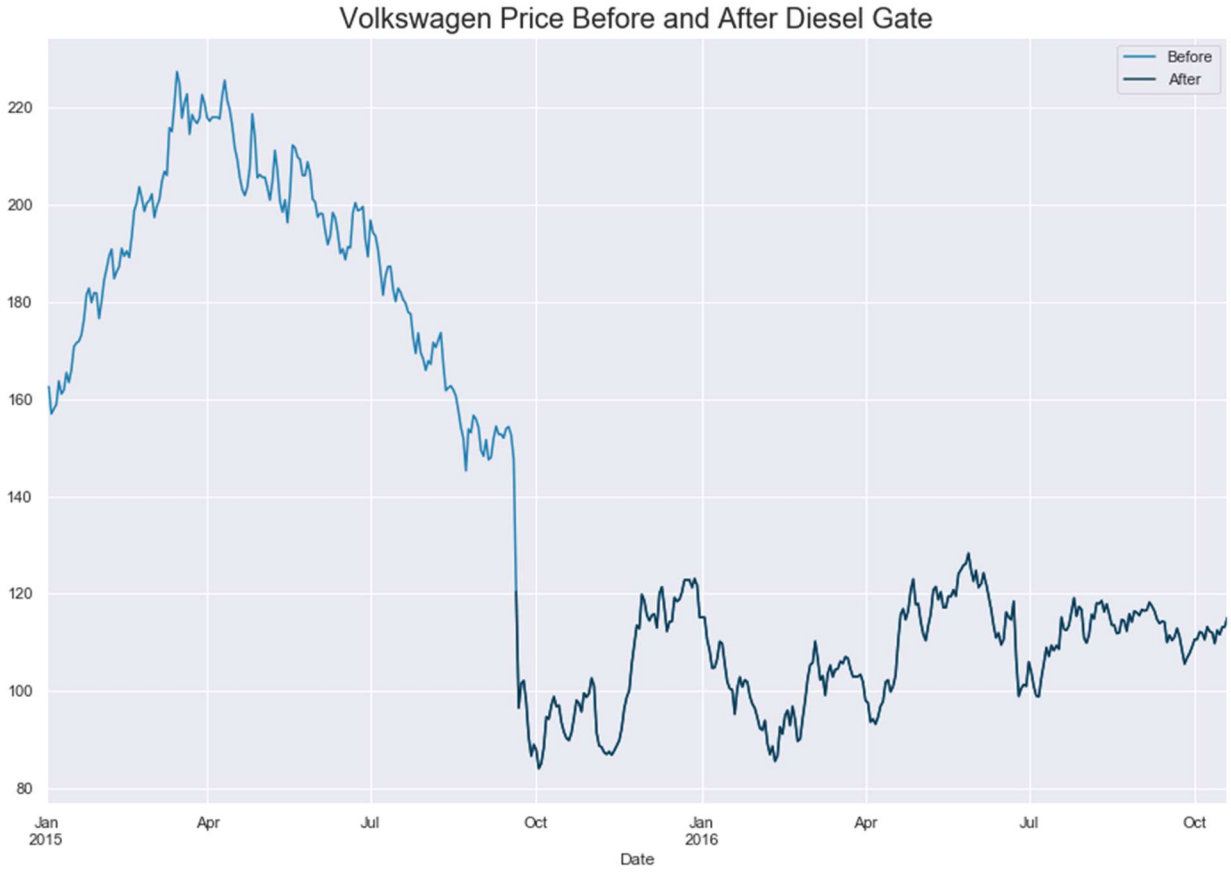

Figure 11: Volkswagen Price during Dieselgate

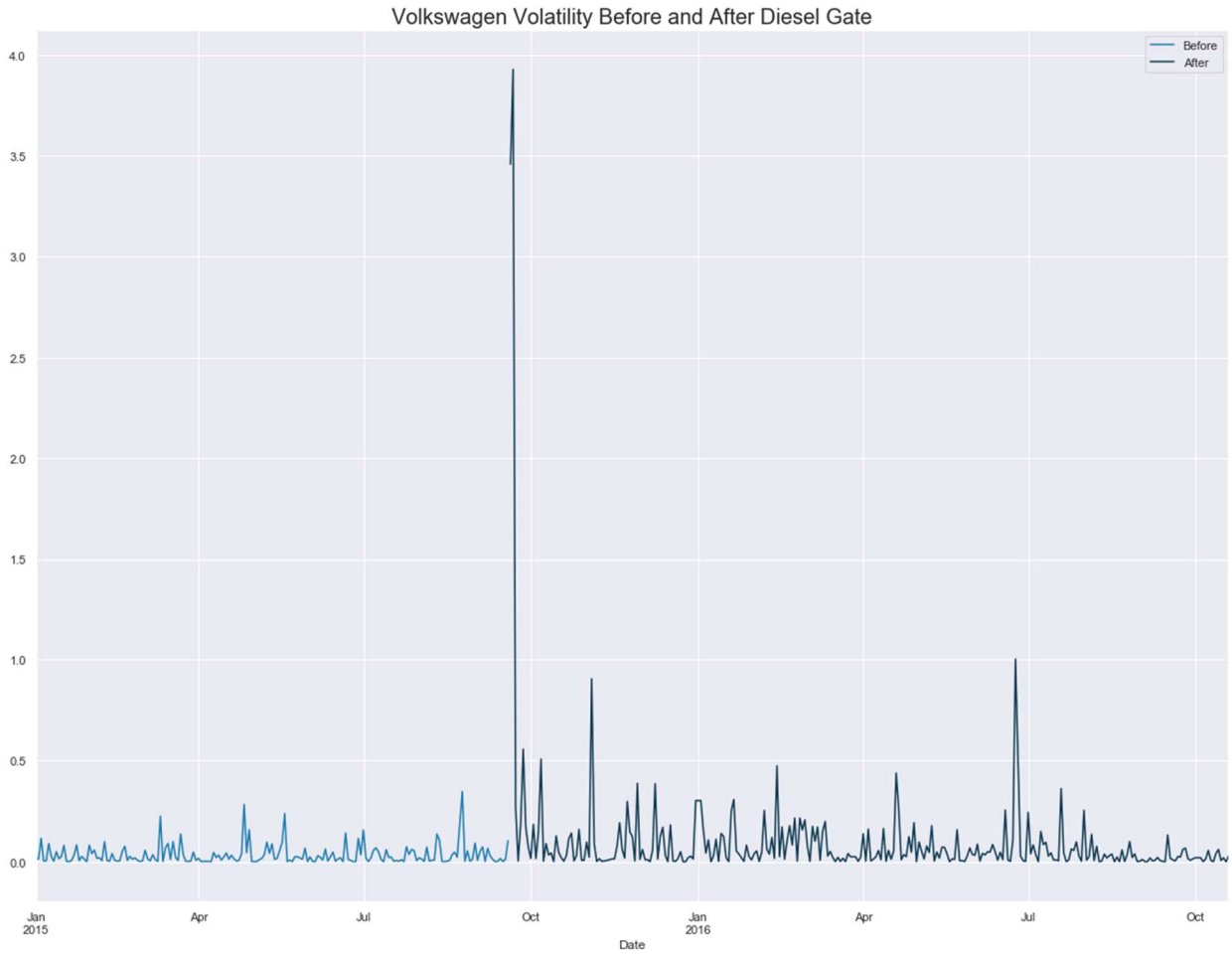

Figure 12: Volkswagen Volatility During Dieselgate

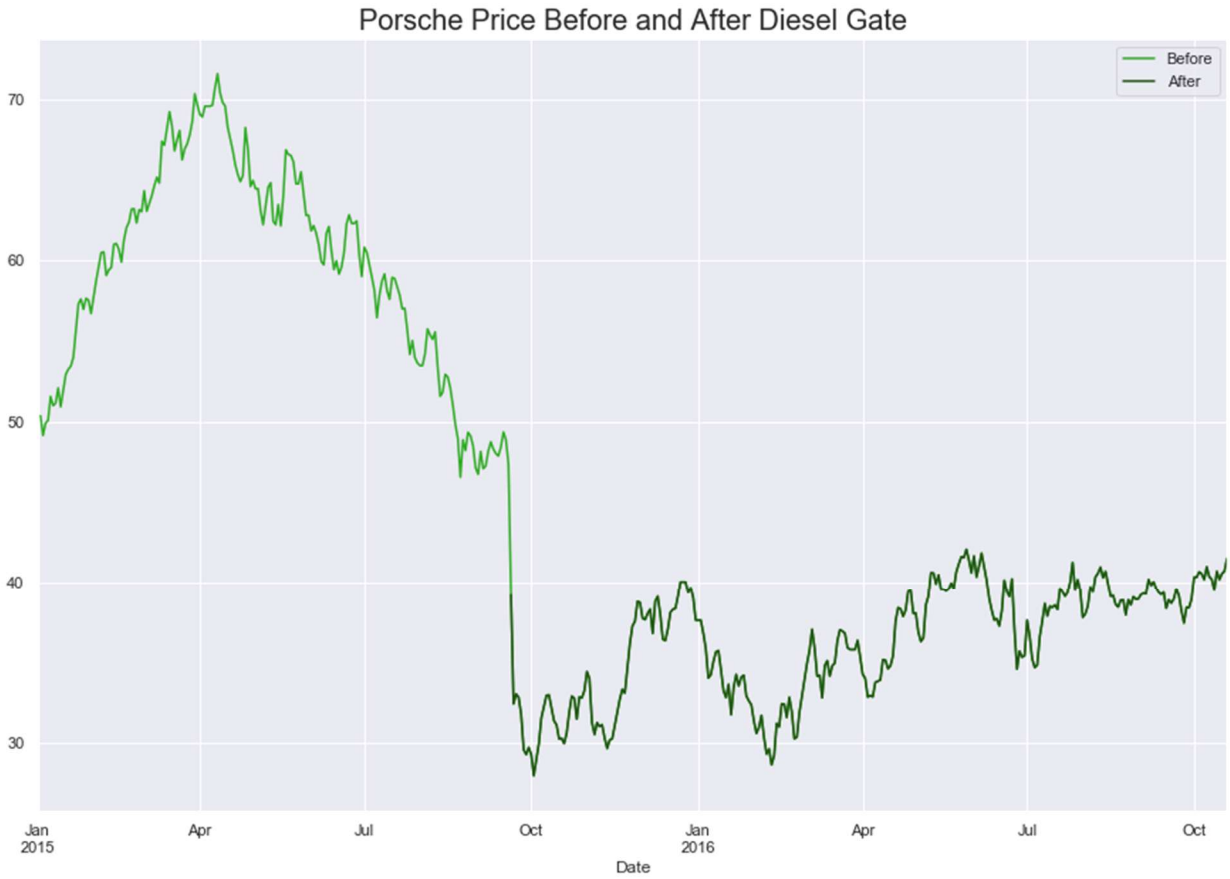

Figure 13: Porsche Price During Dieselgate

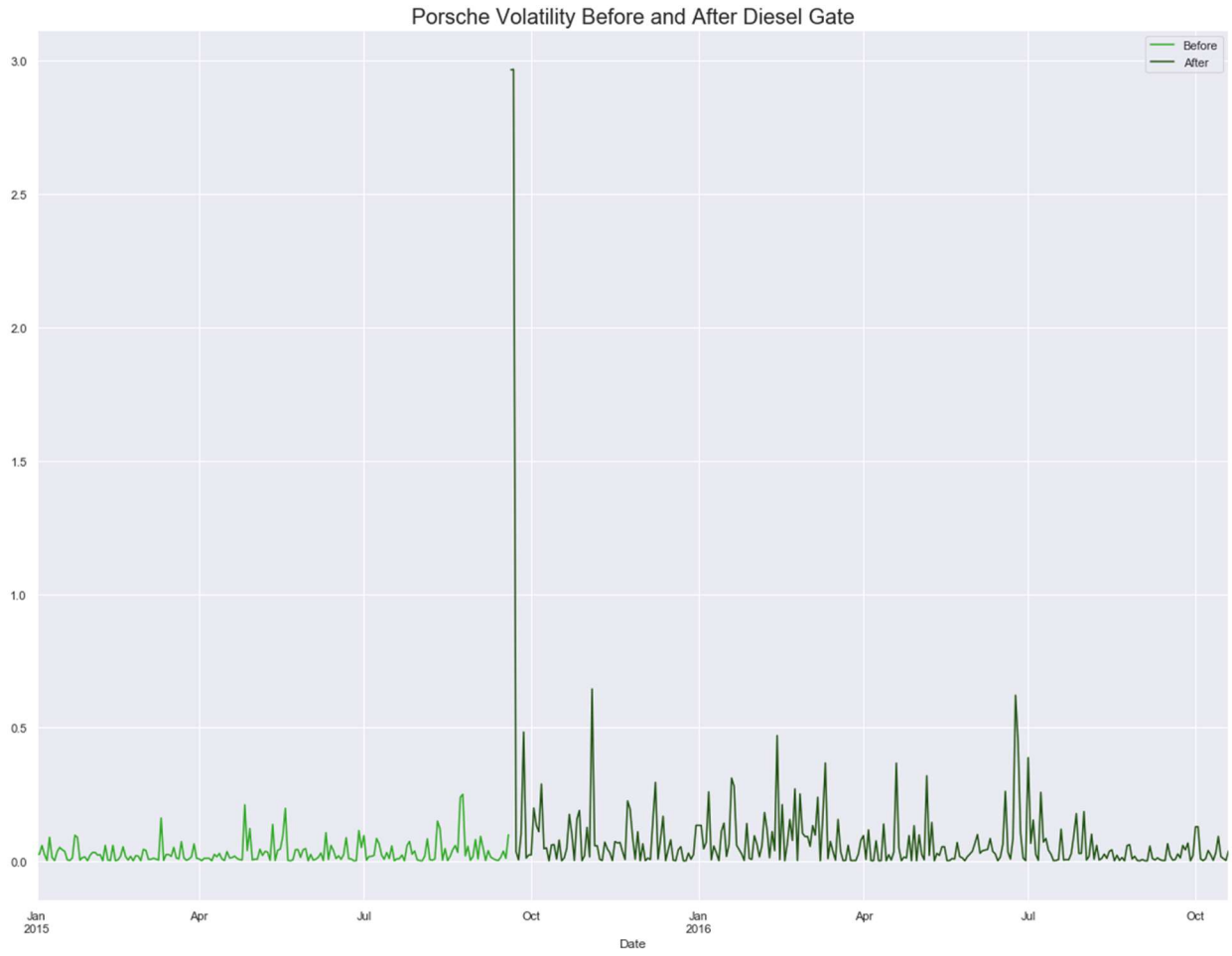

Figure 14: Porsche Volatility During Dieselgate

Conclusion

Throughout this paper, we examined the consequences of Volkswagen's acquisition of Porsche from 2009 to 2012 and the consequences of the Dieselgate scandal in 2015. The Porsche buyout caused Volkswagen to become the leading German car manufacturer and a trendsetter for the market. Volkswagen and, to a lesser extent, Porsche both experience solid growth and relatively stable volatility after each buyout announcement. The fortunes of the buyout were reversed after the Dieselgate scandal in 2015 where both firms saw a significant drop in their share prices and a persistent increase in volatility.

Citations

1) https://www.reuters.com/article/us-volkswagen-porsche-merger/vw-sees-porsche-buyout-clearing-path-to-global-leadership-idUSBRE8630PI20120705

2) https://www.independent.co.uk/news/business/Leading_business_story/volkswagen-diesel-emissions-scandal-the-toxic-legacy-a7312056.html