Covid-19 spread in the UK

October 19, 2020

[803]:
```
import pandas as pd
import numpy as np
from datetime import datetime
import matplotlib.pyplot as plt
import seaborn as sns
from sklearn.preprocessing import PolynomialFeatures
```

1 Covid-19 spread in the UK

This notebook is meant to be an exercise for practicing with data analysis, Machine Learning, data visualisation and more aspects of Data Science / Machine Learning.

Any conclusions from this work have no scientific value. Other models better predict/analyse the spread of infectious diseases, such as the SIR model: https://en.wikipedia.org/wiki/Compartmental_models_in_epidemiology The **data regarding the first period of the pandemic are highly unreliable** due to fewer tests and less awareness of governments/public around Covid-19.

Comments would be very appreciated.

According to the model, cases were doubling every 5 days. it predicts 60 milion of infections by the 14th of May 2020, roughly the size of the British population. If we take into account the SIR model and we assume an exponential growth for until only (roughly) half of the population has been infected, then by the 9th of May, or 47 days after the date of the lockdown enough people would have been infected to cause the death of hundreds of thousands dy the end of June 2020.

My findings are that lockdown quickly and effectively stopped exponential growth of the pandemic, probably saving hundreds of thousands of people between April and June 2020.

I could not find any correlation between masks being made compulsory on London´s public transport network and the the spread of the disease.

It is hard to estimate the real effect of masks and disentangle it from the effect of social ditancing, behaviour and other measures. Nevertheless it is also important to notice that when London emerged from the lockdown, with masks on public transport and in shops and with social distancing, the rate of spreading of covid-19 did not go back to the pre-lockdown exponential growth, but stayed linear.

I did not investigate other interventions due to lack of time. It would be interesting to repeat the analysis with the data from the second wave, mass testing will mean more robust and reliable data

and a different range of approaches has been used in different areas of England over the last few months, unfortunately this dataset only covers the period between the end of January 2020 and the end of July 2020.

1.0.1 firstly, let´s check the dataframe structure

[804]:
```
df= pd.read_csv("covid-19-uk-historical-data.csv")
df
```

[804]:

	Unnamed: 0	date	country	areacode	area	totalcases
0	0	2020-01-30	England	E06000014	York	1.0
1	1	2020-02-03	England	E10000002	Buckinghamshire	1.0
2	2	2020-02-03	Wales	W11000028	Aneurin Bevan	0.0
3	3	2020-02-03	Wales	W11000023	Betsi Cadwaladr	0.0
4	4	2020-02-03	Wales	W11000029	Cardiff and Vale	0.0
…	…	…	…	…	…	…
23293	23293	2020-07-29	Scotland	S08000024	Lothian	3192.0
23294	23294	2020-07-29	Scotland	S08000025	Orkney	9.0
23295	23295	2020-07-29	Scotland	S08000026	Shetland	54.0
23296	23296	2020-07-29	Scotland	S08000030	Tayside	1785.0
23297	23297	2020-07-29	Scotland	S08000028	Western Isles	7.0

[23298 rows x 6 columns]

[805]:
```
"""First task is to translate date in string format into a datetime objects and␣
 ↪then time delta objects,
that is to make computations of intervals possible and more."""


date_lst=[]

for date in df.date:

    date=datetime.strptime(date, "%Y-%m-%d")
```

```
    date_lst.append(date)
df["datetime"]=date_lst



def find_days(df):
    days_lst=[0]
    m=0
    n=0
    for days in df["datetime"]:

            m+=1

            if m<df.shape[0]:

                delta=df["datetime"][m]-df["datetime"][n]
                n+=1

                #print(delta)
                #print(delta.days)
                days_lst.append(delta.days)
            else:
                break
    df["days"] = days_lst


find_days(df)
```

[806]:
```
df.days= df.datetime - df.datetime[0]   # simplest way to find intervals! No function required, no for cycles no df.apply() etc
```

[807]:
```
time_range= df.datetime[df.shape[0]-1]-df.datetime[0]   #This trick is amazing to avoid having a Series as a result. Not sure why it works

"this will be used for plotting later: "

tot_days= time_range.days
```

lockdown was imposed on the 23rd of March 2020, 23-03-2020

[808]:
```
df[df["date"]=="2020-03-23"].head(1)
```

[808]:

	Unnamed: 0	date	country	areacode	area	\
2503	2503	2020-03-23	England	E09000002	Barking and Dagenham	

```
      totalcases   datetime    days
2503        70.0 2020-03-23 53 days
```

Lockdown began on day 52!

[809]:
```
"""To split datsets by nations:"""

England_df= df[df["country"]== "England"]
Scotland_df= df[df["country"]== "Scotland"]
Wales_df= df[df["country"]== "Wales"]
NI_df= df[df["country"]== "Northern Ireland"]
```

[810]:
```
""" This function will computer cumulative cases , fit machine learning models␣
↪on two stages of the epidemic
    and produce several plots.

    - d is the number of days to use to make predictions using the machine␣
↪learning model model_1.
    it does NOT affect the sample used for training.

    !! Please do not set d less than 65 if you want to plot the residual plot.


    Updates of the function:


    - exp is to include a plot of the exponential growth fit on 61 days instead␣
↪of 57
    The reason is that looking at daily cases (see later cells), it seems that␣
↪the exponential growth stopped later than 57
    57 = lockdown date + incubation period.
    !! Please set exp to True or False !! To have the additional plot

    - Please residual to True to have a residual plot, otherwise False

    -please set london equal True to mark the day where masks were made␣
↪mandatory on TFL

"""



def get_total(df,d,exp, residual, london):
    days=[]
    total_cases=[]
    for n in range(182):
        tot= df[df["days"] ==pd.Timedelta(n, unit='d') ].totalcases.sum()
```

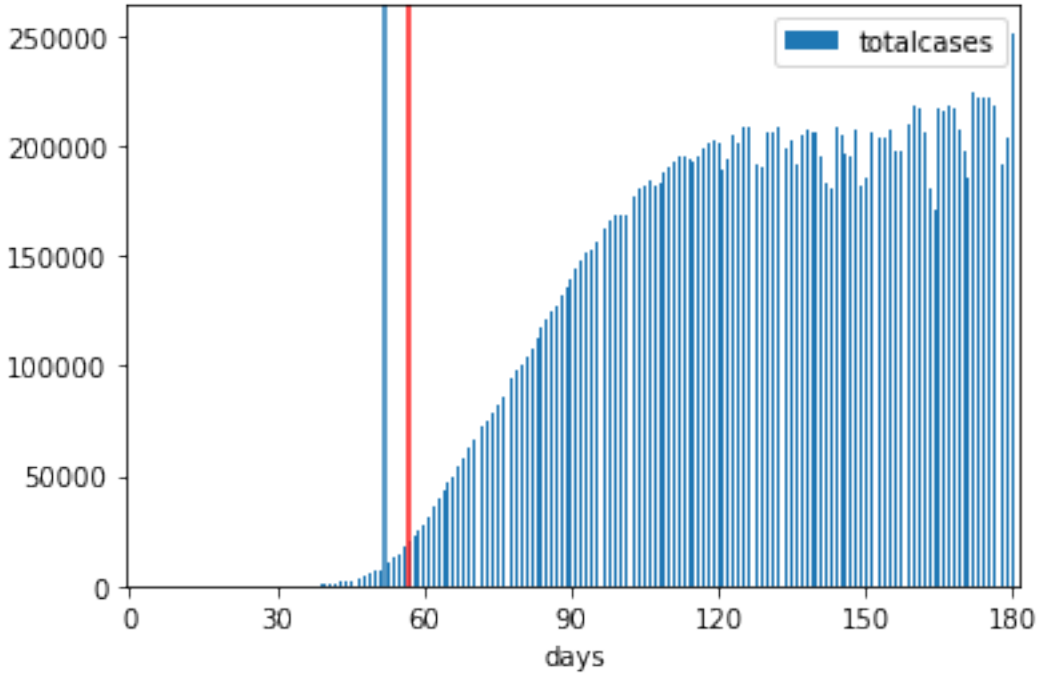
```
        days.append(n)
        total_cases.append(tot)

    new_df= pd.DataFrame({"days": days,"totalcases": total_cases})
    new_df.plot(kind='bar',x='days',y='totalcases', xticks=range(0,182,30),␣
↪rot=0)

    plt.axvline(x=52)


    """A 5 days period has been included to show possible delay in how the␣
↪measures affected transmission,
    namely up to 5 days after the lockdown started,
    the registered cases were still of infections occurred before the lockdown␣
↪itself"""

    plt.axvline(x=57, color='#ff1414') # a buffer period of 10 days has been␣
↪considered



    '''MACHINE LEARNING PART WITH SCI-KIT LEARN '''
    '''MACHINE LEARNING PART WITH SCI-KIT LEARN '''


    Y_1= new_df[new_df["days"] < 57 ][new_df["days"] > 40]
    Y_1= Y_1.totalcases
    Y_1= Y_1 + 0.01 # get rid of zeroes
    Y_1= np.log(Y_1)# to make it "fittable" with linear regression

    Y_2= new_df[new_df["days"] < 90 ][new_df["days"] > 57 ]
    Y_2= Y_2.totalcases

    Y_3= new_df[new_df["days"] < 62 ][new_df["days"] > 40]   #This was added␣
↪later, it is to fit the exponential model on the first 61 days, instead of␣
↪57
    Y_3= Y_3.totalcases
    Y_3= Y_3 + 0.01 # get rid of zeroes
    Y_3= np.log(Y_3)


    'X used to train:'


    X_1=np.array(range(41,57))
    X_2=np.array(range(32))
    X_3=np.array(range(41,62))
```

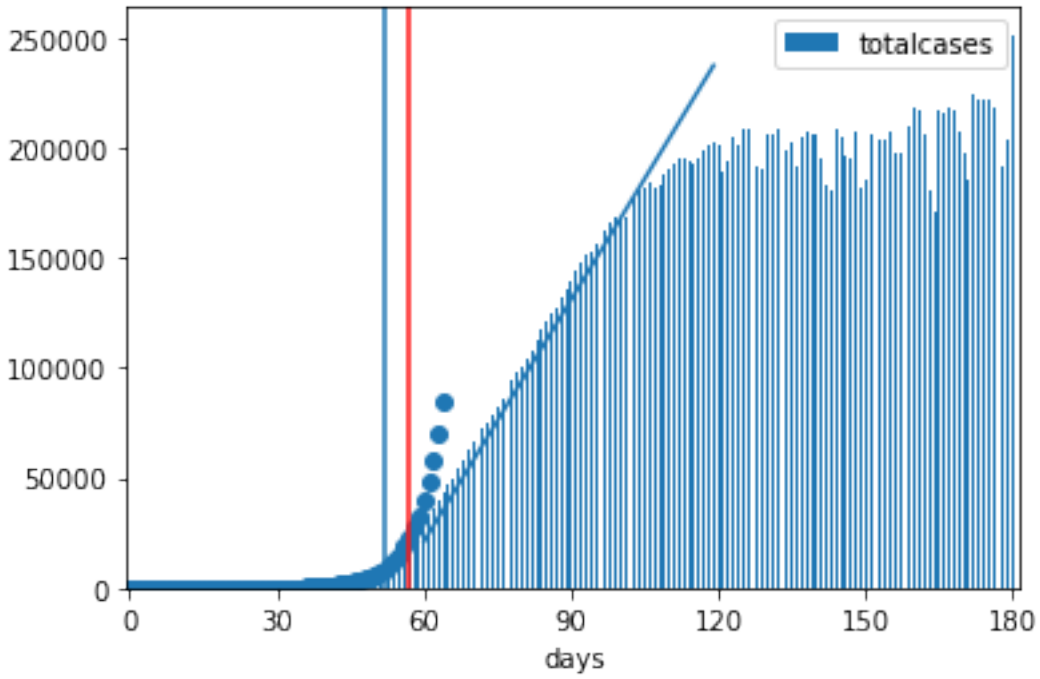
```
   X_1=X_1.reshape(-1, 1)
   X_2=X_2.reshape(-1, 1)
   X_3=X_3.reshape(-1, 1) #This was added later, it is to fit the exponential␣
↪model on the first 61 days, instead of 57

   linear_1=LinearRegression()
   linear_2=LinearRegression()
   linear_3=LinearRegression()

   model_1=linear_1.fit(X_1,Y_1)
   model_2=linear_2.fit(X_2,Y_2)
   model_3=linear_3.fit(X_3,Y_3) #This was added later, it is to fit the␣
↪exponential model on the first 61 days, instead of 57

   'X used to predict:'

   X_pred_2= np.array(range(60))
   X_pred_2= X_pred_2.reshape(-1, 1)

   X_pred_1= np.array(range(d))
   X_pred_1= X_pred_1.reshape(-1, 1)


   pred_1=model_1.predict(X_pred_1) #I expect this to be exponential
   pred_2=model_2.predict(X_pred_2) #I expect this to be linear

   pred_3=model_3.predict(X_pred_1) #This was added later, it is to fit the␣
↪exponential model on the first 61 days, instead of 57


   ''' END OF THE MACHINE LEARNING PART '''
   ''' END OF THE MACHINE LEARNING PART '''

   pred_1= np.exp(pred_1)

   pred_3= np.exp(pred_3)

   "Same code as before. just to duplicate plot"

   new_df.plot(kind='bar',x='days',y='totalcases', xticks=range(0,182,30),␣
↪rot=0)
   plt.axvline(x=52)
   plt.axvline(x=57, color='#ff1414')
   #plt.figure(figsize=(10,8))

   "END"
```

```
    plt.scatter(np.array(range(d)),pred_1)

    plt.plot(np.array(range(60,120)),pred_2)
    while london:
        plt.axvline(x=139, color='#2E8B57')
        break

    while exp:
        plt.scatter(np.array(range(d)),pred_3, color='#ff8a14')
        break

    while residual:

        residual= pred_3- new_df.totalcases[:d]


        fig, (ax1, ax2) = plt.subplots(1, 2)
        fig.set_size_inches(18.5, 7.5, forward=True)
        fig.suptitle('cumulative number of cases predicted and residual plot')
        ax1.bar(np.array(range(d)),residual, color='#ff8a14')

        ax2.scatter(new_df[:57].totalcases,pred_3[:57], label="predicted cases␣
↪pre-lockdown")
        ax2.scatter(new_df[57:65].totalcases,pred_3[57:65],color="#ff1414",␣
↪label="predicted cases after the lockdown")
        ax2.plot(new_df[:d],new_df[:d],'--', color='#ff8a14')
        ax2.legend()
        plt.show()
        break



    return new_df

total_England_df = get_total(England_df, 65, False, False, False)
```

```
<ipython-input-810-f6e714ed381b>:52: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_1= new_df[new_df["days"] < 57 ][new_df["days"] > 40]
<ipython-input-810-f6e714ed381b>:57: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_2= new_df[new_df["days"] < 90 ][new_df["days"] > 57 ]
<ipython-input-810-f6e714ed381b>:60: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_3= new_df[new_df["days"] < 62 ][new_df["days"] > 40]   #This was added
```

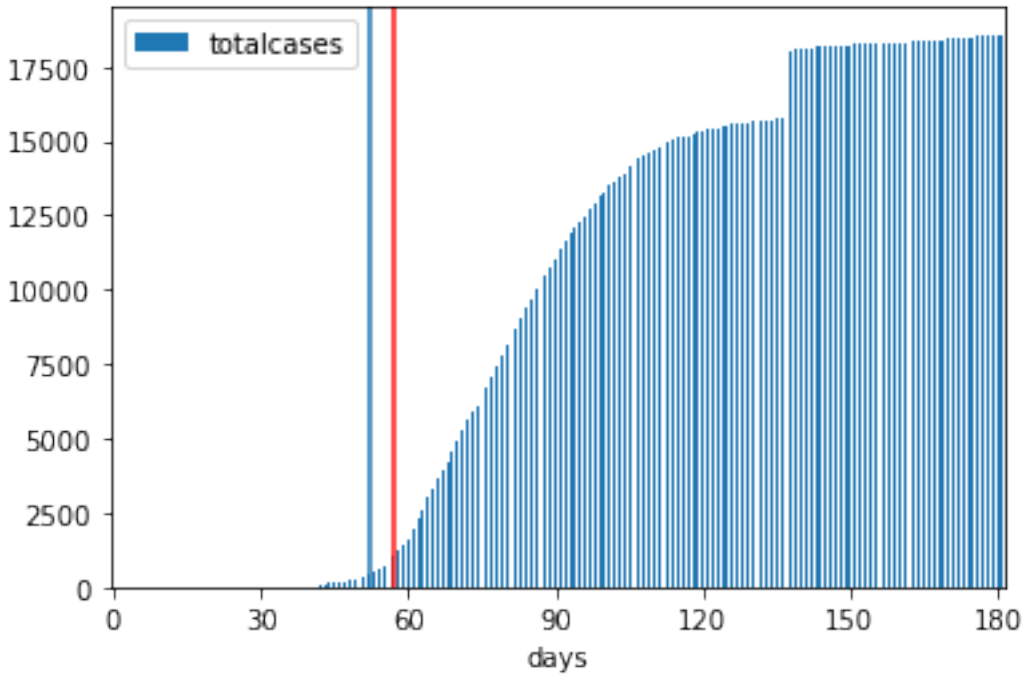
later, it is to fit the exponential model on the first 61 days, instead of 57

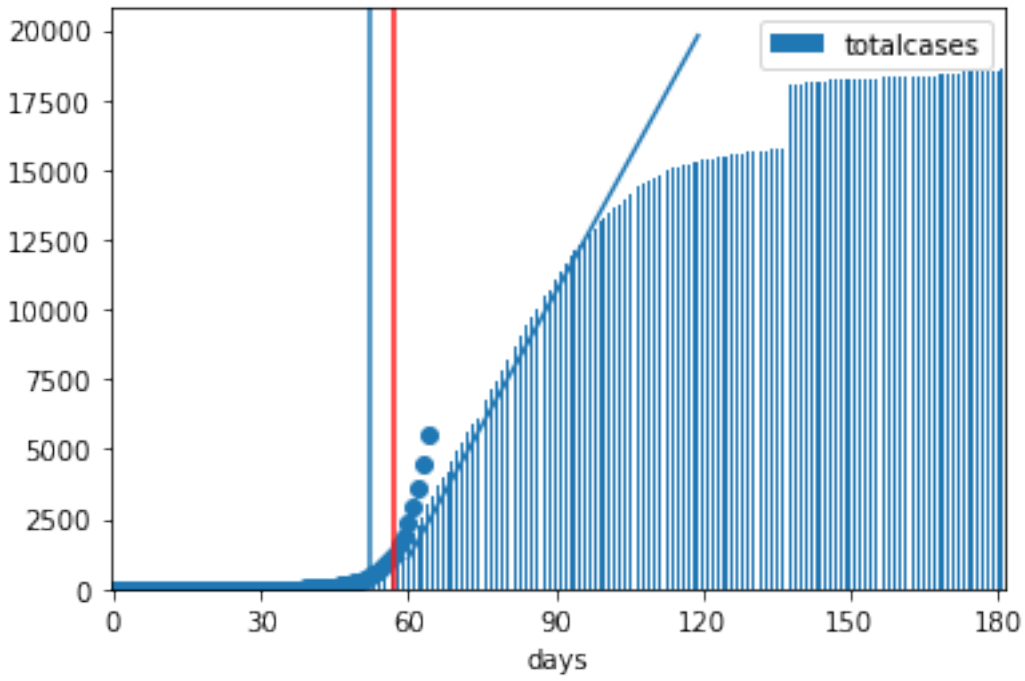




[811]:
```
total_Scotland_df= get_total(Scotland_df,65,False,False, False)
```

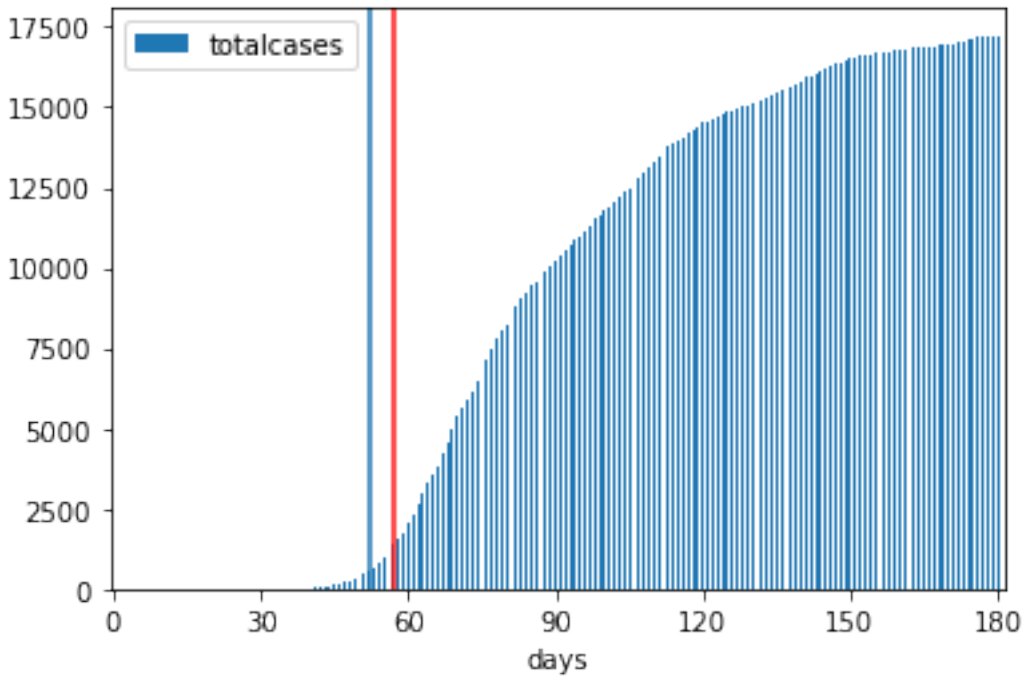
```
<ipython-input-810-f6e714ed381b>:52: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_1= new_df[new_df["days"] < 57 ][new_df["days"] > 40]
<ipython-input-810-f6e714ed381b>:57: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_2= new_df[new_df["days"] < 90 ][new_df["days"] > 57 ]
<ipython-input-810-f6e714ed381b>:60: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_3= new_df[new_df["days"] < 62 ][new_df["days"] > 40]   #This was added
later, it is to fit the exponential model on the first 61 days, instead of 57
```

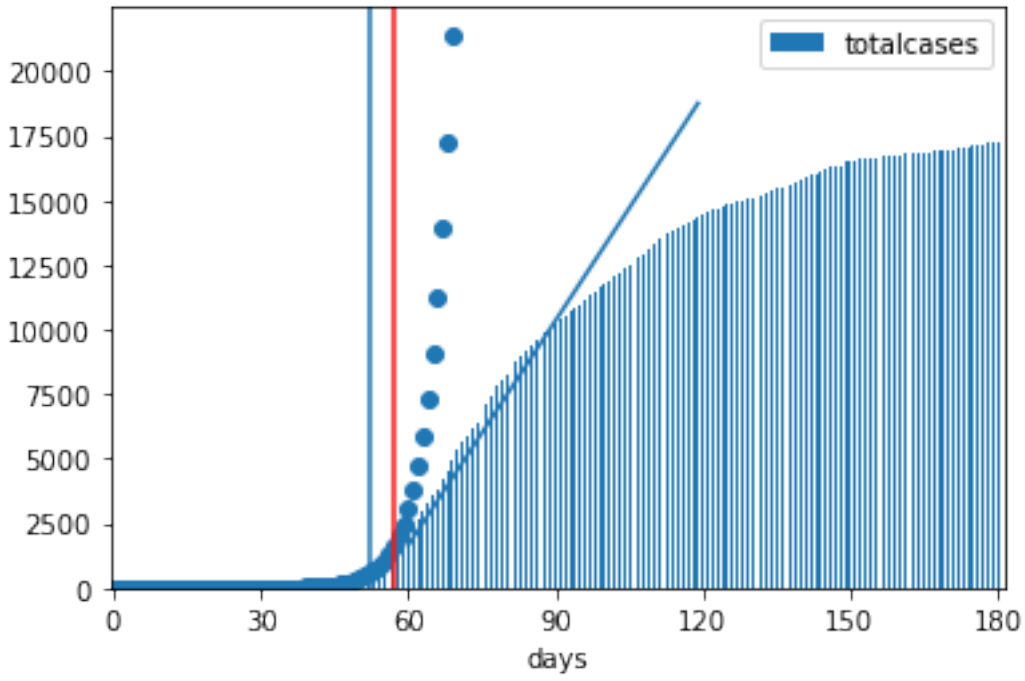




[812]:
```
total_Wales_df= get_total(Wales_df, 70, False,False, False)
```

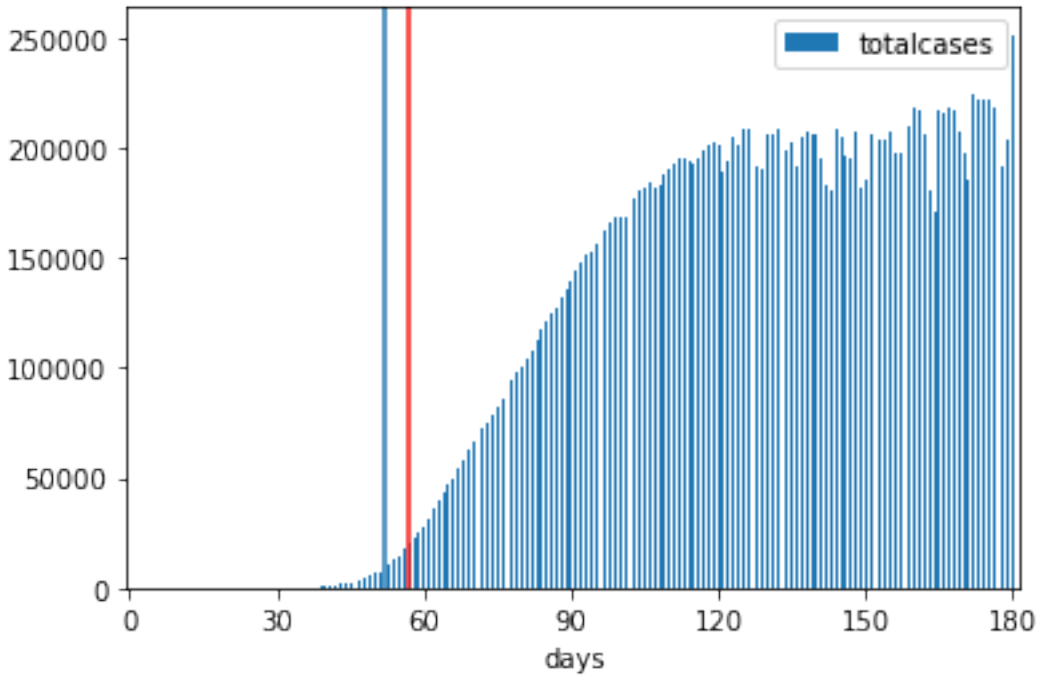
```
<ipython-input-810-f6e714ed381b>:52: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_1= new_df[new_df["days"] < 57 ][new_df["days"] > 40]
<ipython-input-810-f6e714ed381b>:57: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_2= new_df[new_df["days"] < 90 ][new_df["days"] > 57 ]
<ipython-input-810-f6e714ed381b>:60: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_3= new_df[new_df["days"] < 62 ][new_df["days"] > 40]   #This was added
later, it is to fit the exponential model on the first 61 days, instead of 57
```

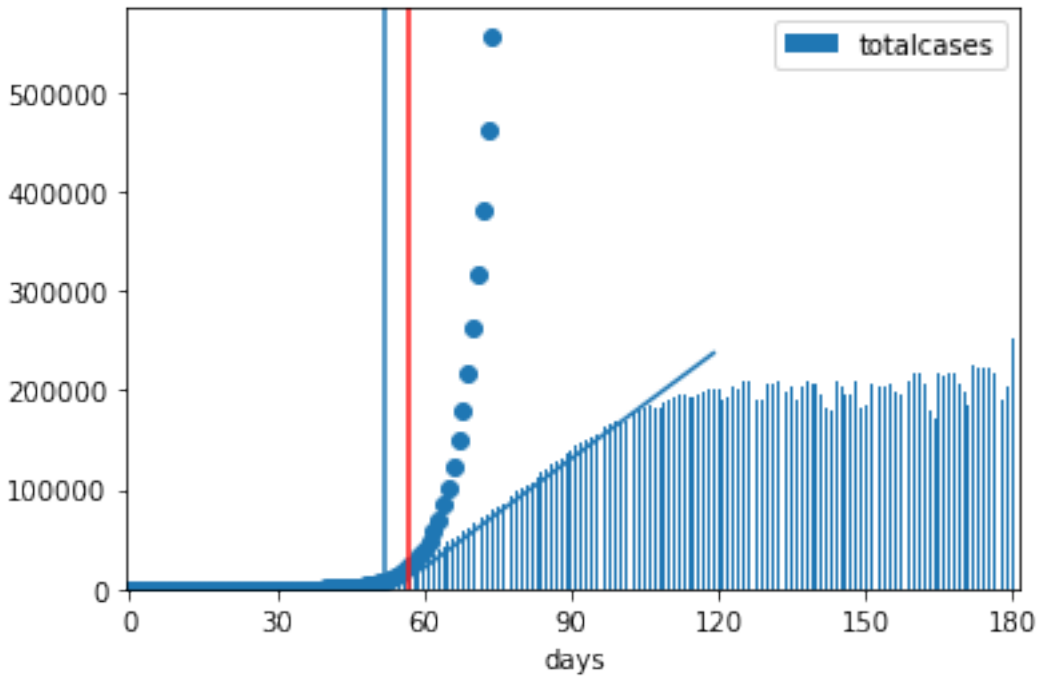




[813]:
```
total_England_df= get_total(England_df, 75, False,False, False)  #let´s check␣
↪the exponential progression at day 75
```

```
<ipython-input-810-f6e714ed381b>:52: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_1= new_df[new_df["days"] < 57 ][new_df["days"] > 40]
<ipython-input-810-f6e714ed381b>:57: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_2= new_df[new_df["days"] < 90 ][new_df["days"] > 57 ]
<ipython-input-810-f6e714ed381b>:60: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_3= new_df[new_df["days"] < 62 ][new_df["days"] > 40]   #This was added
later, it is to fit the exponential model on the first 61 days, instead of 57
```



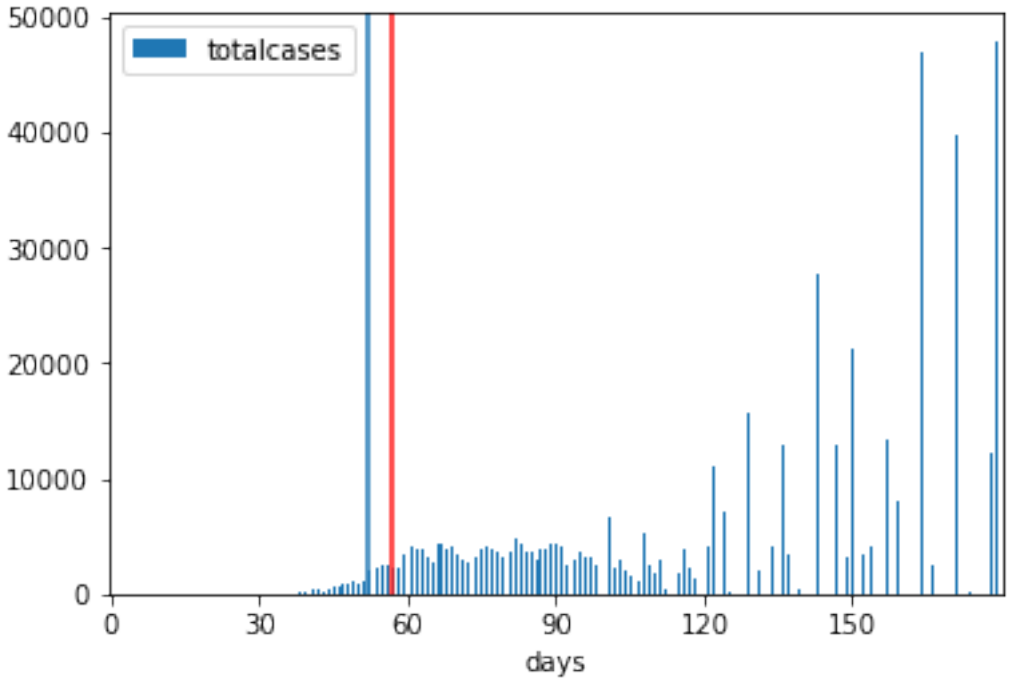


The pre-lockdown trajectiory seems to be dangerously steep.

In order to better analyse the spread of covid-19, I will compute **daily** cases increase in England, further analysis will be performed on areas of London only, to see the effect of masks becoming mandatory on TFL, the public transport network in London.

[814]:
```
def get_daily(df):

    b= df[1:]


    a=df.drop(index=181, axis=0)


    b.index= a.index

    daily_df= b-a

    daily_df[daily_df["totalcases"] < 0] = 0
    daily_df.plot(kind='bar',x='days',y='totalcases', xticks=range(0,180,30),␣
↪rot=0)
    plt.axvline(x=52)
    plt.axvline(x=57, color='#ff1414')

    return daily_df
```

[815]:
```
daily_England_df= get_daily(total_England_df)
```

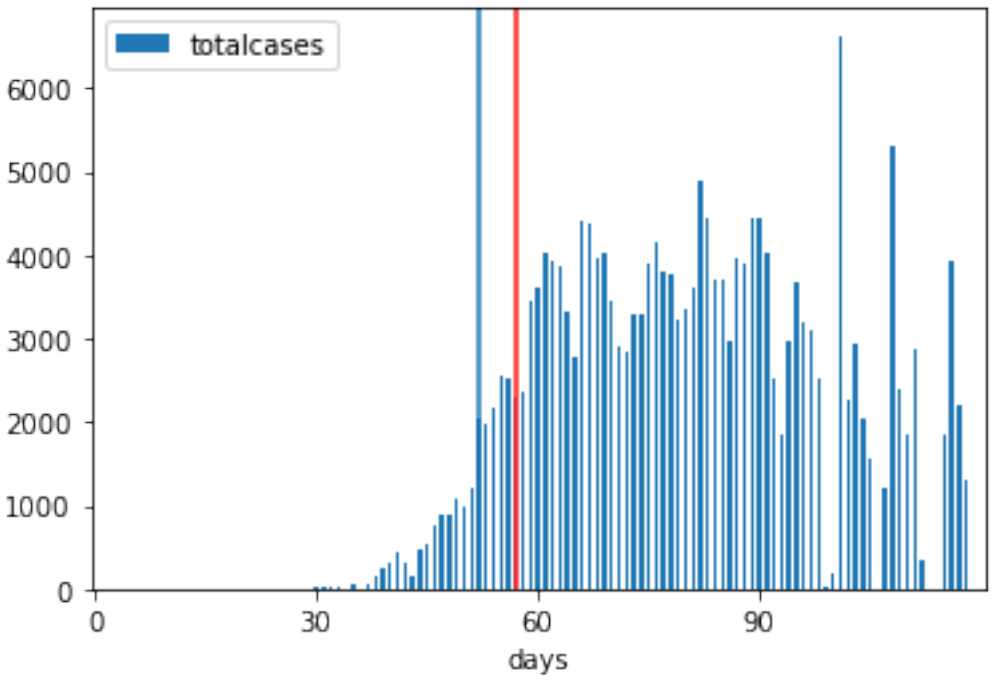


This is roughly a plot similar to the official published records on the progression of covid-19 in the UK. Let's have a closer look at the first half of the data.

Unfortunately this is a bad way to calculate daily infections because the totalcases are not always increasing - not sure why. Some cases removed.

[816]:
```
daily_120= daily_England_df.drop(index=list(range(120,180)))

daily_120.plot(kind='bar',x='days',y='totalcases', xticks=range(0,120,30),␣
↪rot=0)
plt.axvline(x=52)
plt.axvline(x=57, color='#ff1414')
```

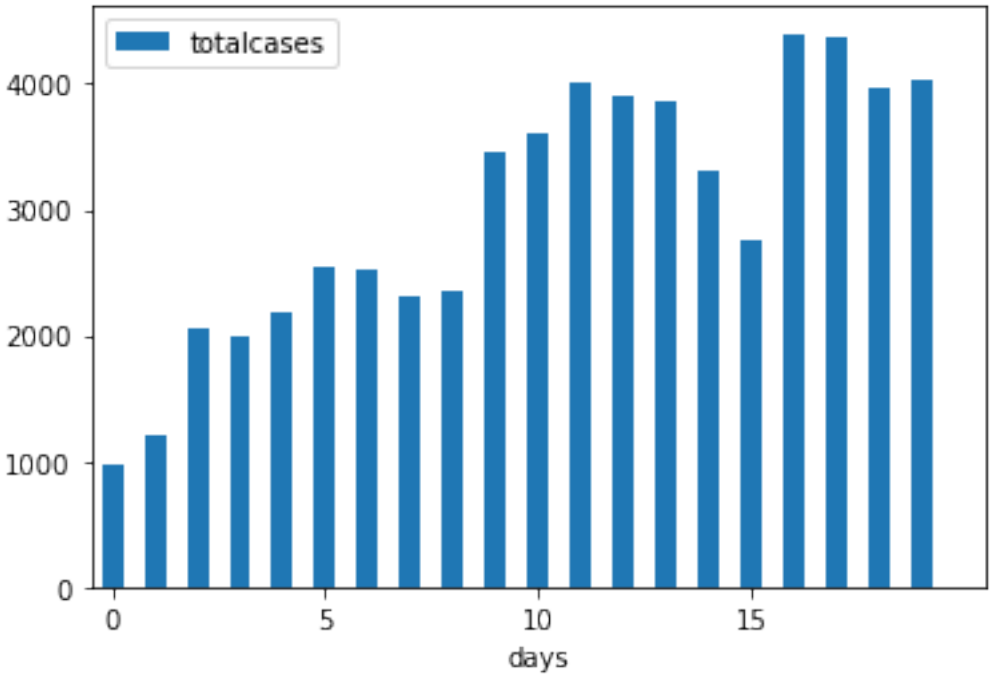
[816]:
```
<matplotlib.lines.Line2D at 0x2a20bc6c6a0>
```



It seems like exponential growth stopped slightly later than 5 days after the lockdown. Daily cases were quickly increasing until they stabilised around an average between 3 and 5 thousands per day.

[817]:
```
daily_50_70= daily_df.drop(index=list(range(70,180)))

daily_50_70= daily_50_70.drop(index=list(range(50)))

daily_50_70.plot(kind='bar',x='days',y='totalcases', xticks=range(0,20,5),␣
↪rot=0)
plt.axvline(x=52)
plt.axvline(x=57, color='#ff1414')
```

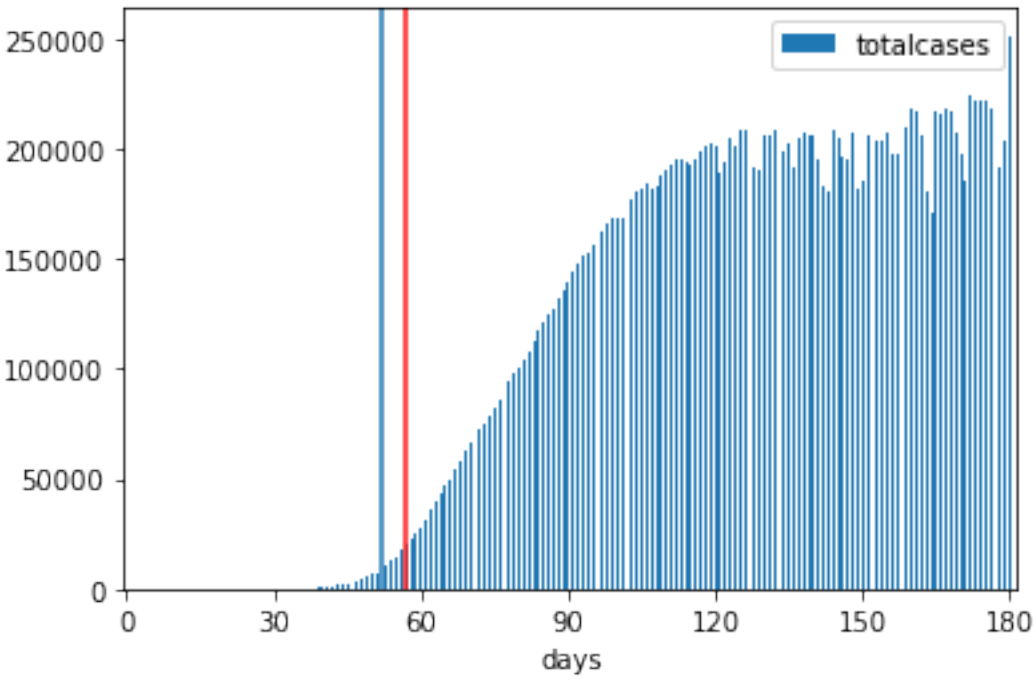
[817]:
```
<matplotlib.lines.Line2D at 0x2a210ac1d90>
```

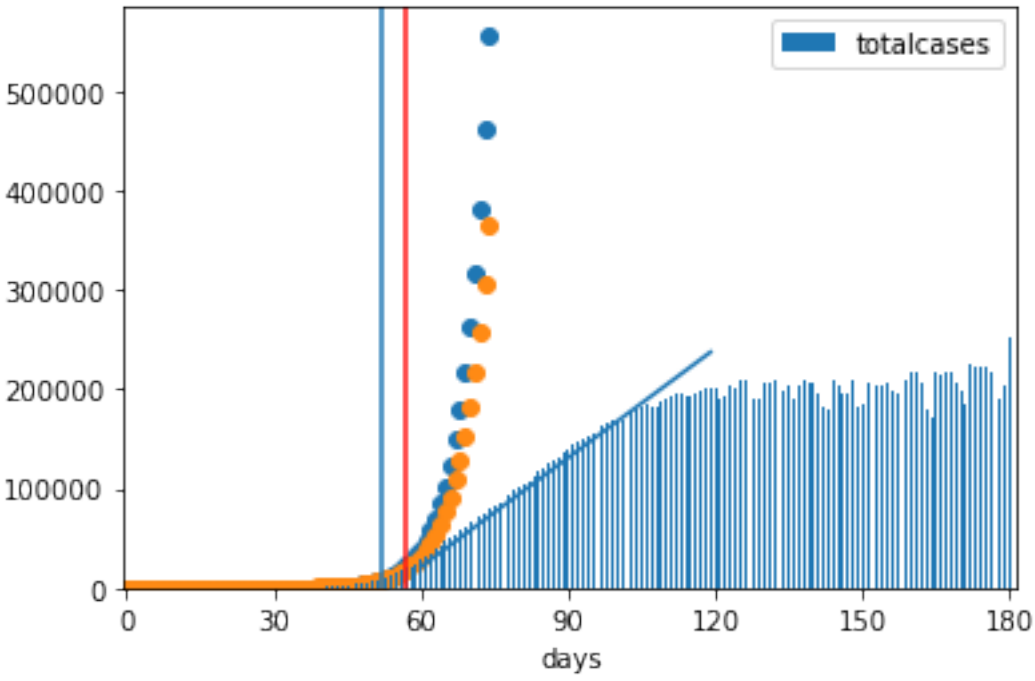


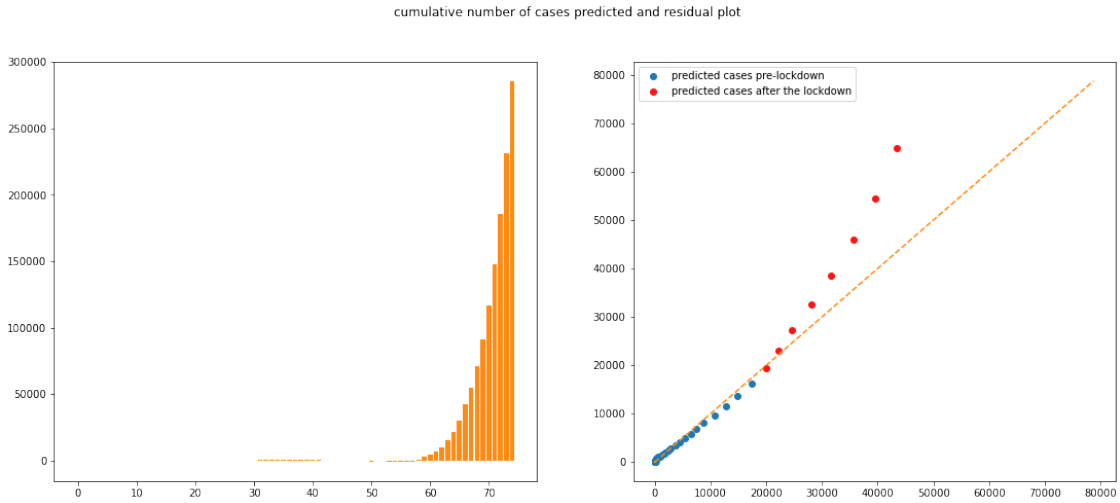
day 61 (11 on the plot above), seems to be a good candidate to when roughly exponential growth stopped. let´s re-fit the model.

[818]:
```
""" True as the fourth argument will display a second exponential model fit␣
 ↪until day 61 (which is after the lockdown)"""

get_total(England_df, 75, True, True, False)
```

```
<ipython-input-810-f6e714ed381b>:52: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_1= new_df[new_df["days"] < 57 ][new_df["days"] > 40]
<ipython-input-810-f6e714ed381b>:57: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_2= new_df[new_df["days"] < 90 ][new_df["days"] > 57 ]
<ipython-input-810-f6e714ed381b>:60: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_3= new_df[new_df["days"] < 62 ][new_df["days"] > 40]   #This was added
later, it is to fit the exponential model on the first 61 days, instead of 57
```


totalcases
250000
200000
150000
100000
50000
0
0
30
60
90
120
150
180
days


totalcases
500000
400000
300000
200000
100000
0
0
30
60
90
120
150
180
days



[818]:

	days	totalcases
0	0	1.0
1	1	0.0
2	2	0.0
3	3	0.0
4	4	1.0
..	…	…
177	177	202671.0
178	178	191016.0
179	179	203307.0
180	180	251247.0
181	181	0.0

[182 rows x 2 columns]

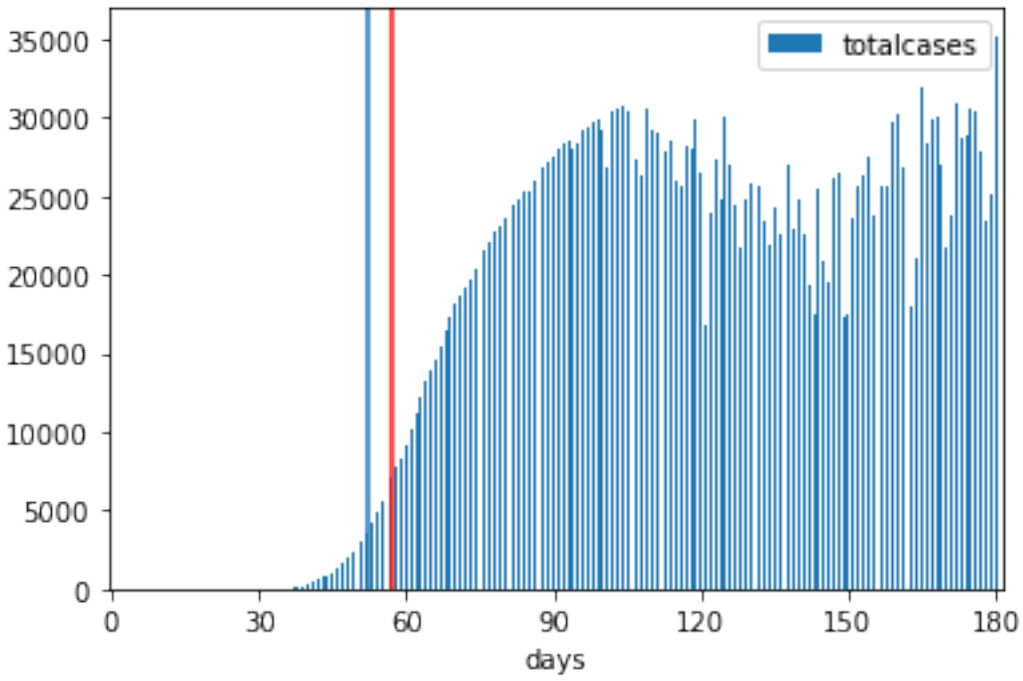
Let´s have a look at London! On June 15 face covering became mandatory on the TFL public transport network.

[819]:
```
London_df= df.loc[df["area"].isin(['Hackney and City of London',
              'Westminster',
"Kensington and Chelsea",
"Hammersmith and Fulham",
"Wandsworth",
"Lambeth",
"Southwark",
"Tower Hamlets",
"Islington",
"Camden",
"Brent",
"Ealing",
```

```
"Hounslow",
"Richmond upon Thames",
"Kingston upon Thames",
"Merton",
"Sutton",
"Croydon",
"Bromley",
"Lewisham",
"Greenwich",
"Bexley",
"Havering",
"Barking and Dagenham",
"Redbridge",
"Newham",
"Waltham Forest",
"Haringey",
"Enfield",
"Barnet",
"Harrow",
"Hillingdon"])]
```

[820]:
```
London_total_df=get_total(London_df, 65, True, True, True)
London_daily_df= get_daily(London_total_df)
```

```
<ipython-input-810-f6e714ed381b>:52: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_1= new_df[new_df["days"] < 57 ][new_df["days"] > 40]
<ipython-input-810-f6e714ed381b>:57: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_2= new_df[new_df["days"] < 90 ][new_df["days"] > 57 ]
<ipython-input-810-f6e714ed381b>:60: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_3= new_df[new_df["days"] < 62 ][new_df["days"] > 40]   #This was added
later, it is to fit the exponential model on the first 61 days, instead of 57
```


totalcases
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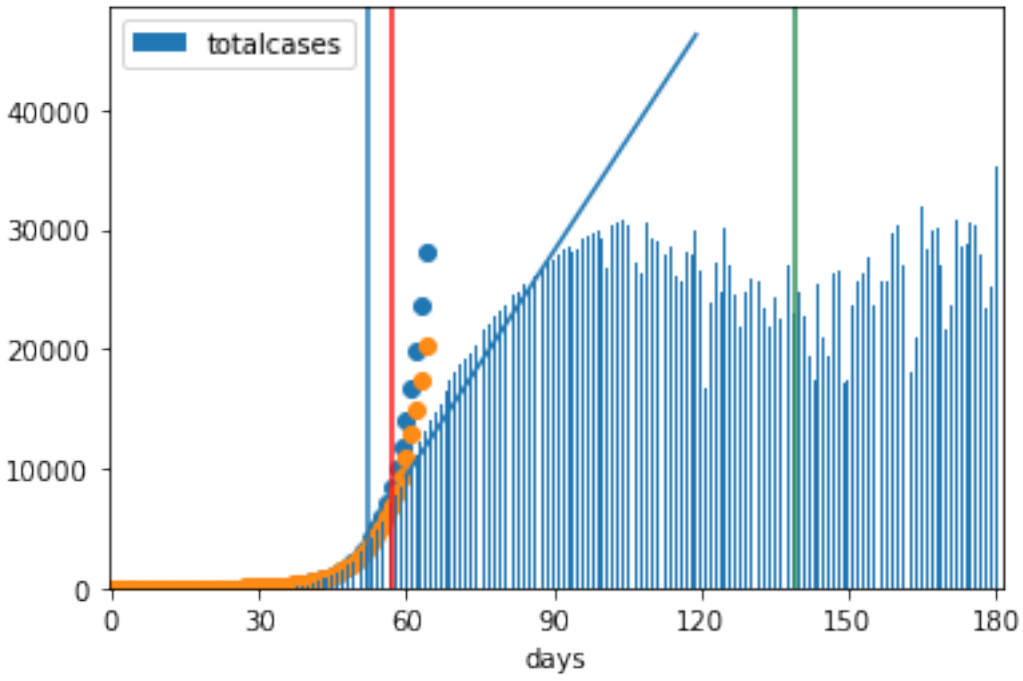
30000
25000
20000
15000
10000
5000
0
0
30
60
90
120
150
180
days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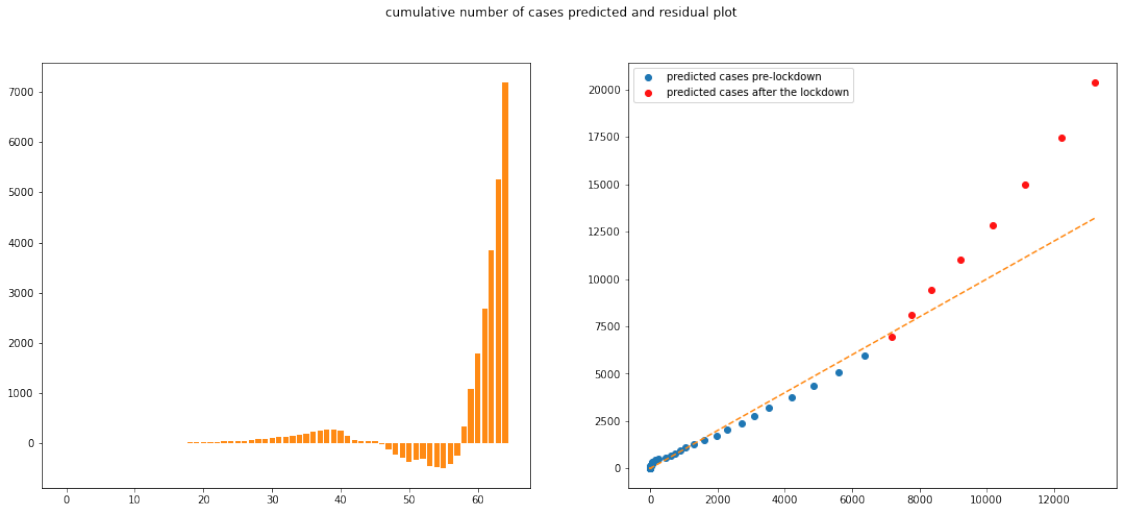
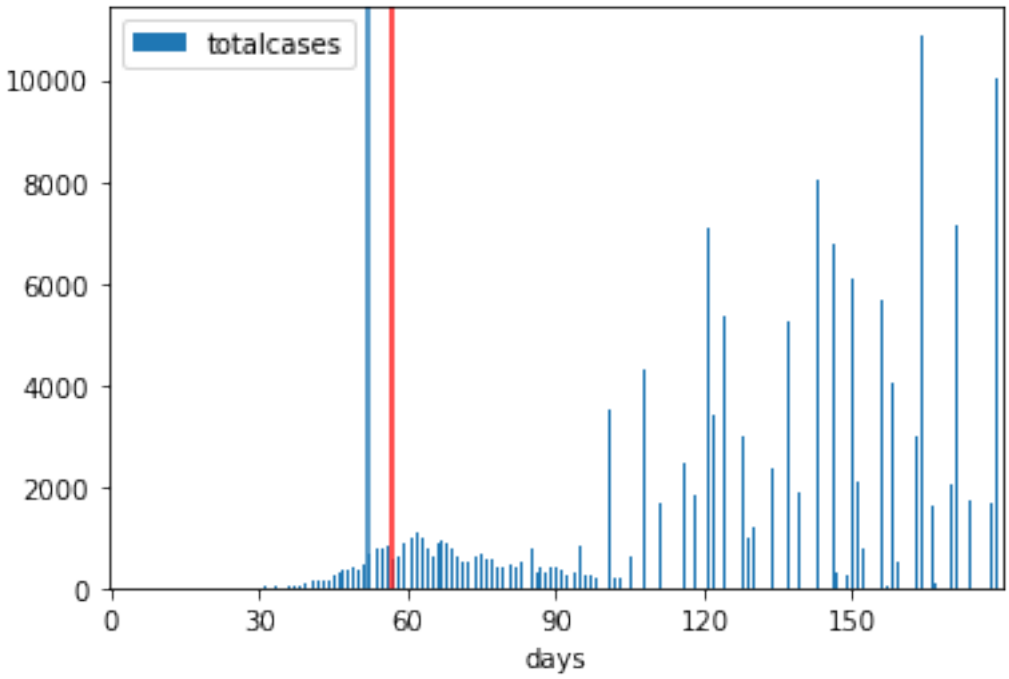
10000
0
0
30
60
90
120
150
180
days





The second, linear model is not very adequate to explain the post-lockdown phase in London looking at how cases were increasing, that is interesting and requires further investigation.

1.0.2 conclusion:

This project was more about getting practice with data and ML, but it is clear that an exponential growth can explain the **early** progression of covid-19 in England, the number of cases were doubling *roughly* every 5 days (simply counting the number of dots in the residual plot between 10k and 20k

for example).

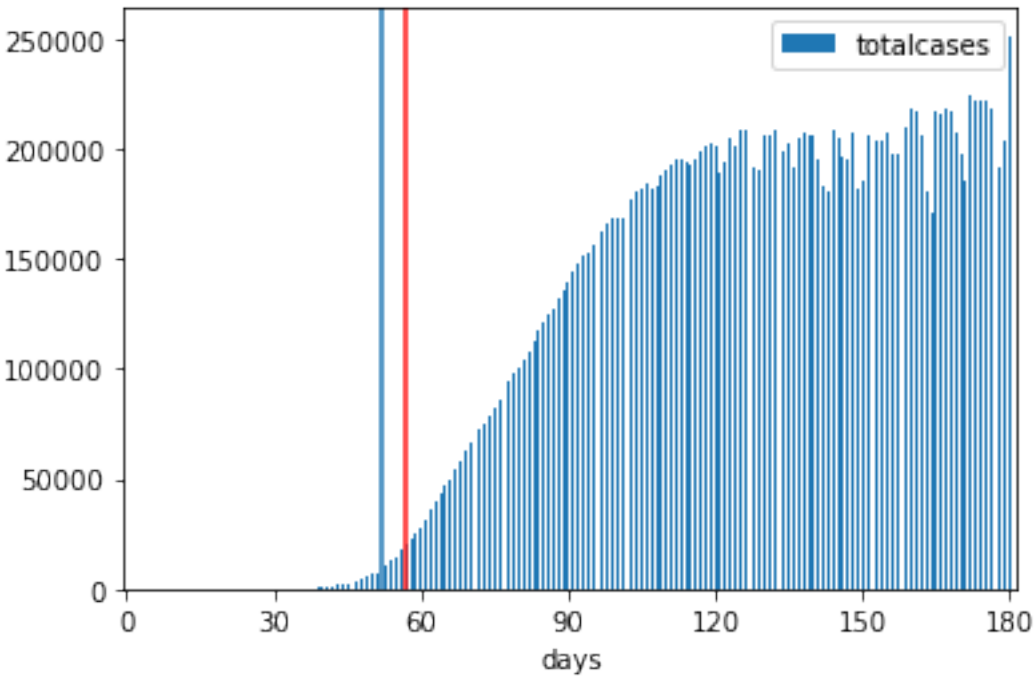
It is also clear that the lockdown stopped exponential growth, a linear growth instead lasted for slightly longer than a month, then the rate of new cases started to slow down even more. The linear growth can probably be explained by the spread of the virus within households, in which one person was infected before the lockdown started or even within households through interactions between close friends, family members etc.

Considering a chain of infection within a family and the incubation period, it is reasonable to expect to see in-household contagion happening over a the period of time mentioned above.

The bottomline is that the exponental growth could have caused several thousand of deaths within a relatively short period of time:

[758]:
```
total_England_df= get_total(England_df, 75, True,False, False)
total_England_df= get_total(England_df, 90, True,False, False)
total_England_df= get_total(England_df, 105, True,False, False)
```

```
<ipython-input-744-954cd232fd64>:50: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_1= new_df[new_df["days"] < 57 ][new_df["days"] > 40]
<ipython-input-744-954cd232fd64>:55: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_2= new_df[new_df["days"] < 90 ][new_df["days"] > 57 ]
<ipython-input-744-954cd232fd64>:58: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_3= new_df[new_df["days"] < 62 ][new_df["days"] > 40]   #This was added
later, it is to fit the exponential model on the first 61 days, instead of 57
<ipython-input-744-954cd232fd64>:50: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_1= new_df[new_df["days"] < 57 ][new_df["days"] > 40]
<ipython-input-744-954cd232fd64>:55: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_2= new_df[new_df["days"] < 90 ][new_df["days"] > 57 ]
<ipython-input-744-954cd232fd64>:58: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_3= new_df[new_df["days"] < 62 ][new_df["days"] > 40]   #This was added
later, it is to fit the exponential model on the first 61 days, instead of 57
<ipython-input-744-954cd232fd64>:50: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_1= new_df[new_df["days"] < 57 ][new_df["days"] > 40]
<ipython-input-744-954cd232fd64>:55: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_2= new_df[new_df["days"] < 90 ][new_df["days"] > 57 ]
<ipython-input-744-954cd232fd64>:58: UserWarning: Boolean Series key will be
reindexed to match DataFrame index.
  Y_3= new_df[new_df["days"] < 62 ][new_df["days"] > 40]   #This was added
later, it is to fit the exponential model on the first 61 days, instead of 57
```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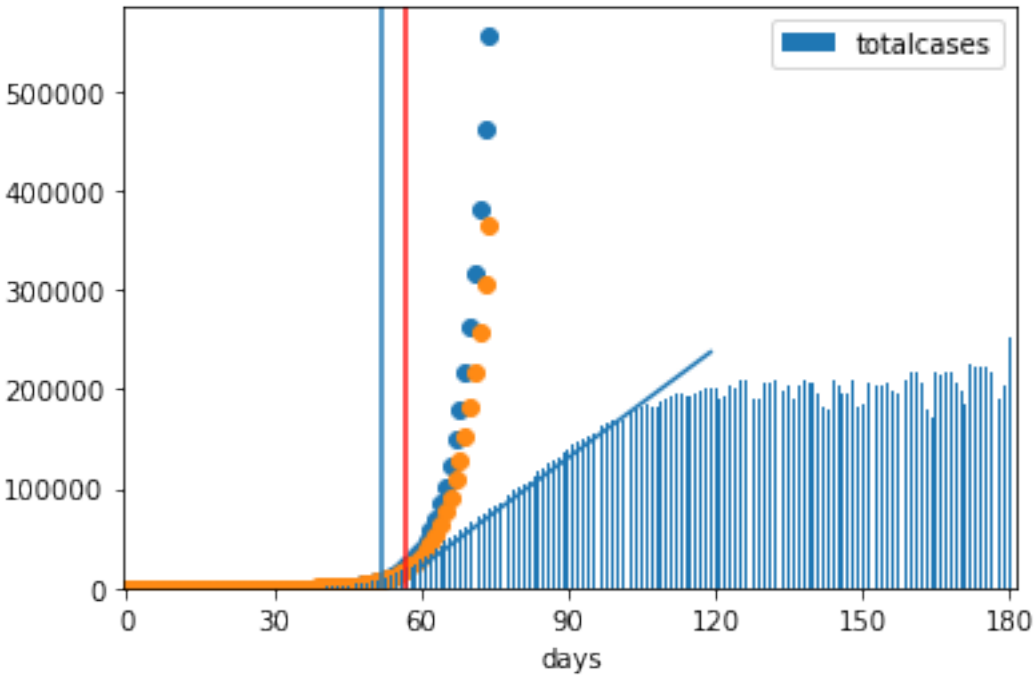
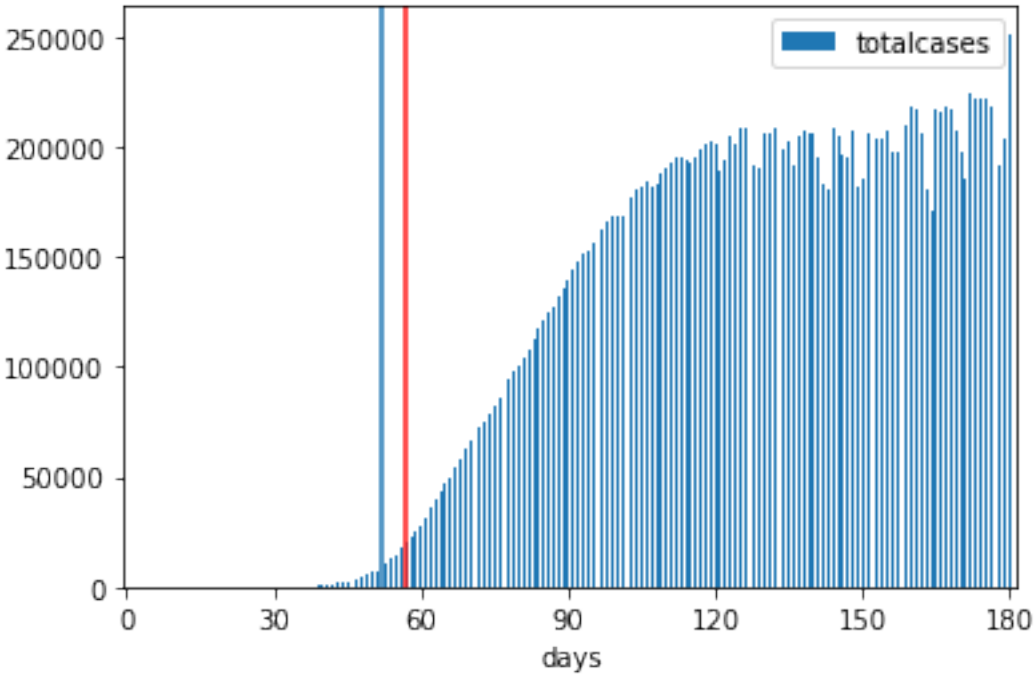
150000
100000
50000
0
0
30
60
90
120
150
180
days


totalcases
500000
400000
300000
200000
100000
0
0
30
60
90
120
150
180
days


totalcases
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200000
150000
100000
50000
0
0
30
60
90
120
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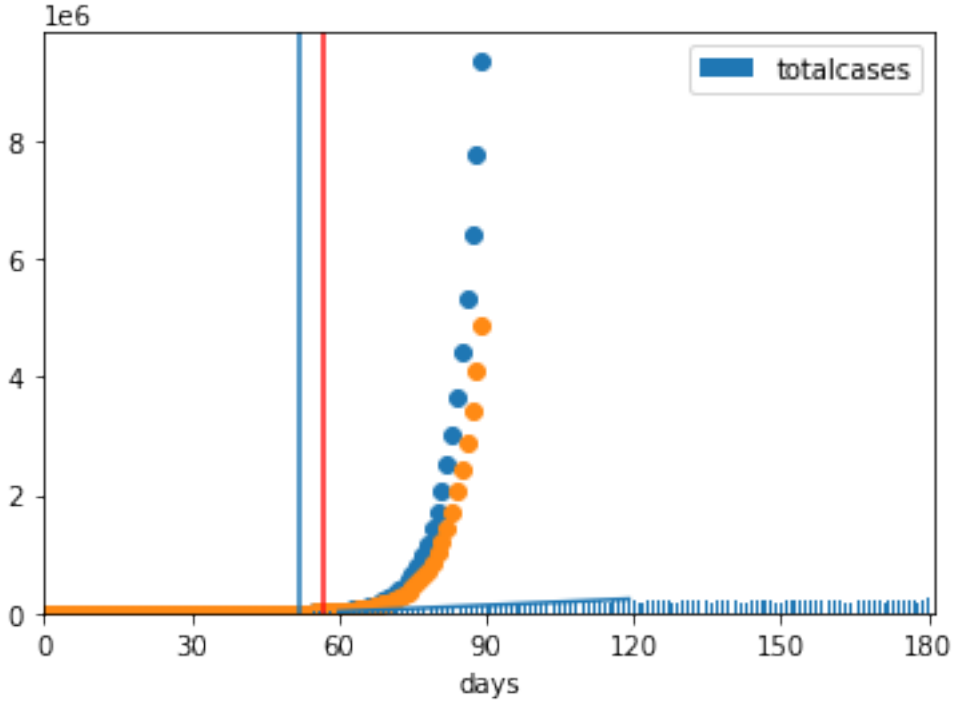
180
days


1e6
totalcases
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6
4
2
0
0
30
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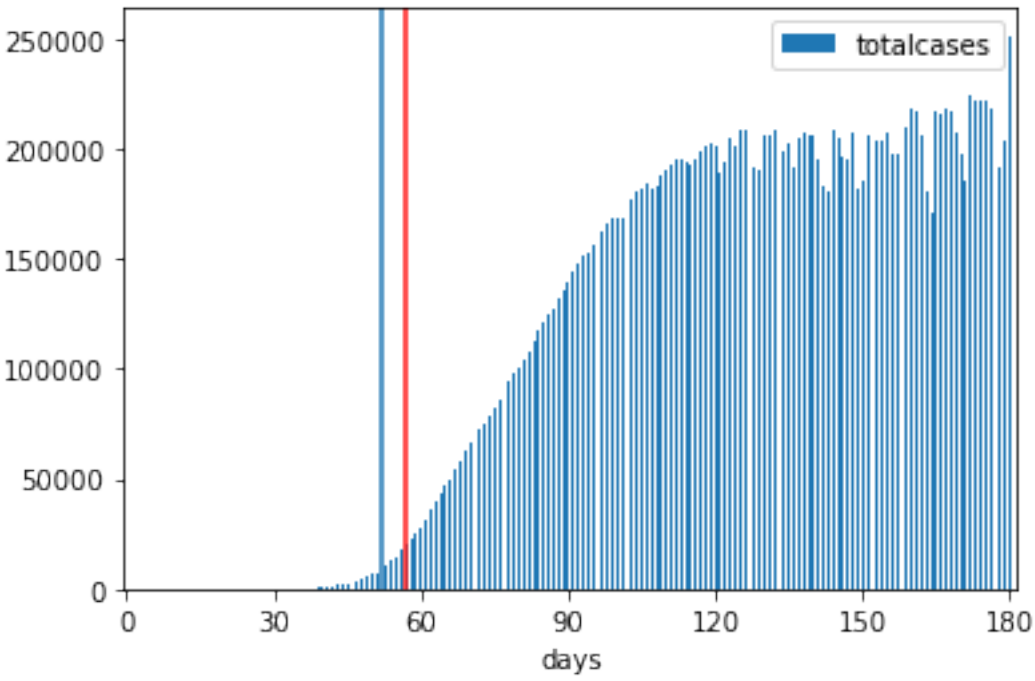
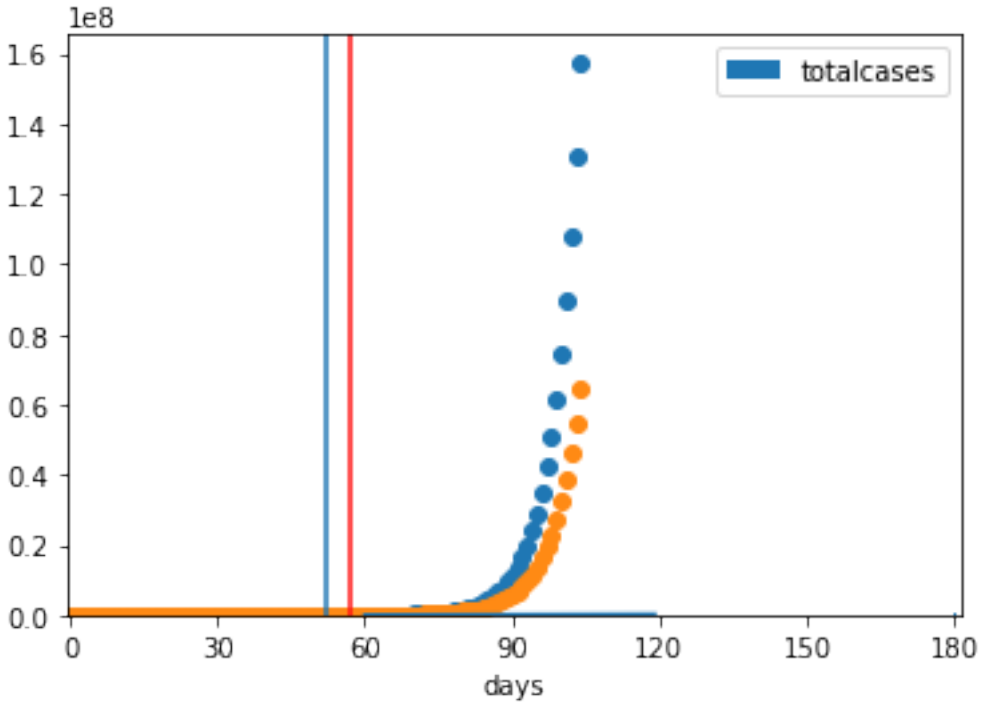
90
120
150
180
days





I am considering the orange exp growth more reliable for the following:

Roughly 500k cases would have been recorded in slighly more than two weeks from day 60, 5 mln within roughly a month if no lockdown was enforced and 60 millions within 45 days, this last figure is not accurate because it is almost the entire population of the UK and I imagine exponential growth to slow down when most people have been infected.

By assuming a mortality rate of 0.5-1%, between 300'000 and 600'000 people would have died as a consequence of infections that would have happened within 45 days from day 60, namely on day 105 which was the 14th of May 2020. Most of these deaths would have occurred, considering the incubation period, between the end of May and the end of June 2020.

This is without considering the effect mentioned above which would have made numbers smaller, but also without considering overwhelmed hospitals, which would have meant many more deaths, even for other medical conditions not related to covid.