# Vaccine Stock Analysis during the COVID-19 Pandemic

May 22, 2022

Vaccine Stock Analysis during the COVID-19 Pandemic

[95]:
```
import sys
!{sys.executable} -m pip install altair
```

```
WARNING: The directory '/home/jovyan/.cache/pip/http' or its parent
directory is not owned by the current user and the cache has been disabled.
Please check the permissions and owner of that directory. If executing pip with
sudo, you may want sudo's -H flag.
WARNING: The directory '/home/jovyan/.cache/pip' or its parent directory is
not owned by the current user and caching wheels has been disabled. check the
permissions and owner of that directory. If executing pip with sudo, you may
want sudo's -H flag.
Requirement already satisfied: altair in /opt/conda/lib/python3.7/site-packages
(4.2.0)
Requirement already satisfied: jsonschema>=3.0 in /opt/conda/lib/python3.7/site-
packages (from altair) (3.0.2)
Requirement already satisfied: numpy in /opt/conda/lib/python3.7/site-packages
(from altair) (1.17.0)
Requirement already satisfied: toolz in /opt/conda/lib/python3.7/site-packages
(from altair) (0.10.0)
Requirement already satisfied: entrypoints in /opt/conda/lib/python3.7/site-
packages (from altair) (0.3)
Requirement already satisfied: jinja2 in /opt/conda/lib/python3.7/site-packages
(from altair) (2.10.1)
Requirement already satisfied: pandas>=0.18 in /opt/conda/lib/python3.7/site-
packages (from altair) (0.25.0)
Requirement already satisfied: six>=1.11.0 in /opt/conda/lib/python3.7/site-
packages (from jsonschema>=3.0->altair) (1.12.0)
Requirement already satisfied: attrs>=17.4.0 in /opt/conda/lib/python3.7/site-
packages (from jsonschema>=3.0->altair) (19.1.0)
Requirement already satisfied: pyrsistent>=0.14.0 in
/opt/conda/lib/python3.7/site-packages (from jsonschema>=3.0->altair) (0.15.4)
Requirement already satisfied: setuptools in /opt/conda/lib/python3.7/site-
packages (from jsonschema>=3.0->altair) (41.0.1)
Requirement already satisfied: MarkupSafe>=0.23 in
/opt/conda/lib/python3.7/site-packages (from jinja2->altair) (1.1.1)
```

```
Requirement already satisfied: python-dateutil>=2.6.1 in
/opt/conda/lib/python3.7/site-packages (from pandas>=0.18->altair) (2.8.0)
Requirement already satisfied: pytz>=2017.2 in /opt/conda/lib/python3.7/site-
packages (from pandas>=0.18->altair) (2019.2)
```

[96]:
```
import datetime
import altair as alt
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt

from functools import reduce
```

Covid Dataset

[97]:
```
df = pd.read_csv("us_covid19_cases.csv")
```

[98]:
```
df.columns
```

[98]:
```
Index(['iso_code', 'continent', 'location', 'date', 'total_cases', 'new_cases',
       'new_cases_smoothed', 'total_deaths', 'new_deaths',
       'new_deaths_smoothed', 'total_cases_per_million',
       'new_cases_per_million', 'new_cases_smoothed_per_million',
       'total_deaths_per_million', 'new_deaths_per_million',
       'new_deaths_smoothed_per_million', 'reproduction_rate', 'icu_patients',
       'icu_patients_per_million', 'hosp_patients',
       'hosp_patients_per_million', 'weekly_icu_admissions',
       'weekly_icu_admissions_per_million', 'weekly_hosp_admissions',
       'weekly_hosp_admissions_per_million', 'total_tests', 'new_tests',
       'total_tests_per_thousand', 'new_tests_per_thousand',
       'new_tests_smoothed', 'new_tests_smoothed_per_thousand',
       'positive_rate', 'tests_per_case', 'tests_units', 'total_vaccinations',
       'people_vaccinated', 'people_fully_vaccinated', 'total_boosters',
       'new_vaccinations', 'new_vaccinations_smoothed',
       'total_vaccinations_per_hundred', 'people_vaccinated_per_hundred',
       'people_fully_vaccinated_per_hundred', 'total_boosters_per_hundred',
       'new_vaccinations_smoothed_per_million',
       'new_people_vaccinated_smoothed',
       'new_people_vaccinated_smoothed_per_hundred', 'stringency_index',
       'population', 'population_density', 'median_age', 'aged_65_older',
       'aged_70_older', 'gdp_per_capita', 'extreme_poverty',
       'cardiovasc_death_rate', 'diabetes_prevalence', 'female_smokers',
       'male_smokers', 'handwashing_facilities', 'hospital_beds_per_thousand',
       'life_expectancy', 'human_development_index',
       'excess_mortality_cumulative_absolute', 'excess_mortality_cumulative',
       'excess_mortality', 'excess_mortality_cumulative_per_million'],
      dtype='object')
```

[99]:
```
covid_df = df[['date', 'new_cases', 'new_deaths', 'new_tests',␣
↪'new_vaccinations']]
```

[100]:
```
covid_df.head()
```

[100]:
```
         date  new_cases  new_deaths  new_tests  new_vaccinations
0  1/22/2020        NaN         NaN        NaN               NaN
1  1/23/2020        0.0         NaN        NaN               NaN
2  1/24/2020        1.0         NaN        NaN               NaN
3  1/25/2020        0.0         NaN        NaN               NaN
4  1/26/2020        3.0         NaN        NaN               NaN
```

[101]:
```
covid_df.dtypes
```

[101]:
```
date                 object
new_cases           float64
new_deaths          float64
new_tests           float64
new_vaccinations    float64
dtype: object
```

Stock Datasts

[102]:
```
df2 = pd.read_csv("moderna.csv")
moderna_df = df2[['date', 'close', 'volume', 'rsi']]

df3 = pd.read_csv("jnj.csv")
jnj_df = df3[['date', 'close', 'volume', 'rsi']]

df4 = pd.read_csv("astra-zeneca.csv")
astra_zeneca_df = df4[['date', 'close', 'volume', 'rsi']]

df5 = pd.read_csv("biontech.csv")
biontech_df = df5[['date', 'close', 'volume', 'rsi']]

df6 = pd.read_csv("novavax.csv")
novavax_df = df6[['date', 'close', 'volume', 'rsi']]

df7 = pd.read_csv("pfizer.csv")
pfizer_df = df7[['date', 'close', 'volume', 'rsi']]
```

Merge Datasets

[103]:
```
stock_df = [moderna_df, jnj_df, astra_zeneca_df, biontech_df, novavax_df,␣
 ↪pfizer_df]

stock_merged = reduce(lambda left, right: pd.merge(left, right, on=['date'],␣
 ↪how='outer'), stock_df)
```

```
stock_merged.columns = ['date', 'moderna_closing_price', 'moderna_volume',␣
 ↪'moderna_rsi', 'jnj_closing_price', 'jnj_volume', 'jnj_rsi',␣
 ↪'astra_zeneca_closing_price', 'astra_zeneca_volume', 'astra_zeneca_rsi',␣
 ↪'biontech_closing_price', 'biontech_volume', 'biontech_rsi',␣
 ↪'novavax_closing_price', 'novavax_volume', 'novavax_rsi',␣
 ↪'pfizer_closing_price', 'pfizer_volume', 'pfizer_rsi']
```

[104]:
```
stock_merged.head()
```

[104]:

| | date | moderna_closing_price | moderna_volume | moderna_rsi | jnj_closing_price | jnj_volume | jnj_rsi | astra_zeneca_closing_price | astra_zeneca_volume | astra_zeneca_rsi | biontech_closing_price | biontech_volume | biontech_rsi | novavax_closing_price | novavax_volume | novavax_rsi | pfizer_closing_price | pfizer_volume | pfizer_rsi |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 2022-04-08 | 160.84 | 5454415.0 | 45.310068 | 182.12 | 7144703.0 | 58.007217 | 71.14 | 9082865.0 | 62.388493 | 170.26 | 886206.0 | 47.024802 | 60.63 | 3603222.0 | 41.168775 | 55.17 | 23128622.0 | 55.231783 |
| 1 | 2022-04-07 | 159.00 | 5720873.0 | 45.059303 | 181.76 | 7385291.0 | 57.800809 | 71.01 | 8310168.0 | 62.271561 | 169.11 | 1505572.0 | 46.875633 | 59.50 | 4367650.0 | 40.924147 | 55.16 | 36292543.0 | 55.220421 |
| 2 | 2022-04-06 | 154.62 | 7401800.0 | 44.465273 | 182.23 | 9991790.0 | 58.166612 | 69.07 | 5596805.0 | 60.474451 | 166.65 | 2275843.0 | 46.560180 | 62.44 | 5162016.0 | 41.362681 | 52.87 | 31718155.0 | 52.515858 |
| 3 | 2022-04-05 | 162.05 | 6641095.0 | 45.279139 | 177.61 | 7279617.0 | 55.450641 | 67.05 | 6953316.0 | 58.455160 | 180.82 | 1878969.0 | 48.174997 | 65.23 | 6661778.0 | 41.779037 | 51.24 | 21027857.0 | 50.427343 |
| 4 | 2022-04-04 | 172.54 | 5908675.0 | 46.455614 | 176.47 | 6595724.0 | 54.740074 | 66.67 | 3987163.0 | 58.060152 | 186.24 | 2350714.0 | 48.809551 | 75.29 | 2642969.0 | 43.319900 | 50.94 | 20491602.0 | 50.030928 |

[105]:
```
stock_merged.dtypes
```

[105]:
```
date                        object
moderna_closing_price      float64
moderna_volume             float64
```

```
moderna_rsi                    float64
jnj_closing_price              float64
jnj_volume                     float64
jnj_rsi                        float64
astra_zeneca_closing_price     float64
astra_zeneca_volume            float64
astra_zeneca_rsi               float64
biontech_closing_price         float64
biontech_volume                float64
biontech_rsi                   float64
novavax_closing_price          float64
novavax_volume                 float64
novavax_rsi                    float64
pfizer_closing_price           float64
pfizer_volume                  float64
pfizer_rsi                     float64
dtype: object
```

[106]:
```
covid_df['date'] = pd.to_datetime(covid_df['date'])
stock_merged['date'] = pd.to_datetime(stock_merged['date'])
covid_df['new_vaccinations'] = covid_df['new_vaccinations'].fillna(0) # The NaN␣
 ↪value in this column cannot be simply dropped since we also need to analyze␣
 ↪the data before the vaccination process.
df_merged = pd.merge(covid_df, stock_merged, on='date').dropna()
```

[107]:
```
df_merged.head(10)
```

[107]:

| | date | new_cases | new_deaths | new_tests | new_vaccinations | \ |
|---|---|---|---|---|---|---|
| 27 | 2020-03-02 | 23.0 | 5.0 | 515.0 | 0.0 | |
| 28 | 2020-03-03 | 19.0 | 1.0 | 620.0 | 0.0 | |
| 29 | 2020-03-04 | 33.0 | 4.0 | 891.0 | 0.0 | |
| 30 | 2020-03-05 | 77.0 | 1.0 | 1203.0 | 0.0 | |
| 31 | 2020-03-06 | 53.0 | 2.0 | 1523.0 | 0.0 | |
| 32 | 2020-03-09 | 75.0 | 1.0 | 2399.0 | 0.0 | |
| 33 | 2020-03-10 | 188.0 | 6.0 | 3481.0 | 0.0 | |
| 34 | 2020-03-11 | 365.0 | 5.0 | 4833.0 | 0.0 | |
| 35 | 2020-03-12 | 439.0 | 10.0 | 8891.0 | 0.0 | |
| 36 | 2020-03-13 | 633.0 | 8.0 | 11732.0 | 0.0 | |

| | moderna_closing_price | moderna_volume | moderna_rsi | jnj_closing_price | \ |
|---|---|---|---|---|---|
| 27 | 29.88 | 33084026.0 | 64.837624 | 140.020004 | |
| 28 | 27.91 | 17599114.0 | 61.075243 | 135.589996 | |
| 29 | 27.49 | 11817666.0 | 60.313849 | 143.479996 | |
| 30 | 28.01 | 14669976.0 | 60.929202 | 142.009995 | |
| 31 | 29.61 | 21097488.0 | 62.742982 | 142.029999 | |
| 32 | 24.29 | 14124076.0 | 54.205308 | 136.440002 | |
| 33 | 22.34 | 13019516.0 | 51.580159 | 141.639999 | |
| 34 | 23.61 | 14825434.0 | 53.089965 | 131.800003 | |

```
35                 22.30      11305347.0    51.402919         125.410004
36                 21.30      11853052.0    50.161307         134.289993

    jnj_volume  ...  astra_zeneca_rsi  biontech_closing_price  \
27  11508200.0  ...         40.456508                   36.60
28  13662500.0  ...         39.738102                   38.48
29  10560500.0  ...         48.025686                   39.19
30  11339200.0  ...         47.549072                   37.12
31  12239100.0  ...         45.738435                   38.09
32  13848600.0  ...         41.449773                   33.48
33  12698100.0  ...         45.268621                   33.96
34  17763400.0  ...         41.437368                   32.17
35  21539200.0  ...         36.278622                   28.55
36  20084200.0  ...         39.344643                   30.93

    biontech_volume  biontech_rsi  novavax_closing_price  novavax_volume  \
27         185100.0     50.791524                  12.02      14261700.0
28         297900.0     52.850212                  10.78       9957300.0
29         127100.0     53.598311                  11.32      10977400.0
30          77000.0     51.182375                  12.87      14057100.0
31         279200.0     52.212347                  12.48      13250800.0
32         190200.0     47.365959                  10.02       8328800.0
33         327500.0     47.879960                  10.65      12365400.0
34         119000.0     46.164460                  10.51       9052100.0
35         184100.0     42.986160                   9.29       5488400.0
36         197600.0     45.503257                   8.41       6115400.0

    novavax_rsi  pfizer_closing_price  pfizer_volume  pfizer_rsi
27    62.899608             33.092979     42034469.0   37.171087
28    59.621290             32.542694     46174475.0   35.568345
29    60.535314             34.535103     38712155.0   44.422057
30    62.989154             33.643265     35096303.0   41.798627
31    61.999390             33.225807     40931036.0   40.651919
32    56.304878             32.030361     43183856.0   37.634936
33    57.329068             32.817837     40548329.0   40.598216
34    57.025971             30.521822     65350213.0   35.569873
35    54.465420             28.481974     62731445.0   31.979150
36    52.722981             31.034157     60553038.0   39.744867

[10 rows x 23 columns]
```

[108]:
```
df_merged.dtypes
```

[108]:
```
date                          datetime64[ns]
new_cases                            float64
new_deaths                           float64
new_tests                            float64
new_vaccinations                     float64
```

```
moderna_closing_price               float64
moderna_volume                      float64
moderna_rsi                         float64
jnj_closing_price                   float64
jnj_volume                          float64
jnj_rsi                             float64
astra_zeneca_closing_price          float64
astra_zeneca_volume                 float64
astra_zeneca_rsi                    float64
biontech_closing_price              float64
biontech_volume                     float64
biontech_rsi                        float64
novavax_closing_price               float64
novavax_volume                      float64
novavax_rsi                         float64
pfizer_closing_price                float64
pfizer_volume                       float64
pfizer_rsi                          float64
dtype: object
```

[109]:
```
df_merged = df_merged[(df_merged['date']>='2020-03-01') &␣
 ↪(df_merged['date']<'2022-04-01')]
df_merged.head()
```

[109]:

| | date | new_cases | new_deaths | new_tests | new_vaccinations | \ |
|---|---|---|---|---|---|---|
| 27 | 2020-03-02 | 23.0 | 5.0 | 515.0 | 0.0 | |
| 28 | 2020-03-03 | 19.0 | 1.0 | 620.0 | 0.0 | |
| 29 | 2020-03-04 | 33.0 | 4.0 | 891.0 | 0.0 | |
| 30 | 2020-03-05 | 77.0 | 1.0 | 1203.0 | 0.0 | |
| 31 | 2020-03-06 | 53.0 | 2.0 | 1523.0 | 0.0 | |

| | moderna_closing_price | moderna_volume | moderna_rsi | jnj_closing_price | \ |
|---|---|---|---|---|---|
| 27 | 29.88 | 33084026.0 | 64.837624 | 140.020004 | |
| 28 | 27.91 | 17599114.0 | 61.075243 | 135.589996 | |
| 29 | 27.49 | 11817666.0 | 60.313849 | 143.479996 | |
| 30 | 28.01 | 14669976.0 | 60.929202 | 142.009995 | |
| 31 | 29.61 | 21097488.0 | 62.742982 | 142.029999 | |

| | jnj_volume | ... | astra_zeneca_rsi | biontech_closing_price | \ |
|---|---|---|---|---|---|
| 27 | 11508200.0 | ... | 40.456508 | 36.60 | |
| 28 | 13662500.0 | ... | 39.738102 | 38.48 | |
| 29 | 10560500.0 | ... | 48.025686 | 39.19 | |
| 30 | 11339200.0 | ... | 47.549072 | 37.12 | |
| 31 | 12239100.0 | ... | 45.738435 | 38.09 | |

| | biontech_volume | biontech_rsi | novavax_closing_price | novavax_volume | \ |
|---|---|---|---|---|---|
| 27 | 185100.0 | 50.791524 | 12.02 | 14261700.0 | |
| 28 | 297900.0 | 52.850212 | 10.78 | 9957300.0 | |

```
29         127100.0     53.598311                  11.32      10977400.0
30          77000.0     51.182375                  12.87      14057100.0
31         279200.0     52.212347                  12.48      13250800.0

    novavax_rsi  pfizer_closing_price  pfizer_volume  pfizer_rsi
27    62.899608             33.092979     42034469.0   37.171087
28    59.621290             32.542694     46174475.0   35.568345
29    60.535314             34.535103     38712155.0   44.422057
30    62.989154             33.643265     35096303.0   41.798627
31    61.999390             33.225807     40931036.0   40.651919

[5 rows x 23 columns]
```

Data Analysis

Q1: How did each pharmaceutical stock perform during the pandemic, and is there a trend between performance and COVID-19 cases?

[110]:
```
df1 =␣
 ↪df_merged[["date","new_cases","new_deaths","new_vaccinations","moderna_closing_price","jnj_
                "astra_zeneca_closing_price","biontech_closing_price",
                "novavax_closing_price","pfizer_closing_price"]]

#normalize values
df1['cases'] = round(100*df1['new_cases']/df1['new_cases'].max())
df1['deaths'] = round(100*df1['new_deaths']/df1['new_deaths'].max())
df1['vaccinations'] = round(100*df1['new_vaccinations']/df1['new_vaccinations'].
 ↪max())
df1['moderna'] = round(100*df1['moderna_closing_price']/
 ↪df1['moderna_closing_price'].max())
df1['jnj'] = round(100*df1['jnj_closing_price']/df1['jnj_closing_price'].max())
df1['astra_zeneca'] = round(100*df1['astra_zeneca_closing_price']/
 ↪df1['astra_zeneca_closing_price'].max())
df1['biontech'] = round(100*df1['biontech_closing_price']/
 ↪df1['biontech_closing_price'].max())
df1['novavax'] = round(100*df1['novavax_closing_price']/
 ↪df1['novavax_closing_price'].max())
df1['pfizer'] = round(100*df1['pfizer_closing_price']/
 ↪df1['pfizer_closing_price'].max())

#normalized df
normalized_df =␣
 ↪df1[["date","cases","deaths","vaccinations","moderna","jnj","astra_zeneca","biontech","nova
```

[111]:
```
#melted_dfs for covid cases viz
moderna_df = normalized_df[["date","cases","moderna"]]
moderna = pd.melt(moderna_df, id_vars=["date"],value_vars=["cases","moderna"])
jnj_df = normalized_df[["date","cases","jnj"]]
jnj = pd.melt(jnj_df, id_vars=["date"],value_vars=["cases","jnj"])
```

```
astra_zeneca_df = normalized_df[["date","cases","astra_zeneca"]]
astra_zeneca = pd.melt(astra_zeneca_df,␣
 ↪id_vars=["date"],value_vars=["cases","astra_zeneca"])
biontech_df = normalized_df[["date","cases","biontech"]]
biontech = pd.melt(biontech_df,␣
 ↪id_vars=["date"],value_vars=["cases","biontech"])
novavax_df = normalized_df[["date","cases","novavax"]]
novavax = pd.melt(novavax_df, id_vars=["date"],value_vars=["cases","novavax"])
pfizer_df = normalized_df[["date","cases","pfizer"]]
pfizer = pd.melt(pfizer_df, id_vars=["date"],value_vars=["cases","pfizer"])

dfs=[moderna,jnj,astra_zeneca,biontech,novavax,pfizer]

#create covid cases charts
charts=[]
for df in dfs:
    charts.append(
        alt.Chart(df,title=alt.TitleParams(str(df.iloc[-1,1]),fontSize=12)
                ).mark_line(
                ).transform_window(
                        rolling_30d_mean='mean(value)',
                        frame=[-15, 15],
                        groupby=['variable']
                ).encode(
                        x=alt.X('date',
                                axis=alt.Axis(labels=True),
                                title='date'),
                        y=alt.Y('rolling_30d_mean:Q',
                                scale=alt.Scale(domain=[0, 100]),
                               title='rolling mean'),
                        color=alt.Color('variable',legend=alt.
 ↪Legend(direction='vertical', titleAnchor='middle')),
                        tooltip=['variable:N',alt.Tooltip('rolling_30d_mean:Q',␣
 ↪format='.2f')]
                ).properties(
                        width=325,
                        height=100
                )
                )

x = alt.vconcat(charts[0], charts[1], charts[2])
y = alt.vconcat(charts[3], charts[4], charts[5])

(x|y).properties(title="30-day Rolling Average Covid Cases vs. Stocks"
                ).configure_title(fontSize=14,anchor='middle')
```

[111]: `alt.HConcatChart(...)`

[112]:
```
#melted_dfs for covid deaths
moderna_df = normalized_df[["date","deaths","moderna"]]
moderna = pd.melt(moderna_df, id_vars=["date"],value_vars=["deaths","moderna"])
jnj_df = normalized_df[["date","deaths","jnj"]]
jnj = pd.melt(jnj_df, id_vars=["date"],value_vars=["deaths","jnj"])
astra_zeneca_df = normalized_df[["date","deaths","astra_zeneca"]]
astra_zeneca = pd.melt(astra_zeneca_df,␣
 ↪id_vars=["date"],value_vars=["deaths","astra_zeneca"])
biontech_df = normalized_df[["date","deaths","biontech"]]
biontech = pd.melt(biontech_df,␣
 ↪id_vars=["date"],value_vars=["deaths","biontech"])
novavax_df = normalized_df[["date","deaths","novavax"]]
novavax = pd.melt(novavax_df, id_vars=["date"],value_vars=["deaths","novavax"])
pfizer_df = normalized_df[["date","deaths","pfizer"]]
pfizer = pd.melt(pfizer_df, id_vars=["date"],value_vars=["deaths","pfizer"])

dfs=[moderna,jnj,astra_zeneca,biontech,novavax,pfizer]

#create covid deaths charts
charts=[]
for df in dfs:
    charts.append(
        alt.Chart(df,title=alt.TitleParams(str(df.iloc[-1,1]),fontSize=12)
                ).mark_line(
                ).transform_window(
                        rolling_30d_mean='mean(value)',
                        frame=[-15, 15],
                        groupby=['variable']
                ).encode(
                        x=alt.X('date',
                                axis=alt.Axis(labels=True),
                                title='date'),
                        y=alt.Y('rolling_30d_mean:Q',
                                scale=alt.Scale(domain=[0, 100]),
                               title='rolling mean'),
                        color=alt.Color('variable',legend=alt.
 ↪Legend(direction='vertical', titleAnchor='middle')),
                        tooltip=['variable:N',alt.Tooltip('rolling_30d_mean:Q',␣
 ↪format='.2f')]
                ).properties(
                        width=325,
                        height=100
                )
                )

x = alt.vconcat(charts[0], charts[1], charts[2])
y = alt.vconcat(charts[3], charts[4], charts[5])
```

```
(x|y).properties(title="30-day Rolling Average Covid Deaths vs. Stocks"
                ).configure_title(fontSize=14,anchor='middle')
```

[112]:
```
alt.HConcatChart(...)
```

[113]:
```
#melted_dfs for covid vaccinations
moderna_df = normalized_df[["date","vaccinations","moderna"]]
moderna = pd.melt(moderna_df,␣
 ↪id_vars=["date"],value_vars=["vaccinations","moderna"])
jnj_df = normalized_df[["date","vaccinations","jnj"]]
jnj = pd.melt(jnj_df, id_vars=["date"],value_vars=["vaccinations","jnj"])
astra_zeneca_df = normalized_df[["date","vaccinations","astra_zeneca"]]
astra_zeneca = pd.melt(astra_zeneca_df,␣
 ↪id_vars=["date"],value_vars=["vaccinations","astra_zeneca"])
biontech_df = normalized_df[["date","vaccinations","biontech"]]
biontech = pd.melt(biontech_df,␣
 ↪id_vars=["date"],value_vars=["vaccinations","biontech"])
novavax_df = normalized_df[["date","vaccinations","novavax"]]
novavax = pd.melt(novavax_df,␣
 ↪id_vars=["date"],value_vars=["vaccinations","novavax"])
pfizer_df = normalized_df[["date","vaccinations","pfizer"]]
pfizer = pd.melt(pfizer_df,␣
 ↪id_vars=["date"],value_vars=["vaccinations","pfizer"])

dfs=[moderna,jnj,astra_zeneca,biontech,novavax,pfizer]

#create covid vaccinations charts
charts=[]
for df in dfs:
    charts.append(
        alt.Chart(df,title=alt.TitleParams(str(df.iloc[-1,1]),fontSize=12)
                ).mark_line(
                ).transform_window(
                       rolling_30d_mean='mean(value)',
                       frame=[-15, 15],
                       groupby=['variable']
                ).encode(
                       x=alt.X('date',
                               axis=alt.Axis(labels=True),
                               title='date'),
                       y=alt.Y('rolling_30d_mean:Q',
                               scale=alt.Scale(domain=[0, 100]),
                              title='rolling_mean'),
                       color=alt.Color('variable', legend=alt.
 ↪Legend(direction='vertical', titleAnchor='middle')
                                       ),
```

```
                        tooltip=['variable:N',alt.Tooltip('rolling_30d_mean:Q',␣
 ↪format='.2f')]
                ).properties(
                        width=325,
                        height=100
                )
                )

x = alt.vconcat(charts[0], charts[1], charts[2])
y = alt.vconcat(charts[3], charts[4], charts[5])

(x|y).properties(title="30-day Rolling Average Covid Vaccinations vs. Stocks"
                ).configure_title(fontSize=14,anchor='middle')
```

[113]:
```
alt.HConcatChart(...)
```

Q2: Is there a positive or negative relationship between COVID-19 cases and pharmaceutical stock prices of the aforementioned companies? Could a rise in COVID-19 cases be used as a factor to predict a rise in pharmaceutical stock prices?

[ ]:

Q3: Assuming there is a pattern/relationship, what are the nuances that explain any breaks from the pattern between COVID-19 cases and stock prices? If not, what else could be the core indicators?

Since there were no obvious trends and correlations have been observed from the patterns created in Question 1. We would like to further analyse the relationship between techinical trading indicator, Relative Strength Index (RSI) and stock price.

The basic idea behind the RSI is to measure how quickly traders are bidding the price of the security up or down. The RSI plots this result on a scale of 0 to 100. An asset is usually considered overbought when the RSI is above 70% and oversold when it is below 30%.

[114]:
```
stock_names = ['moderna', 'jnj', 'biontech', 'novavax', 'pfizer',␣
 ↪'astra_zeneca']
rsi_df =␣
 ↪df_merged[["date","new_cases","new_deaths","new_vaccinations","moderna_closing_price","jnj_
                "astra_zeneca_closing_price","biontech_closing_price",␣
 ↪"novavax_closing_price","pfizer_closing_price",
                   "moderna_rsi","jnj_rsi", "astra_zeneca_rsi",␣
 ↪"biontech_rsi", "novavax_rsi","pfizer_rsi"]]

for stock_name in stock_names:
    norm_name = f'{stock_name}_normalized_closing_price'
    closing_price = f'{stock_name}_closing_price'
    rsi_df[norm_name] = round(100 * rsi_df[closing_price] /␣
 ↪rsi_df[closing_price].max())
```

[115]:
```
stock_rsi_dfs = {}
stock_rsi = {}
```

```
for stock_name in stock_names:
    df = rsi_df[["date", f"{stock_name}_normalized_closing_price",␣
 ↪f"{stock_name}_closing_price", f"{stock_name}_rsi"]]
    df.rename(columns={f'{stock_name}_normalized_closing_price':␣
 ↪'normalized_closing_price', f'{stock_name}_rsi': 'rsi',␣
 ↪f"{stock_name}_closing_price": "closing_price"}, inplace=True)
    stock_rsi_dfs.update({stock_name: df})
    rsi = pd.melt(df, id_vars=["date"],value_vars=["normalized_closing_price",␣
 ↪"rsi"])
    stock_rsi.update({stock_name: rsi})
```

[119]:
```
# rsi vs stock price
charts=[]
for title, df in stock_rsi.items():
    charts.append(
        alt.Chart(df, title=alt.TitleParams(title, fontSize=12)
                ).mark_line(
                ).transform_window(
                        rolling_30d_mean='mean(value)',
                        frame=[-15, 15],
                        groupby=['variable']
                ).encode(
                        x=alt.X('date:T',
                                axis=alt.Axis(labels=True),
                                title='date'),
                        y=alt.Y('rolling_30d_mean:Q',
                                scale=alt.Scale(domain=[0, 100]),
                               title='rolling_30d_mean mean'),
                        color=alt.Color('variable', legend=alt.
 ↪Legend(direction='vertical', titleAnchor='middle')
                                        ),
                        tooltip=['variable:N',alt.Tooltip('rolling_30d_mean:Q',␣
 ↪format='.2f')]
                ).properties(
                        width=375,
                        height=250
                )
        )


x = alt.vconcat(charts[0], charts[1], charts[2])
y = alt.vconcat(charts[3], charts[4], charts[5])

(x|y).properties(title="30-day Rolling Average Relative Strength Index vs.␣
 ↪Stock Price"
                ).configure_title(fontSize=14,anchor='middle')
```

[119]:
```
alt.HConcatChart(...)
```

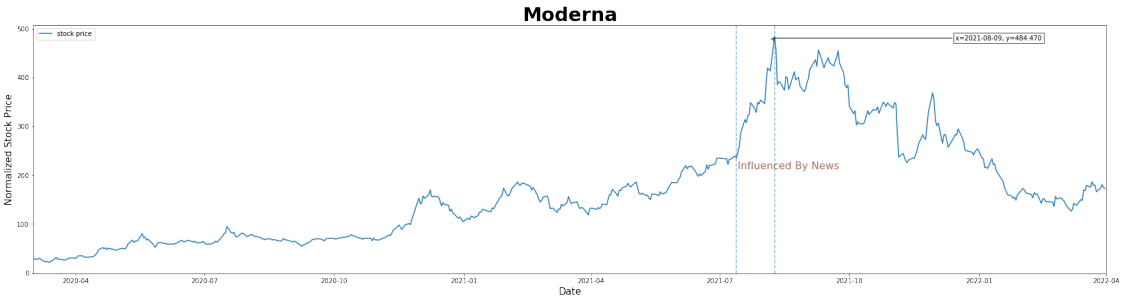
The patterns of Pfizer, Astra Zeneca and Johnson & Johnson show a quiet strong correlation bewteen rsi and stock price. But RSI seems not a core indicator for Moderna, Biontech and Novavax. There must be some other factors influcend the stock price at the same time.

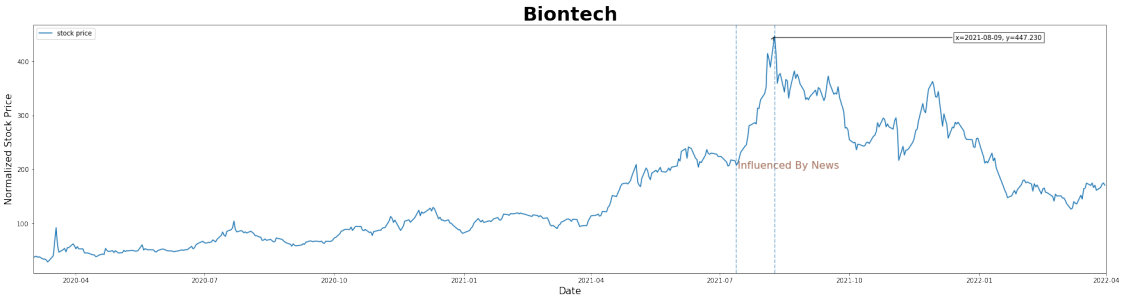
So we can pick some typical short-term scenarios and do the following analysis.

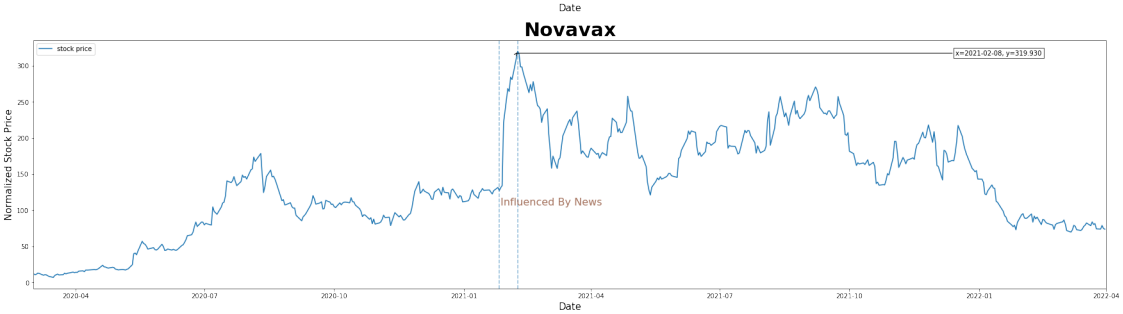
[117]:
```
def set_chart_annotaion(x_line_annotation, x_text_annotation,␣
↪x_line_annotation2, y_value, reason):
    ax[i].axvline(x=x_line_annotation, linestyle='dashed', alpha=0.5)
    ax[i].text(x=x_text_annotation, y=y_value, s=reason, alpha=0.7,␣
↪color='#7E3517', fontsize=16)
    ax[i].axvline(x=x_line_annotation2, linestyle='dashed', alpha=0.5)
```

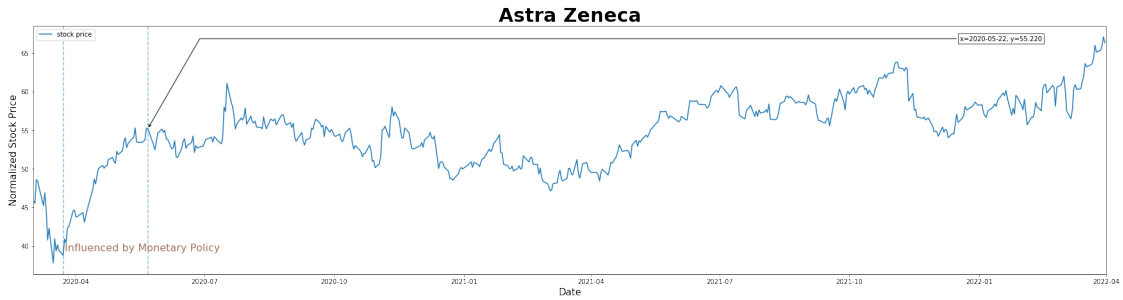
[118]:
```
single_rsi_dfs = [{'moderna': stock_rsi_dfs['moderna']}, {'biontech':␣
↪stock_rsi_dfs['biontech']}, {"novavax": stock_rsi_dfs['novavax']}, {"astra␣
↪zeneca": stock_rsi_dfs['astra_zeneca']},
                  {"pfizer": stock_rsi_dfs['pfizer']}, {"johnson & johnson":␣
↪stock_rsi_dfs['jnj']}]

fig, ax = plt.subplots(6,1,figsize=(30,50))

for i in range(len(single_rsi_dfs)):
    df = list(single_rsi_dfs[i].values())[0]
    stock_name = list(single_rsi_dfs[i].keys())[0]
    x = df['date']
    y = df['closing_price']
    ax[i].plot(x, y, label='stock price')
    ax[i].legend(loc='upper left')
    ax[i].set_title(stock_name.title(), fontweight="bold", size=30)
    ax[i].set_xlabel('Date', size=15)
    ax[i].set_ylabel('Normalized Stock Price', size=15)
    if stock_name == 'moderna':
        set_chart_annotaion(datetime.datetime(2021, 7, 13), datetime.
↪datetime(2021, 7, 14),
                            datetime.datetime(2021, 8, 9), 212.940, 'Influenced␣
↪By News')

    if stock_name == 'biontech':
        set_chart_annotaion(datetime.datetime(2021, 7, 13), datetime.
↪datetime(2021, 7, 14),
                            datetime.datetime(2021, 8, 9), 201.230, 'Influenced␣
↪By News')

    if stock_name == 'novavax':
        set_chart_annotaion(datetime.datetime(2021, 1, 26), datetime.
↪datetime(2021, 1, 27),
```

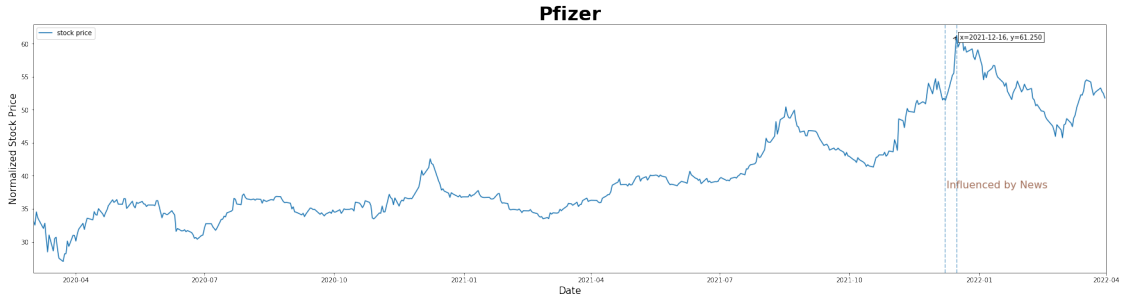
```
                            datetime.datetime(2021, 2, 8), 107.160, 'Influenced␣
↪By News')

    if stock_name == "astra zeneca":
        set_chart_annotaion(datetime.datetime(2020, 3, 23), datetime.
↪datetime(2020, 3, 24),
                            datetime.datetime(2020, 5, 22), 39.360, 'Influenced␣
↪by Monetary Policy')

    if stock_name == "pfizer":
        set_chart_annotaion(datetime.datetime(2021, 12, 8), datetime.
↪datetime(2021, 12, 9),
                            datetime.datetime(2021, 12, 16), 38.110,␣
↪'Influenced by News')

    if stock_name == "johnson & johnson":
        set_chart_annotaion(datetime.datetime(2022, 3, 8), datetime.
↪datetime(2021, 10, 15),
                            datetime.datetime(2022, 3, 29), 150.72, 'Influenced␣
↪by Annual Financial Statements')


    xmax = x[np.argmax(y)].strftime("%Y-%m-%d")
    ymax = y.max()
    text= "x={}, y={:.3f}".format(xmax, ymax)
    if not ax[i]:
        ax=plt.gca()
    bbox_props = dict(boxstyle="square,pad=0.3", fc="w", ec="k", lw=0.72)
    arrowprops=dict(arrowstyle="->",connectionstyle="angle,angleA=0,angleB=60")
    kw = dict(xycoords='data',textcoords="axes fraction",
              arrowprops=arrowprops, bbox=bbox_props, ha="right", va="top")

    if stock_name == "astra zeneca":
        ax[i].annotate("x=2020-05-22, y=55.220", xy=('2020-05-22', 55.22),␣
↪xytext=(0.94,0.96), **kw)
    else:
        ax[i].annotate(text, xy=(xmax, ymax), xytext=(0.94,0.96), **kw)

    ax[i].set_xlim([datetime.date(2020, 3, 2).strftime("%Y-%m-%d"), datetime.
↪date(2022, 4, 1).strftime("%Y-%m-%d")])

plt.show()
```

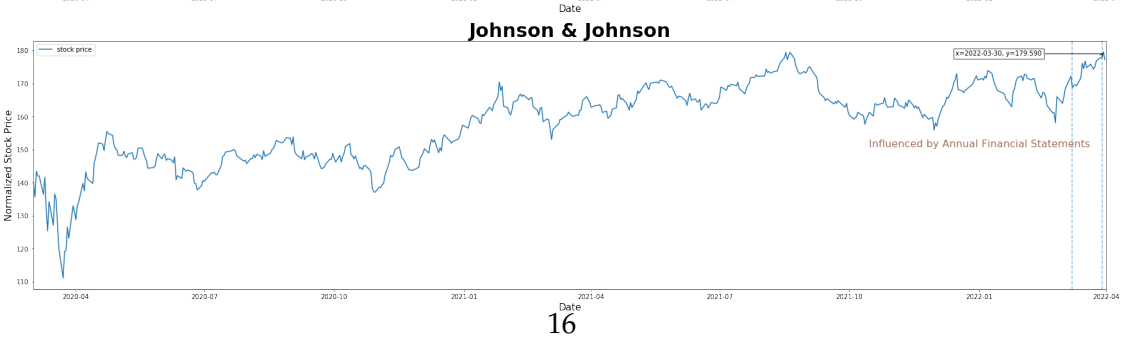

Moderna
stock price
x=2021-08-09, y=484.470
Influenced By News
Normalized Stock Price
Date


Biontech
stock price
x=2021-08-09, y=447.230
Influenced By News
Normalized Stock Price
Date


Novavax
stock price
x=2021-02-08, y=319.930
Influenced By News
Normalized Stock Price
Date


Astra Zeneca
stock price
x=2020-05-22, y=55.220
Influenced by Monetary Policy
Normalized Stock Price
Date


Pfizer
stock price
x=2021-12-16, y=61.250
Influenced by News
Normalized Stock Price
Date


Johnson & Johnson
stock price
x=2022-03-30, y=179.590
Influenced by Annual Financial Statements
Normalized Stock Price
Date

In conclusion, the stock price of pharmaceutical companies from 2020-03-01 to 2022-04-01 do not have strong correlation with covid-19 cases. The trend indicators can be numerous and diverse, such as macroscopical monetary policy, relative strength index, social sentiment, negative news, their quarterly/annualy finialcial statements and etc.

[ ]: