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Title:

"Vaccine Companies and their Relations to the Market Trends"

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Companies and Research

The goal of this study is to find trends amongst vaccination companies and their roles played throughout the COVID-19 pandemic. We have collected over a year's worth of data, September 2019 through December 2020, providing entries across the stocks: Moderna (MRNA), Pfizer (PZE), AstraZeneca (AZN), Arcturus Therapeutics Holdings (ARCT), BioNTech (BNTX). We are able to clearly see similar patterns across the stock charts while cross comparing the data. It is clear that there are certain indicators that are firing off that lead to spikes in the data charts. The spikes in the industry can also lead to spikes in other companies, leading us to further analyze why that may be happening. Furthermore, we are analyzing why the stock prices are reacting the way that they are. There are cases that one vaccination may take off or fall hard while the rest of the market holds steady. This could indicate flaws with the product, company, bad press, etc. By discovery of a pattern, we can identify market leaders and correlations for the future. Patterns also allow us to better understand indicators and why they fired off the way that they did. To sum up everything that has been stated thus far, data analysis allows us to see things that the naked eye cannot identify. Throughout this study, we are able to use data to see things that we could not see by merely looking at the charts. This creates the ability to dive deeper into the datasets and come to conclusions as to why something may be happening.

Preliminary data at a Glance

Figure 1 shows a scatter plot of the daily closing price of Pfizer (PFE) vs the daily closing price of AstraZeneca (AZN). Each bubble therefore represents one day, with the X coordinate determined by the price of PFE that day and the Y coordinate determined by the price of AZN. The relationship displays a fairly strong correlation, even without including a fitted trend line there

is a discernible pattern: the two prices tend to move together. When PFE is higher, AZN tends to be higher as well and vice versa.
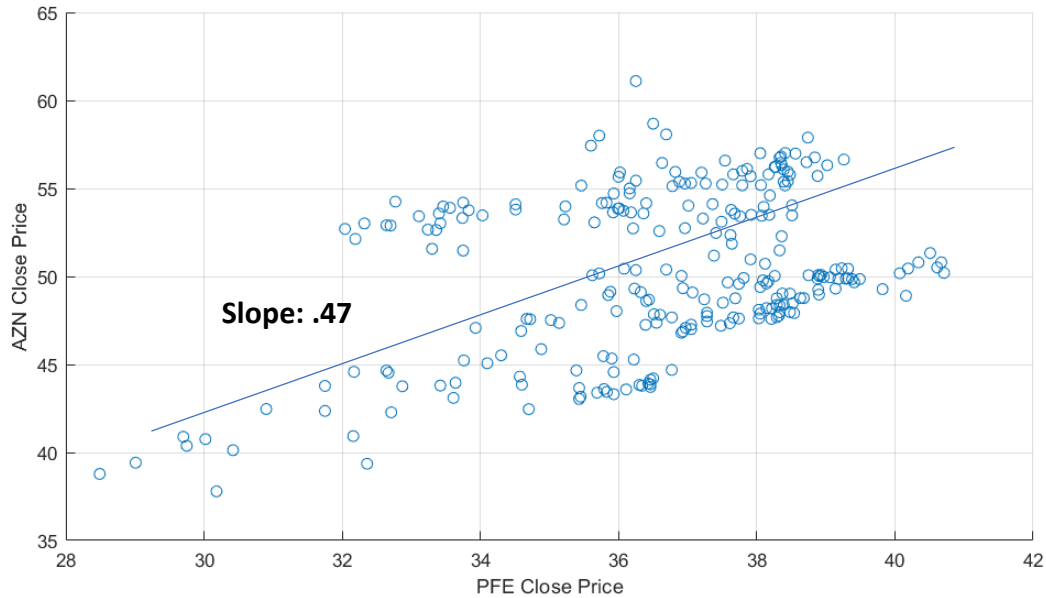
Figure 1: PFE vs AZN

Figure 2 performs the same exercise for the PFE closing price versus the closing price of Moderna (MRNA). MRNA is a company involved not so much with making pharmaceuticals themselves, but the implementation or delivery of them. So, for example, the sales and distribution of a COVID-19 vaccination. Note that the correlation coefficient between these two prices is not as strong as the relationship between PFE and AZN with a slope of .47. There may be one, of course, as many other control variables are not present here, but the difference between the first two figures is apparent.

Figure 3 then performs the same exercise again, but with AZN's price versus MRNA's. Now a potentially more interesting pattern emerges. The relationship between AZN and MRNA does exhibit a very clear and strong correlation coefficient of .66 for daily close values, but almost no correlation at lower values. This indicates that there may have been what is known as a

structural break in the time series. This means that some major event occurred that changed their patterns, and after that event their predictability may have changed. Using the prices at which the break seems to have occurred and a different view of the data, we can start to isolate when the relationship between AZN and MRNA gets more predictable, which may also help clarify the relationship between other prices such as AZN and PFE. These three prices are just one example, but we can use similar logic to uncover other price relationships.
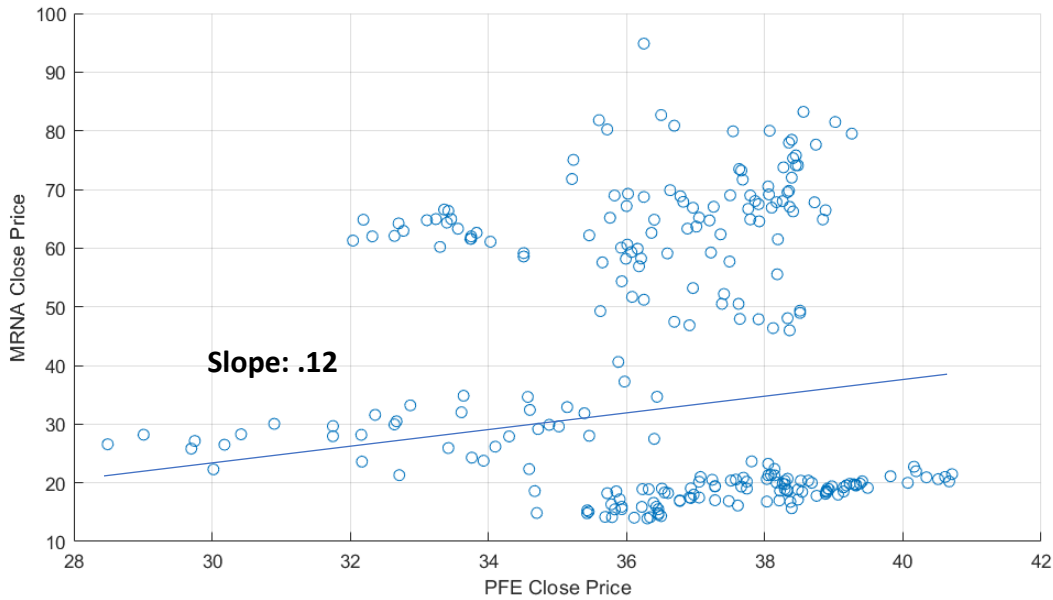
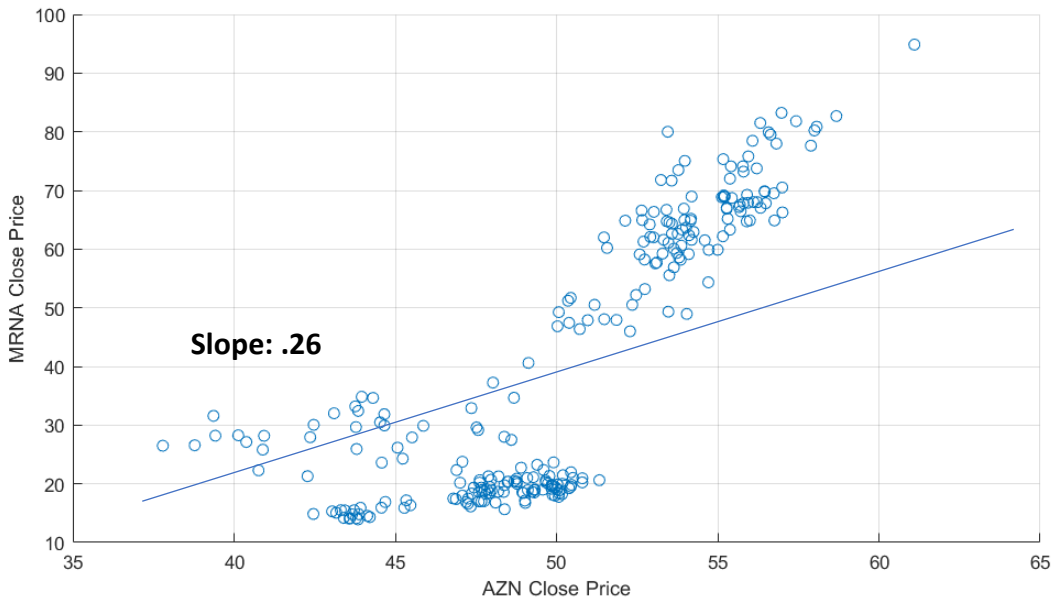Figure 2: PFE vs. MRNA

Figure 3: AZN vs. MRNA

Figure 4 looks at the daily closing prices of PFE and AZN over time. The trend line in Figure 1 revealed that they move with one another, but what's more is that – although it's hard to see with the eye alone – there are times when one moves first and the other follows. If possible, it would be great if there were a consistent pattern to one moving first and signaling when and how the other was going to move. We can run statistical tests to establish whether or not such relationships exist, but finding the right window of data, when the pattern is most consistent and free of structural breaks, can make the tests more accurate.
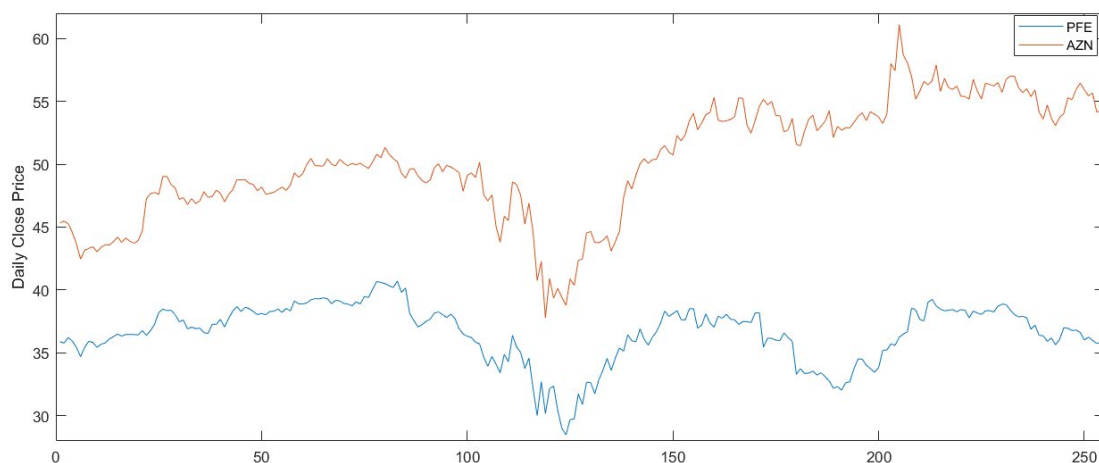
Figure 4: PFE and AZN Over Time

Figure 5 adds the MRNA price over time to the same prices series as in Figure 4, and now we see where the likely *structural break* occurred. The data is from the past year, 9/25/2019– 9/25/2020. The x-axis on the figures is daily trading data. This will not include the 100 weekend days equivalent to 20 weeks. This puts the initial jump of MRNA a bit early, but still seems highly likely to be related to the Corona virus. The real break in the series looks to be around the 120th data point, which would put it right in early March. This is not at all unexpected, but it does provide us with evidence of the data changing how its relationship patterns.

Figure 5: PFE, AZN, and MRNA Over Time
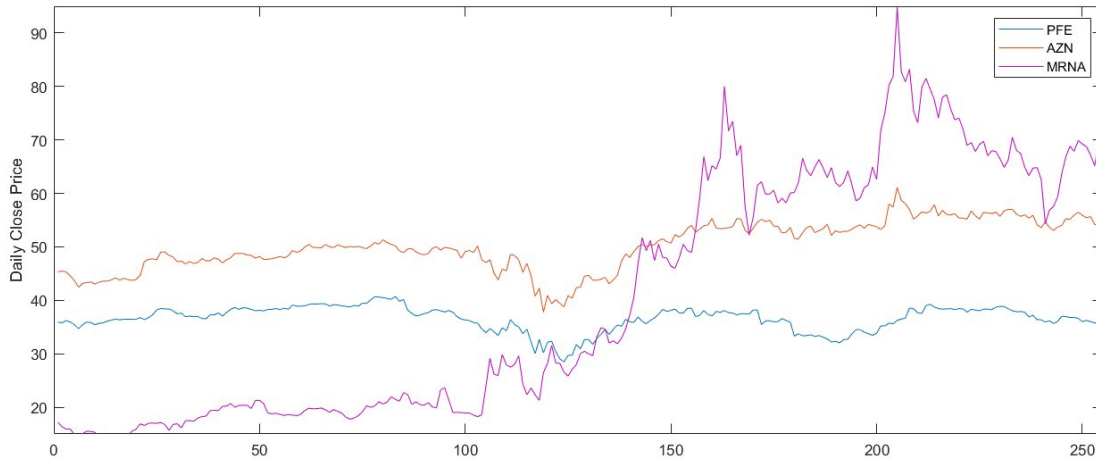
In fact, it is hard to see due to the scale of the graph, but as per Figure 3, but AZN and MRNA may even have a lagged relationship that would allow for improved predictions. Some regression results are included here which suggest an increase in AZN for a few days may mean an increase in MRNA. The results from the following figure show that MRNA, PFE, and AZN have data close to the mean values represented by the standard error. Further, PFE has the greatest strength of correlation as represented by the R-Sq value. PFE is .65. MRNA and AZN come in at just over .35 representing a much weaker strength of correlation. PFE continues this strength with the lowest RMSE at .455. The RMSE is a measure of how far the data falls from the line of best fit. PFE is showing us early strength between the RMSE, R-Sq, and low standard error. This continues a strong case for Pfizer. That's just a quick run of the whole sample period (the last year) with those three variables. Running the estimation with only the data after the virus was announced and/or with other variables included could produce better or completely different results.

```
Vector autoregression

Sample:  43741 - 44099, but with gaps        Number of obs    =        92
Log likelihood =  -361.1895                  AIC              =   8.50412
FPE            =   .9930993                  HQIC             =  8.836016
Det(Sigma_ml)  =   .515981                   SBIC             =  9.326442

Equation          Parms      RMSE     R-sq      chi2     P>chi2

dMRNA               10      2.2473   0.3525   50.08902   0.0000
dPFE                10     .455191   0.6536   173.6265   0.0000
dAZN                10     .890317   0.3786   56.05609   0.0000
```

	Coef.	Std. Err.	z	P>|z|	[95% Conf. Interval]	
dMRNA						
dMRNA						
L1.	.0643754	.1171277	0.55	0.583	-.1651907	.2939416
L2.	.2303593	.106261	2.17	0.030	.0220916	.438627
L3.	-.2221984	.069085	-3.22	0.001	-.3576025	-.0867944
dPFE						
L1.	-.4251711	.3565053	-1.19	0.233	-1.123909	.2735665
L2.	-.3991673	.4117543	-0.97	0.332	-1.206191	.4078563
L3.	-.1451807	.3533726	-0.41	0.681	-.8377783	.5474169
dAZN						
L1.	.6729333	.2573694	2.61	0.009	.1684986	1.177368
L2.	1.20805	.3009285	4.01	0.000	.6182406	1.797859
L3.	.9646679	.2517826	3.83	0.000	.4711829	1.458153
dSP	.0049473	.0040498	1.22	0.222	-.0029901	.0128847
dPFE						
dMRNA						
L1.	.0446908	.0237243	1.88	0.060	-.0018079	.0911896
L2.	.0128879	.0215232	0.60	0.549	-.0292969	.0550726
L3.	-.0315007	.0139932	-2.25	0.024	-.0589268	-.0040745
dPFE						
L1.	.0266577	.0722104	0.37	0.712	-.114872	.1681874
L2.	-.1747111	.0834011	-2.09	0.036	-.3381742	-.0112479
L3.	-.0468597	.0715758	-0.65	0.513	-.1871458	.0934264
dAZN						
L1.	-.0046252	.0521303	-0.09	0.929	-.1067988	.0975483
L2.	-.0285181	.0609532	-0.47	0.640	-.1479842	.0909481
L3.	.131163	.0509987	2.57	0.010	.0312073	.2311186
dSP	.0089575	.0008203	10.92	0.000	.0073498	.0105653
dAZN						
dMRNA						
L1.	.0297895	.0464028	0.64	0.521	-.0611583	.1207373
L2.	.0482601	.0420977	1.15	0.252	-.0342498	.1307701
L3.	.0183479	.0273696	0.67	0.503	-.0352954	.0719913
dPFE						
L1.	.3773221	.1412376	2.67	0.008	.1005015	.6541428
L2.	.1682015	.1631258	1.03	0.302	-.1515191	.4879221
L3.	.0334888	.1399965	0.24	0.811	-.2408994	.307877
dAZN						
L1.	-.1445103	.1019627	-1.42	0.156	-.3443535	.0553329
L2.	.0843026	.1192196	0.71	0.479	-.1493636	.3179687
L3.	.2666121	.0997494	2.67	0.008	.0711069	.4621173
dSP	.0085334	.0016044	5.32	0.000	.0053889	.011678

Analysis of Current Data

Figure 6 represents the daily highs of PFE and AZN from December 2019 through December 2020. The figure clearly shows that the daily highs follow almost the exact same patterns between data. The charts seem to fall at the same points along the timelines as well as rise at approximately the same points along the timelines. The initial dip in the chart is understood because this lies between January 1st 2020 and March 1st 2020. At this time, COVID-19 was just starting to make its way to the United States and was still a large unknown. The rest of the market is also showing a bearish pattern at this time. Vaccination companies are falling through their resistance lines and setting lower lows.

Figure 6: PFE and AZN over Time
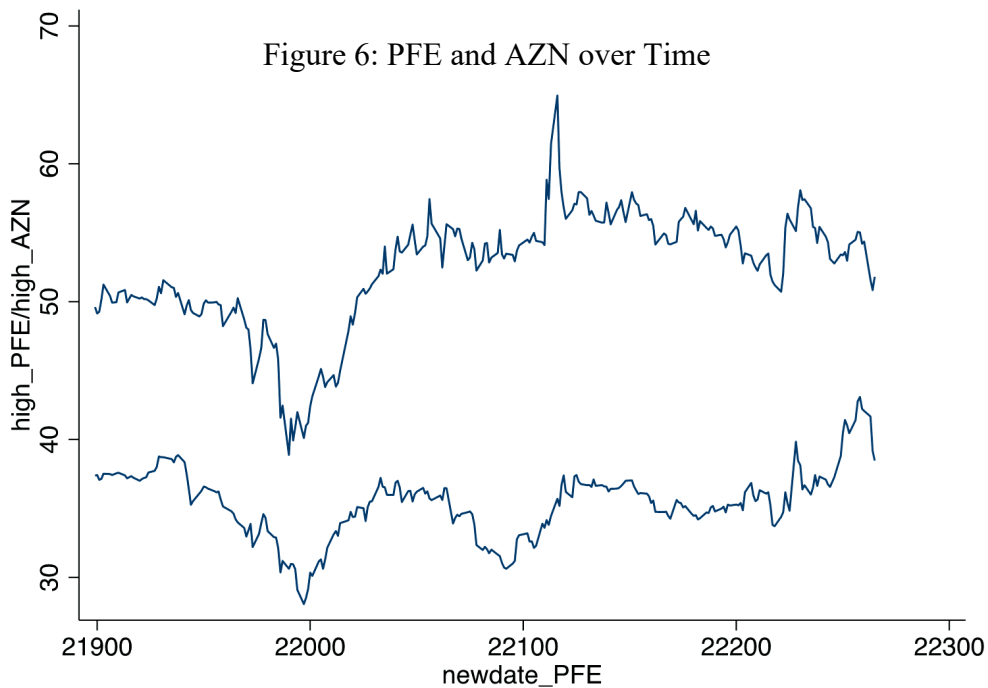
March is when things quickly turn around. Pfizer hits its low in the beginning of March and AstraZeneca quickly follows suit. Both stocks immediately switch direction when COVID-

19 is announced as a pandemic. The volume behind this bullish push links to the fact that buyers see both PFE and AZN as top companies in creating a vaccine. To the naked eye, the correlation between the two stocks appears to be strong in strength but it only carries a correlation coefficient of .54. This gives evidence that the stocks move alike yet perhaps not as closely as predicted. The trend is still on the upside and positive yet have variation for seemingly moving close together. Nonetheless, seeing these trends give us a good understanding of who the stock market believes to be the leaders in the rush of creating the first vaccinations. Figure 7 shows a similar trend.
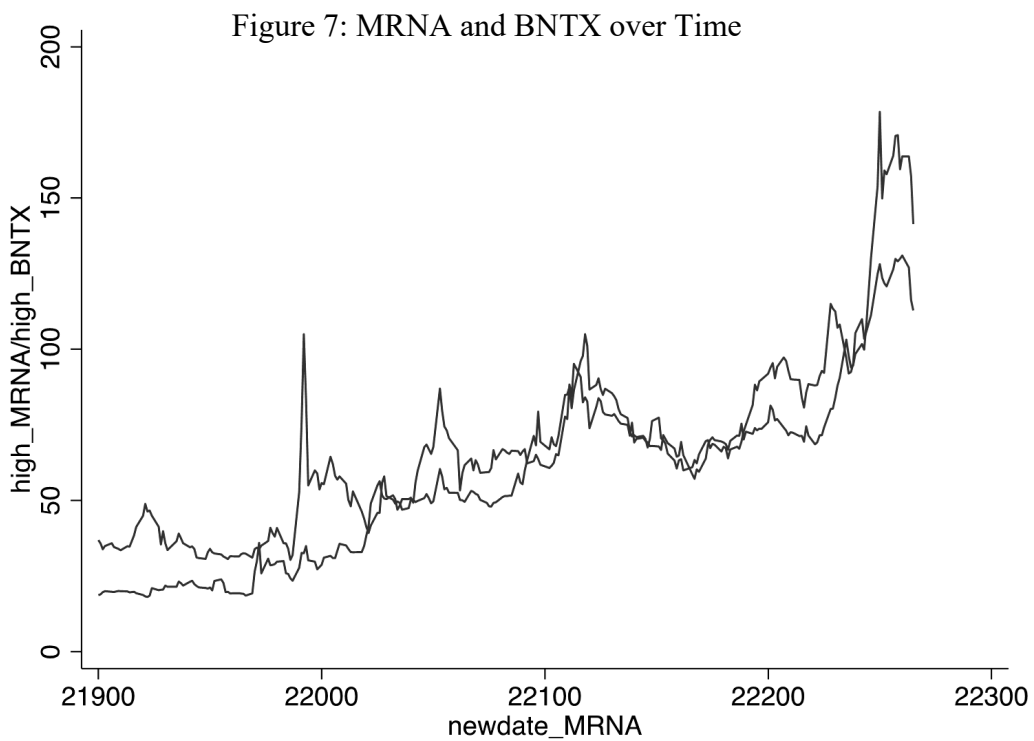
Figure 7: MRNA and BNTX over Time

Figure 7 shows a spike in the data in the March-April 2020 time frame. This is another interesting move as these two vaccination companies spike up near the announcement of COVID-19 in the United States. In addition, there is an announcement about a mandatory lockdown to be

put in place shutting down many businesses. Moderna is taking off at a much more substantial

rate, yet BioNTech spikes first and has a long consistent uptrend in their data. The noticeable

difference between Figure 6 and 7 is that MRNA/BNTX have relatively flat stock prices in

comparison to Figure 6. MRNA/BNTX never entered the large bearish trends that PFE/AZN had.

This leads to a possible conclusion that there is more trust in MRNA and BNTX after the original

announcements of COVID-19 in China. MRNA/BNTX also go against the trends of the general

market as they avoid the bearish trends.
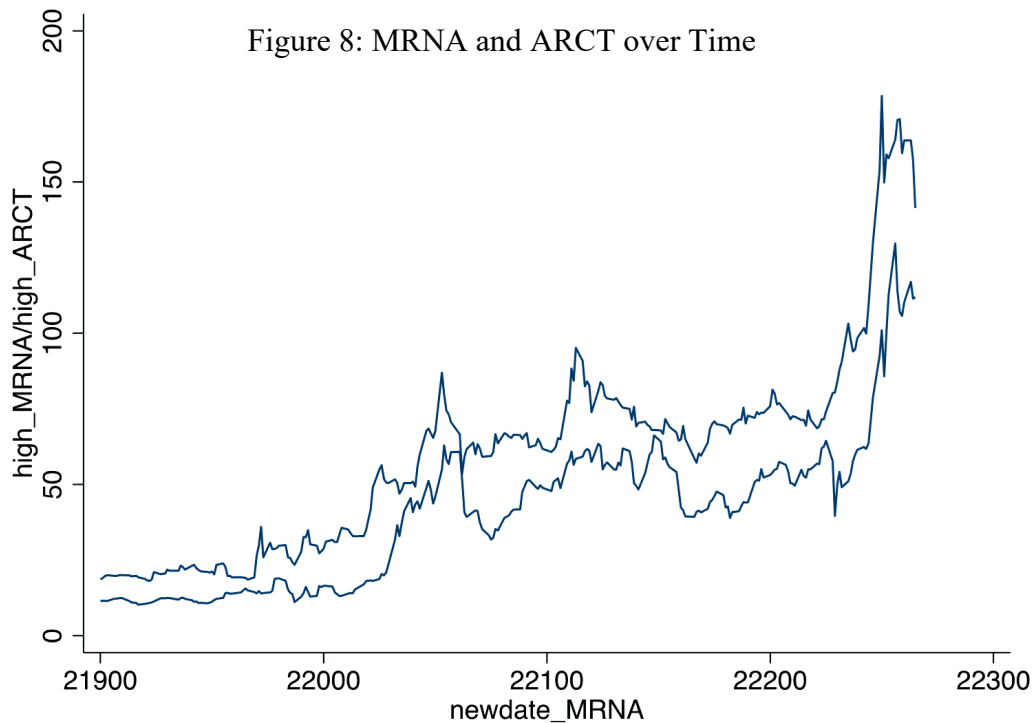

Figure 8: MRNA and ARCT over Time

Figure 8 compares the Moderna daily high price to Arcturus Therapeutics. ARCT has

similar spikes to MRNA as visibly displayed above. The figure exhibits one fall in price that causes

the charts to cross in direction. The MRNA stock crosses over ARCT in the beginning of June.

This is the only case of the figure in which the points do not follow along the same trends. The

June data point is a significant point as it does not follow the general trends of the other vaccination companies. As we look back to June 2020, news broke that the Moderna vaccination may not live up to expectations. A patient reported that he felt "the sickest of his life". His feelings of illness were paired with severe symptoms of the same virus that he was trying to protect himself from. Yet, this is not the worst news from Moderna as of June. Moderna knew about these symptoms in several patients and lied to the public about the trials. They not only left this information out, but they falsely reported about what was actually happening. Eventually, the truth came out creating this pullback in their stock price. MRNA had lost some customer faith and hurt their names from the bad press. It took four months for them to set a new low, and then they bounced back in stock price.

Nonetheless, Arcturus Therapeutics has fallen into the category of four other companies predicted to be in the race for coming out with the first COVID-19 vaccinations. From these three figures we can see stout upward moving charts. They were amongst the strongest competitors for creating a vaccination and their stock prices soared despite the announcement of a global pandemic. This all correlates to strong bullish trends, setting higher highs, and pushing higher because of a pandemic.

Final Conclusions

The COVID-19 pandemic is certainly something new and unknown for everyone. The entire medical industry is changing their practices to better accommodate, and businesses are looking for ways to profit. Unfortunately, this could lead to companies taking short cuts to rush something to completion. This happened specifically with AstraZeneca. News broke in late March 2021 that they had used old information to falsify their claims on the vaccine. The NIAID reported

on this stating that they could not accurately view the trial results due to the false numbers. This led to other federal health organizations becoming aware of the issue. AZN is still not allowed to have their vaccination in the United States, and many are hesitant if or when this will be cleared. The health organizations are reporting that AZN must return to trial and provide both timely and accurate results from the tests. The US is not the only country that has reported issues with AstraZeneca. The vaccine is in use around the world, yet there are several reports of blood clotting. Europe ran their own investigation of the company yet did not come up with anything showing that the vaccine was unsafe. AstraZeneca has fallen behind with this hiccup in their data. For them to be able to compete amongst the other companies, they must rapidly come up with up-to-date results that work.

Only time will tell the direction that things move following COVID, but we must beat it first. The data is certainly able to help us along with the countless people dedicating everything to beat this new disease. With these two paired hand-in-hand, we will be back stronger than ever!

Citations

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