# Vaccination in the UK

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## Contents

# 1 Introduction

Hello. My name is Elena, and I am a Data Scientist.

When I came to Bristol in May 2021, I decided to be vaccinated because, in my opinion, this is a safer way to live my normal life. So, I started my long research about Covid vaccination. And now I am ready to show you interesting facts.

## 1.1 Questions

I live in Bristol. What do I know about Bristol?

- This city is a part of the UK, England, and South West.
- There are two universities.

Question 0: Are there dependencies between academic year events and vaccination waves?

I was vaccinated by the first, the second, and booster doses on 8 August 2021, 3 October 2021, 8 January 2022, respectively. Question 1: How many people got their jabs with me?

I got the first and the second jabs on Sunday. There were fewer people in the vaccination centre. When I got the third jab on Saturday, there was a big queue. Question 2: When do people prefer to get a jab: weekdays or weekends/Saturdays or Sundays?

Finally, Question 3: Can I predict vaccination data?

## 1.2 Overall

I need to find datasets to answer my questions.

- Data is about the UK, England, South West, and Bristol.
- Data is about new people who got the jabs by dates.

And I was lucky to find the website “Coronavirus (COVID-19) in the UK”.

## 2 Choosing datasets

Look at the vaccination metrics from the website “Coronavirus (COVID-19) in the UK”.

Cumulative people vaccinated booster dose by publish date
Cumulative people vaccinated complete by publish date
Cumulative people fully vaccinated by vaccination date
Cumulative people vaccinated 1st dose by publish date
Cumulative people vaccinated 1st dose by vaccination date

Cumulative people vaccinated 2nd dose by publish date
Cumulative people vaccinated 2nd dose by vaccination date
Cumulative people vaccinated 3rd dose by publish date
Cumulative people vaccinated with a booster dose plus new people vaccinated with a third dose by publish date
Cumulative people vaccinated booster or third dose by vaccination date

Cumulative percentage of people vaccinated with a booster dose by publish date
Cumulative vaccination complete coverage by publish date percentage
Cumulative percentage of people fully vaccinated by vaccination date
Cumulative vaccination 1st dose uptake by publish date percentage
Cumulative percentage of people vaccinated with a first dose by vaccination date

Cumulative vaccination 2nd dose uptake by publish date percentage
Cumulative percentage of second dose vaccination uptake by vaccination date
Cumulative percentage of people vaccinated with a booster dose plus people vaccinated with third dose by publish date
Cumulative percentage of people vaccinated with a booster or third dose by vaccination date
Cumulative vaccines given by publish date

New people receiving 1st dose
New people receiving 2nd dose
New people vaccinated with a booster dose by publish date
New people vaccinated complete by publish date
New people fully vaccinated by vaccination date

New people vaccinated 1st dose by publish date
New people vaccinated with a first dose by vaccination date
New people vaccinated 2nd dose by publish date
New people vaccinated with a second dose by vaccination date
New people vaccinated with a third dose by publish date

New people vaccinated with a booster dose plus new people vaccinated with a third dose by publish date
New people vaccinated with a booster or third dose by vaccination date
New vaccines given by publish date
Vaccinations age demographics breakdown
Vaccination register (NIMS) population by vaccination date

Weekly people vaccinated 1st dose by vaccination date
Weekly people vaccinated 2nd dose by vaccination date

I am going to use metrics

1. which names start with “New”,
2. by vaccination date,
3. and are not deprecated.

Which datasets have these metrics?

| | ltla | msoa | nation | nhsRegion | nhsTrust | overview | region | utla |
|---|---|---|---|---|---|---|---|---|
| cumPeopleVaccinatedBoosterDoseByPublishDate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cumPeopleVaccinatedCompleteByPublishDate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cumPeopleVaccinatedCompleteByVaccinationDate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cumPeopleVaccinatedFirstDoseByPublishDate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cumPeopleVaccinatedFirstDoseByVaccinationDate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cumPeopleVaccinatedSecondDoseByPublishDate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cumPeopleVaccinatedSecondDoseByVaccinationDate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cumPeopleVaccinatedThirdDoseByPublishDate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cumPeopleVaccinatedThirdInjectionByPublishDate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cumPeopleVaccinatedThirdInjectionByVaccinationDate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cumVaccinationBoosterDoseUptakeByPublishDatePercentage | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cumVaccinationCompleteCoverageByPublishDatePercentage | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cumVaccinationCompleteCoverageByVaccinationDatePercentage | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cumVaccinationFirstDoseUptakeByPublishDatePercentage | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cumVaccinationFirstDoseUptakeByVaccinationDatePercentage | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cumVaccinationSecondDoseUptakeByPublishDatePercentage | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cumVaccinationSecondDoseUptakeByVaccinationDatePercentage | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cumVaccinationThirdInjectionUptakeByPublishDatePercentage | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cumVaccinationThirdInjectionUptakeByVaccinationDatePercentage | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| cumVaccinesGivenByPublishDate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| newPeopleReceivingFirstDose | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| newPeopleReceivingSecondDose | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| newPeopleVaccinatedBoosterDoseByPublishDate | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| newPeopleVaccinatedCompleteByPublishDate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| newPeopleVaccinatedCompleteByVaccinationDate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| newPeopleVaccinatedFirstDoseByPublishDate | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 |
| newPeopleVaccinatedFirstDoseByVaccinationDate | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| newPeopleVaccinatedSecondDoseByPublishDate | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 |
| newPeopleVaccinatedSecondDoseByVaccinationDate | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| newPeopleVaccinatedThirdDoseByPublishDate | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| newPeopleVaccinatedThirdInjectionByPublishDate | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 |
| newPeopleVaccinatedThirdInjectionByVaccinationDate | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| newVaccinesGivenByPublishDate | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| vaccinationsAgeDemographics | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| VaccineRegisterPopulationByVaccinationDate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| weeklyPeopleVaccinatedFirstDoseByVaccinationDate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| weeklyPeopleVaccinatedSecondDoseByVaccinationDate | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

Table 1: Vaccination metrics with highlight

So, I need to look at the datasets:

| |
|---|
| Lower Tier Local Authority (LTLA) |
| Nation |
| Region |
| Upper Tier Local Authority (UTLA) |

The dataset “Overview” presents the UK. Which metrics do we have for this dataset?

| |
|---|
| newPeopleVaccinatedFirstDoseByPublishDate |
| newPeopleVaccinatedSecondDoseByPublishDate |
| newPeopleVaccinatedThirdInjectionByPublishDate |
| newVaccinesGivenByPublishDate |

So, we do not have data by vaccination date for the UK. I am going to use metrics from the Table 1 for

1. Bristol (Lower Tier Local Authority (LTLA)),
2. South West (Region)
3. and England (Nation).

That is enough for answering.

# 3 Exploring datasets

## 3.1 South West

Look at the dataset for South West.

| |
|---|
| areaCode |
| areaName |
| areaType |
| date |
| newPeopleVaccinatedFirstDoseByVaccinationDate |
| newPeopleVaccinatedSecondDoseByVaccinationDate |
| newPeopleVaccinatedThirdInjectionByVaccinationDate |

We have additional columns. Let's look at them.

- For **areaCode** unique value is E12000009,
- for **areaName** unique value is South West,
- for **areaType** unique value is region.

So, we do not need to look at them in the future because these columns are used for filtering that we have already done on the website.

Let's prepare data for the plotting.

- Rename columns
- Create a long table

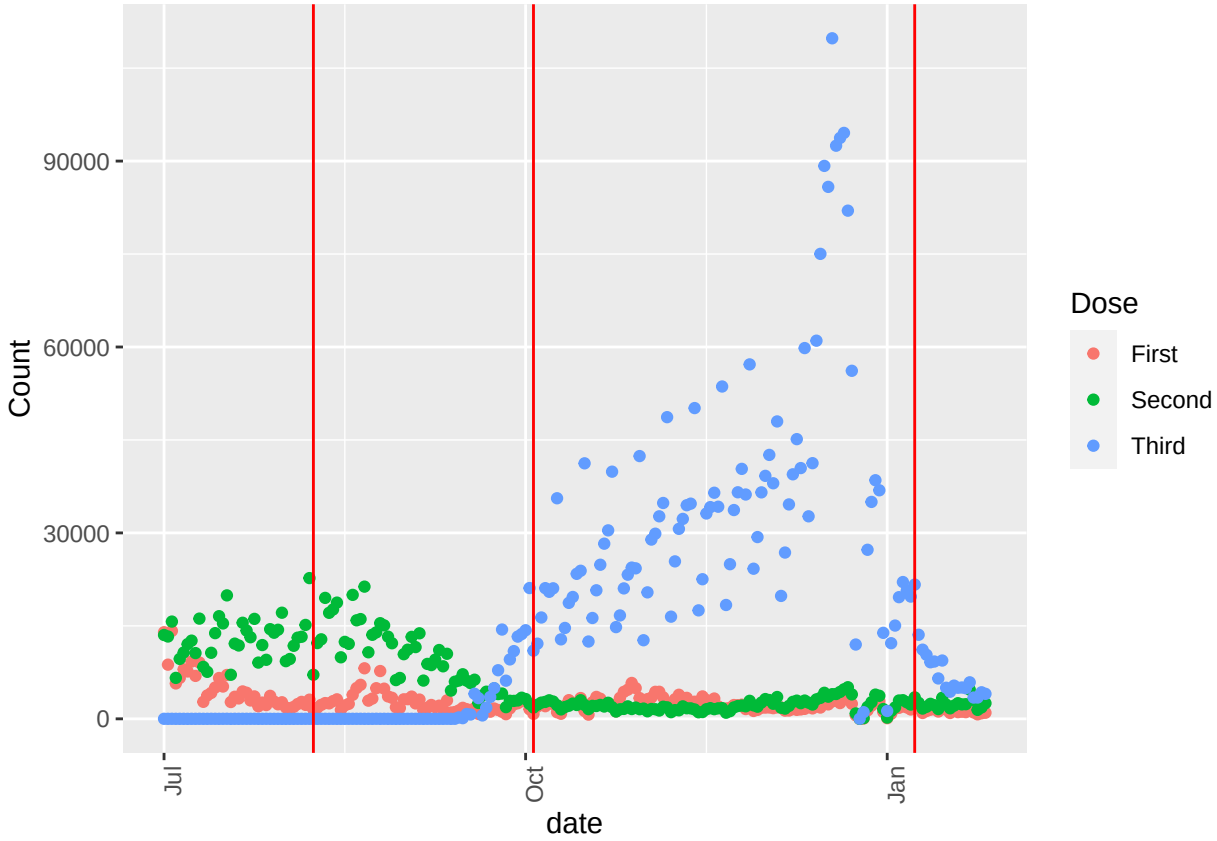
| date | Dose | Count |
|---|---|---|
| 2022-01-26 | First | 986 |
| 2022-01-25 | First | 899 |
| 2022-01-24 | First | 723 |
| 2022-01-23 | First | 1035 |
| 2022-01-22 | First | 1822 |
| 2022-01-21 | First | 1085 |

Let's plot data.

### 3.1.1 Question 1

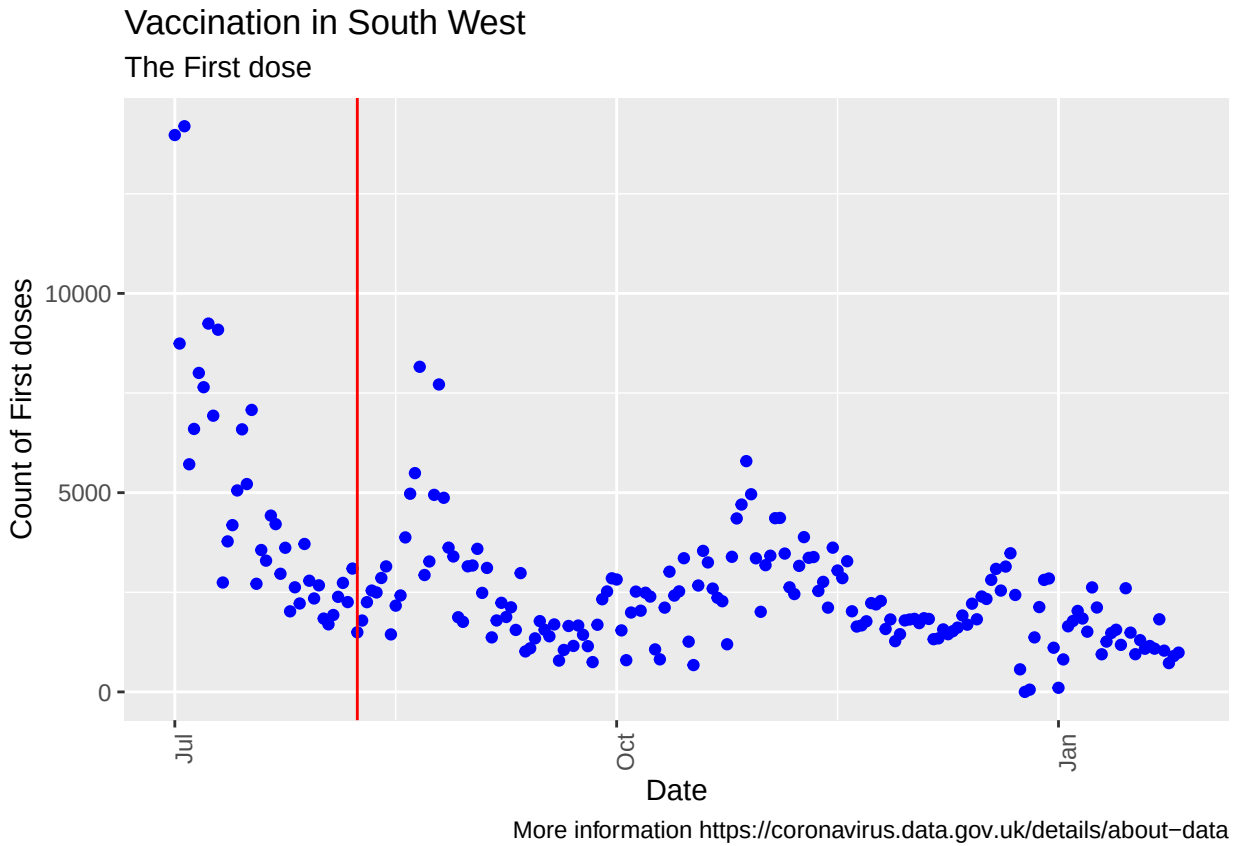
As I say in the part 1, I have a question: How many people got their jabs with me?

Let's answer. The red lines are my vaccination dates.

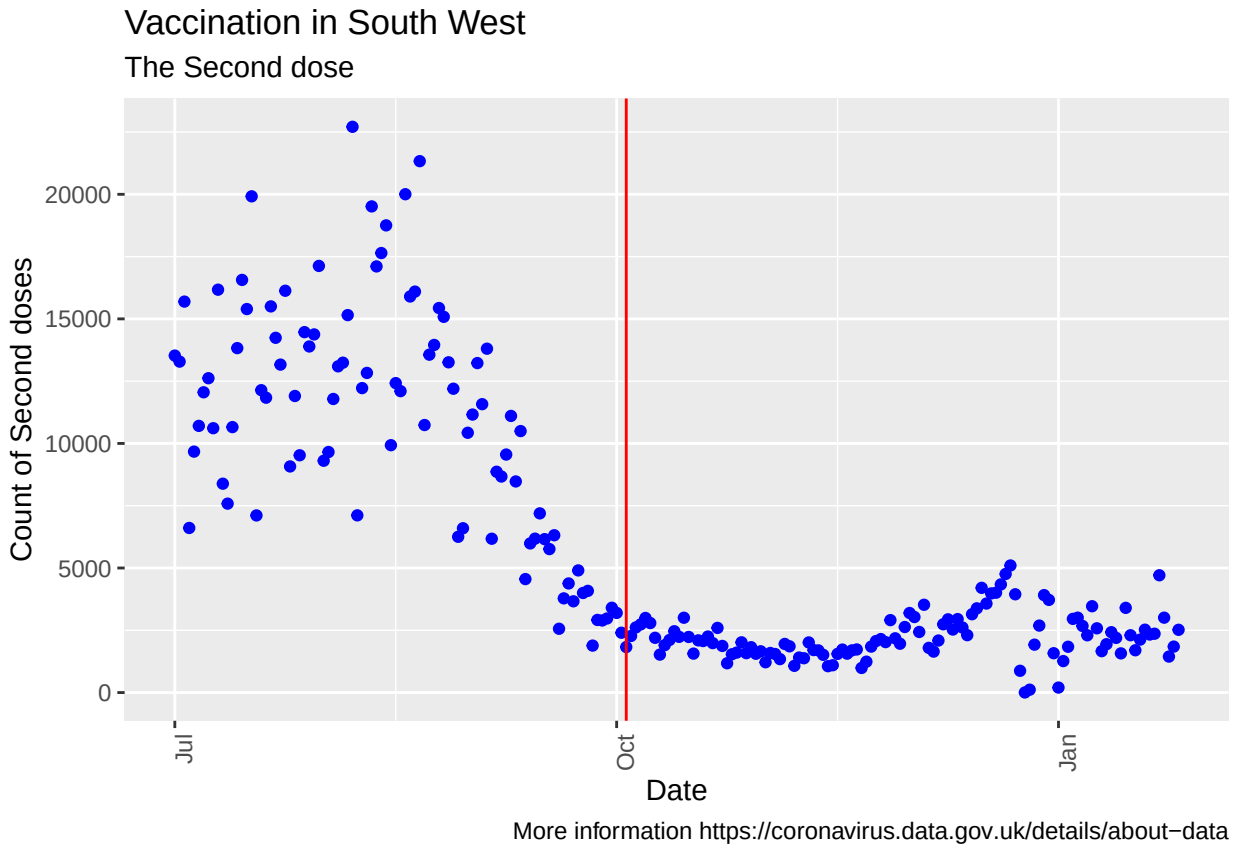

90000
60000
30000
0
Count
Jul
Oct
Jan
date
Dose
First
Second
Third

The result is not beautiful because of the active growth of the third jabs count at the end of 2021.

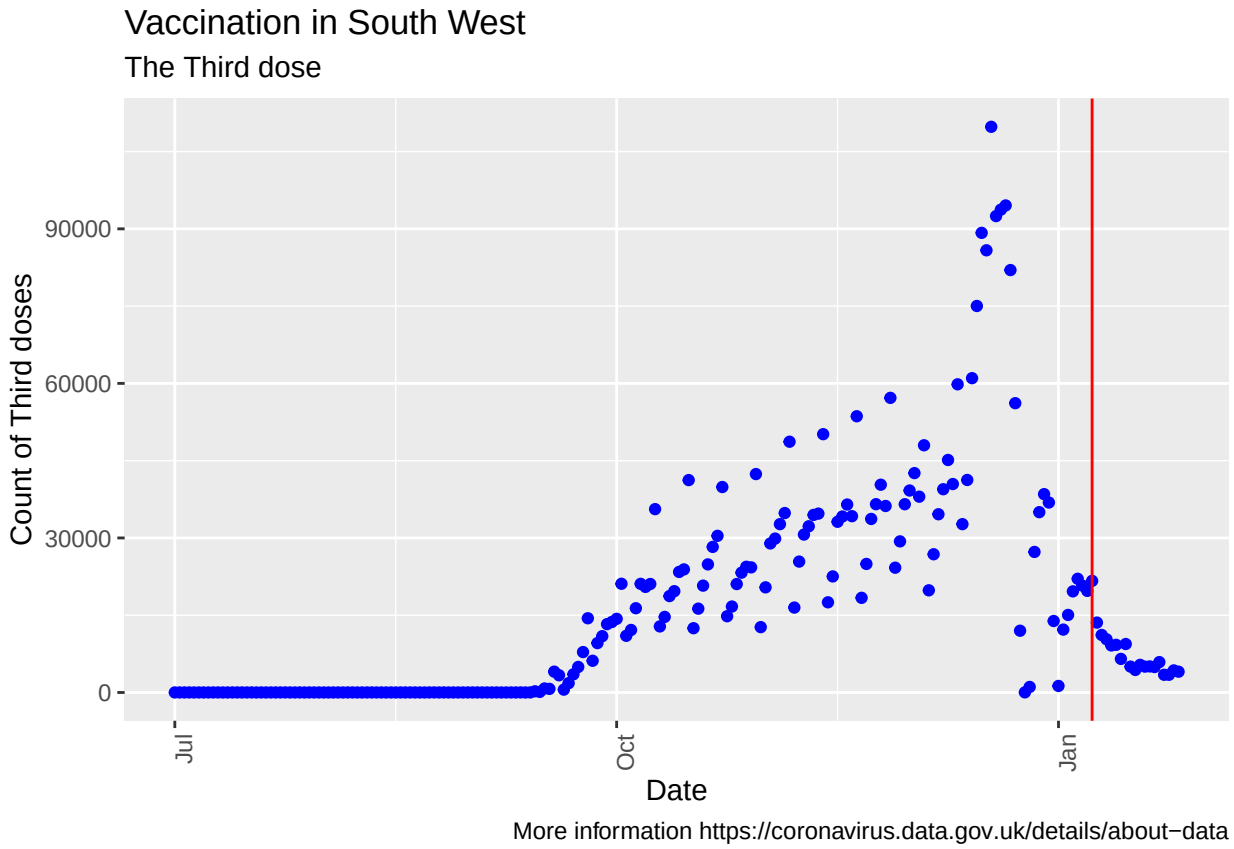
Let's plot them separately.




It is so interesting why the graph is wavy. 1496 people got their first jabs with me.

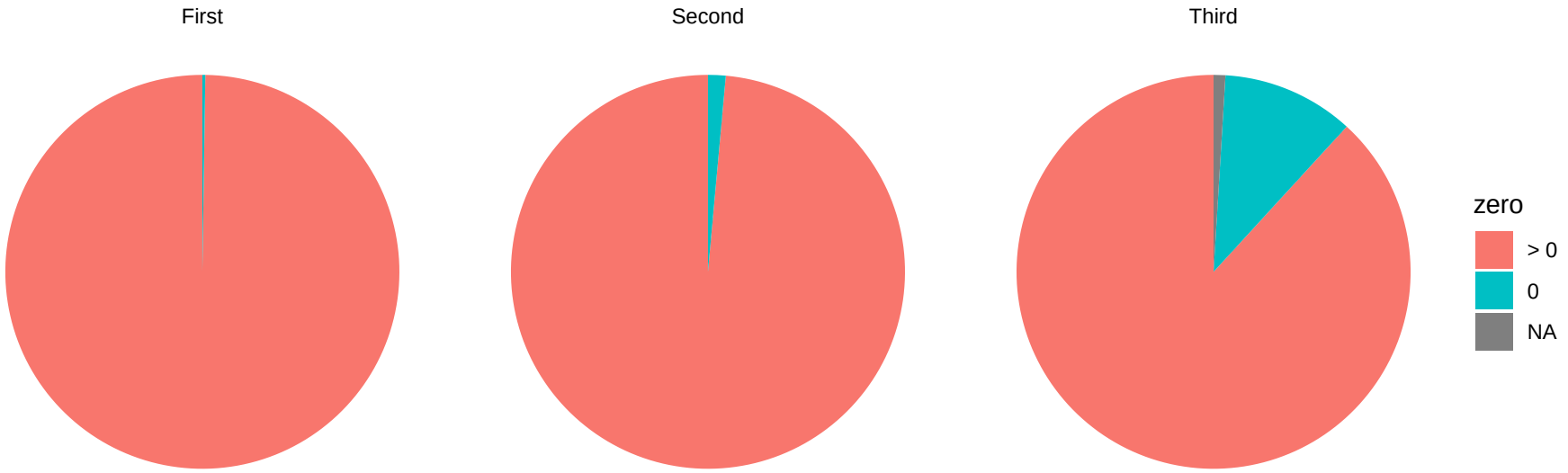



1828 people got their second jabs with me.




21664 people got their third jabs with me. We can see when the active phase of vaccination by the third dose started.

### 3.1.2 Zeroes




The column “Third” has more zero values than “First” and “Second; but, I think, it won’t influence models’ accuracy. Also, we can see missing values for the column”Third”; in our case, missing values mean that nobody got the third jab. I suggest replacing them with zeroes.

Replace missing values.

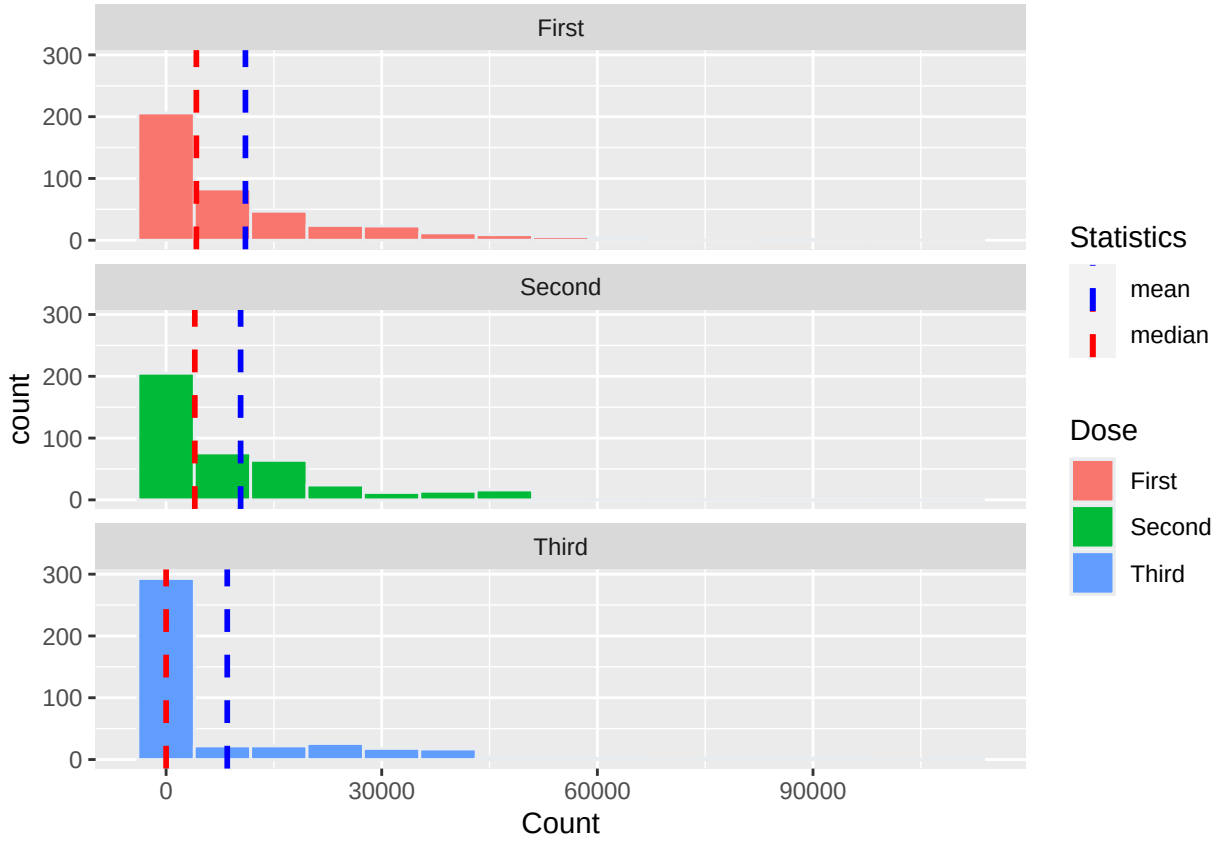
### 3.1.3 Data description

*Median, percentiles and mean*

| | mean | median | Q0.25 | Q0.75 | Q0.9 |
|---|---|---|---|---|---|
| First | 11037.614 | 4210 | 2072.0 | 14213.0 | 31224.6 |
| Second | 10367.352 | 3998 | 1659.5 | 13708.5 | 28700.6 |
| Third | 8589.925 | 6 | 2.0 | 10629.5 | 33689.0 |

What can I say?

- Mean and median have a visible difference. So, there are large extreme values.
- For the Third dose, half of the values are below 6. That is not surprising. In the beginning, people needed to get two jabs.
- If we look at “Q0.25”, “Q0.75”, “Q0.90”, we find out that the Third dose’s wave caught up with other doses’ waves quickly. We already saw this fact on the plots.




*Standard deviation (sd), IQR and range*

| | sd | range | IQR |
|---|---|---|---|
| First | 13971.58 | 84537 | 12141.0 |
| Second | 13477.22 | 78425 | 12049.0 |
| Third | 17512.10 | 109810 | 10627.5 |

IQR and standard deviation for each dose are big, consequently, the data spread out. Also, we can see the difference between largest and smallest values in the column "range".

## 3.2 Bristol

The dataset's columns:

| |
|---|
| date |
| age |
| newPeopleVaccinatedFirstDoseByVaccinationDate |
| newPeopleVaccinatedSecondDoseByVaccinationDate |
| newPeopleVaccinatedThirdInjectionByVaccinationDate |

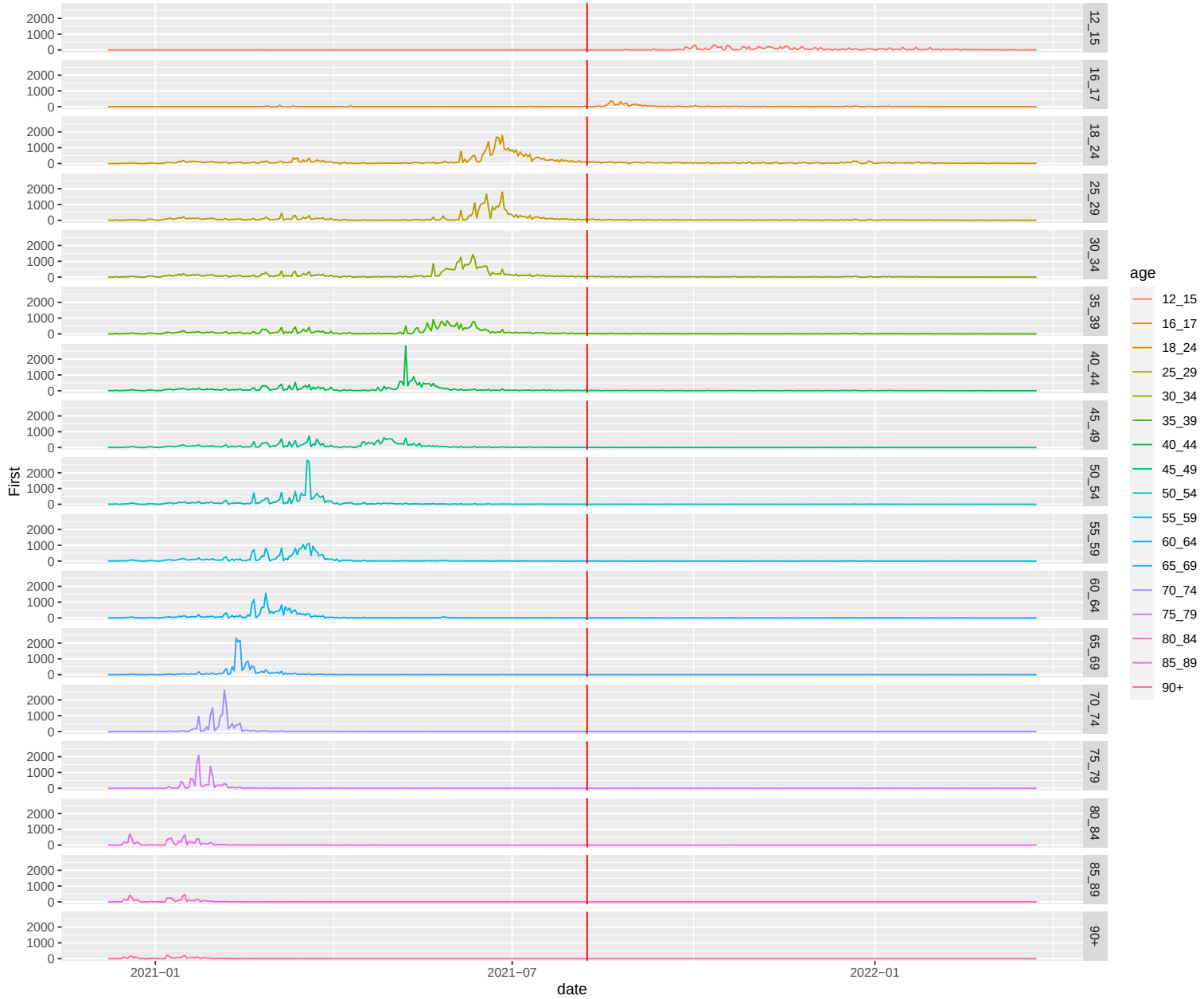
Just rename columns and we will move on to answer the questions.

| age | date | First | Second | Third |
|---|---|---|---|---|
| 12_15 | 2022-03-24 | 6 | 34 | 0 |
| 16_17 | 2022-03-24 | 0 | 7 | 23 |
| 18_24 | 2022-03-24 | 13 | 15 | 30 |
| 25_29 | 2022-03-24 | 3 | 11 | 14 |
| 30_34 | 2022-03-24 | 0 | 5 | 13 |
| 35_39 | 2022-03-24 | 1 | 3 | 7 |

### 3.2.1 Question 1

How many people got their jabs with me?

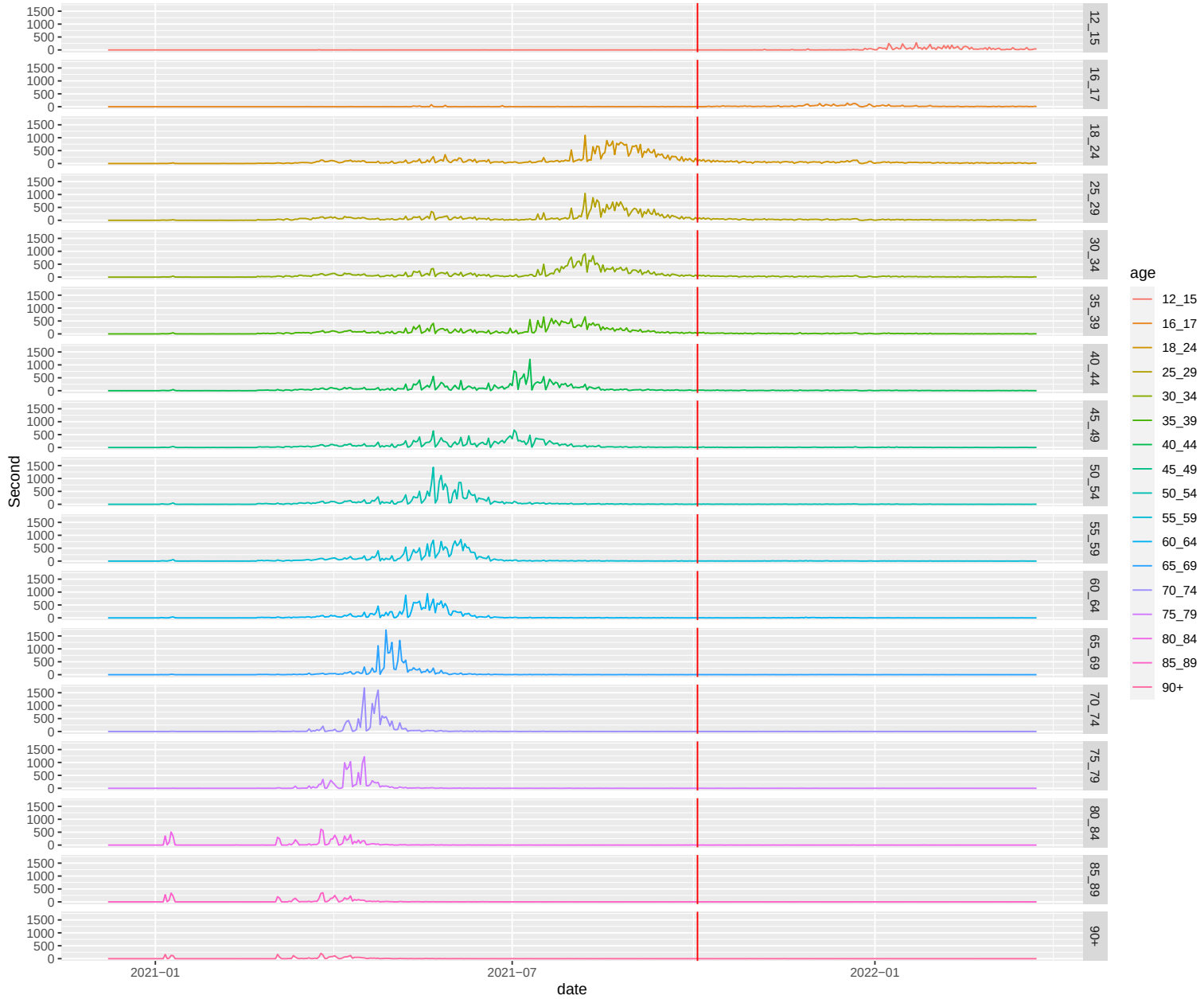
I suggest looking at this graph from left to right and from down to up. Also, I put my dates on the graphs as the red lines.


First
2000
1000
0
12_15
16_17
18_24
25_29
30_34
35_39
40_44
45_49
50_54
55_59
60_64
65_69
70_74
75_79
80_84
85_89
90+
2021−01
2021−07
2022−01
date
age
12_15
16_17
18_24
25_29
30_34
35_39
40_44
45_49
50_54
55_59
60_64
65_69
70_74
75_79
80_84
85_89
90+

20 people in my age group got their First jabs with me in Bristol.

We can see that the active phases of the vaccination depends on the age group. The first group was people 90 years and older. The last one is the people 12-15 years old. It is not surprising, because, as I know, it was a government strategy.

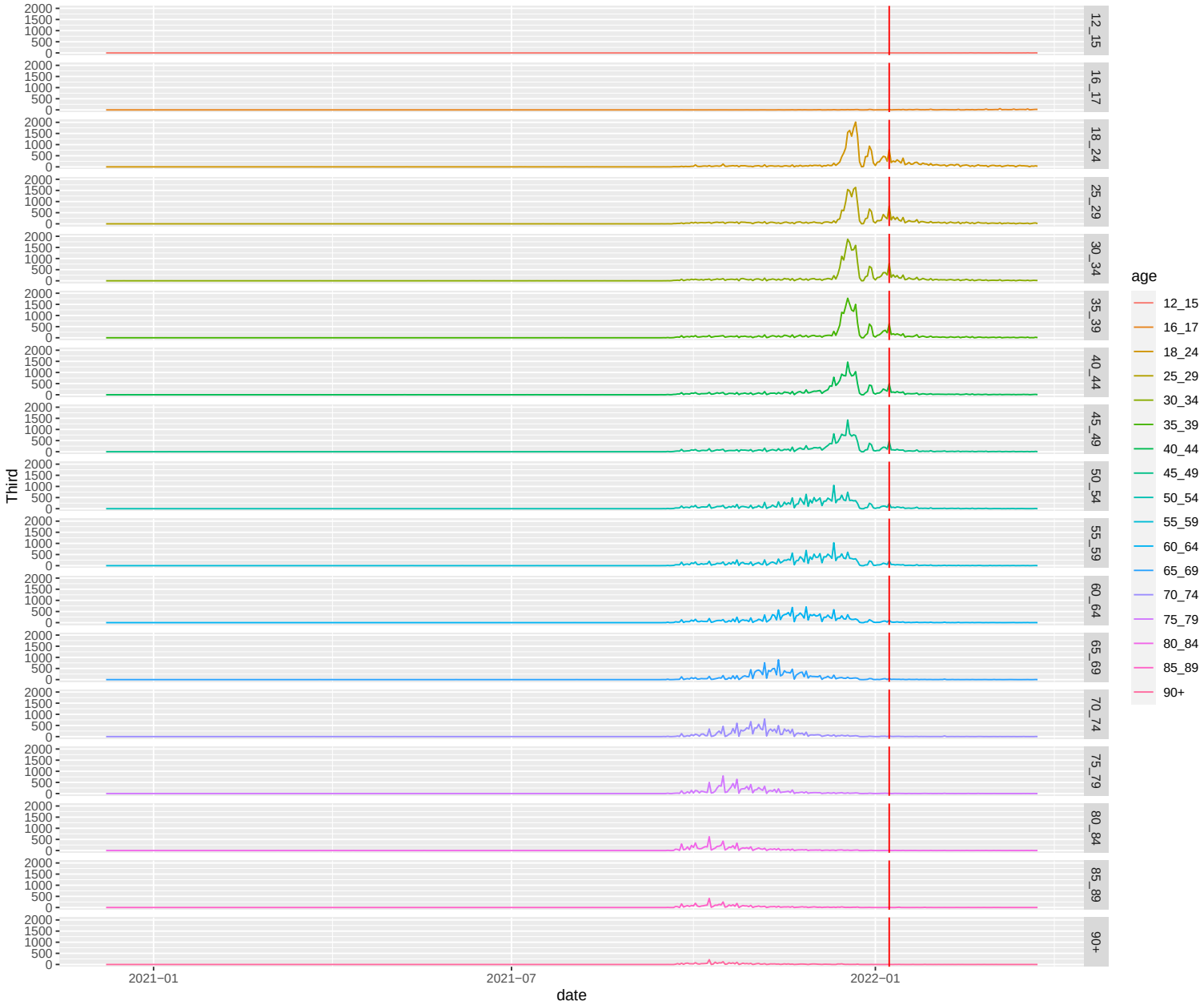
Look at the graph for the second dose.


Second
1500
1000
500
0
12_15
16_17
18_24
25_29
30_34
35_39
40_44
45_49
50_54
55_59
60_64
65_69
70_74
75_79
80_84
85_89
90+
2021−01
2021−07
2022−01
date
age
12_15
16_17
18_24
25_29
30_34
35_39
40_44
45_49
50_54
55_59
60_64
65_69
70_74
75_79
80_84
85_89
90+

38 people in my age group got their Second jabs with me in Bristol.

The second dose is 2 months after the first. And we can see the waves too.

Look at the graph for the third dose.


Third
2000
1500
1000
500
0
12_15
16_17
18_24
25_29
30_34
35_39
40_44
45_49
50_54
55_59
60_64
65_69
70_74
75_79
80_84
85_89
90+
2021−01
2021−07
2022−01
date
age
12_15
16_17
18_24
25_29
30_34
35_39
40_44
45_49
50_54
55_59
60_64
65_69
70_74
75_79
80_84
85_89
90+

804 people in my age group got their Third jabs with me in Bristol.

So, my date of the vaccination was not in the active phase. And I can't imagine how many people were in the vaccination centre at the end of December 2021.

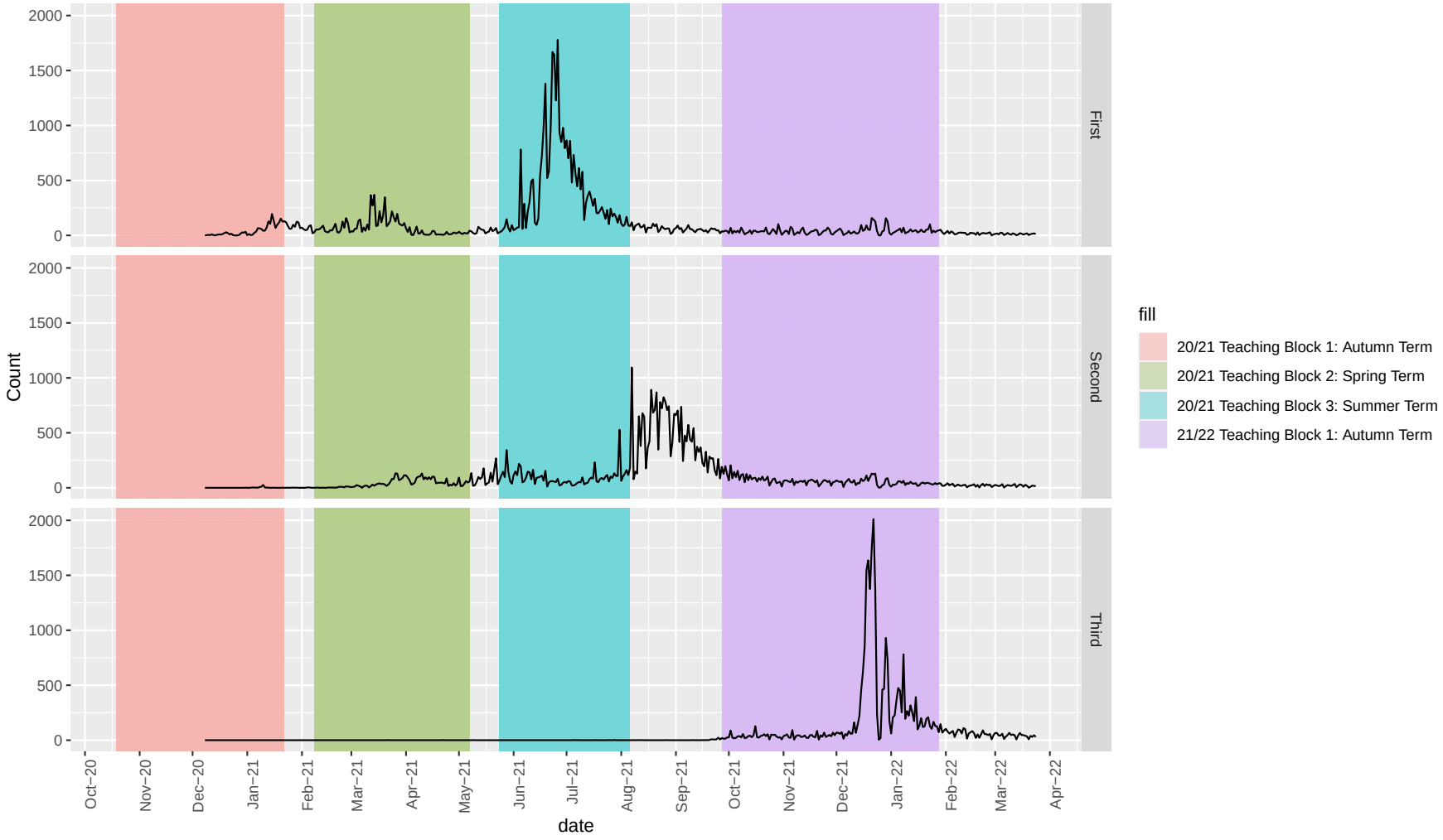
Overall, I got my jabs in the not active phases of the vaccination, but I got the third one with a lot of people. And the count of jabs depends on dates. Keep this fact in mind.

#### 3.2.2 Question 0

Are there dependencies between academic year events and vaccination waves?

There are two large universities in Bristol. I guess that the vaccination waves also depend on the academic year events.

I will be use term-dates of UWE academic years: 2020-2021, 2021-2022, 2022-2023.




The result is interesting but requires research. As I can see, the active phase of the vaccination for the age group 18-24 was during the Summer term. But why? It may be because students decided to prepare themselves for the new academic year. It may be because of the government or NHS suggestions. It is an open question.

## 3.3 England

Look at the dataset's columns.

| |
|---|
| areaCode |
| areaName |
| areaType |
| date |
| newPeopleVaccinatedFirstDoseByVaccinationDate |
| newPeopleVaccinatedSecondDoseByVaccinationDate |
| newPeopleVaccinatedThirdInjectionByVaccinationDate |

We are not going to look at the columns areaCode, areaName, areaType, because these columns have one unique value (E92000001 for areaCode, England for areaName, nation for areaType), they are used for filtering on the website.

Rename columns and exclude unnecessary columns.

| | Date | First | Second | Third |
|---|---|---|---|---|
| 457 | 2020-12-08 | 5370 | 146 | NA |
| 456 | 2020-12-09 | 9648 | 137 | 2 |
| 455 | 2020-12-10 | 11888 | 119 | 1 |
| 454 | 2020-12-11 | 12516 | 82 | 1 |
| 453 | 2020-12-12 | 10565 | 23 | 3 |
| 452 | 2020-12-13 | 6134 | 30 | 0 |

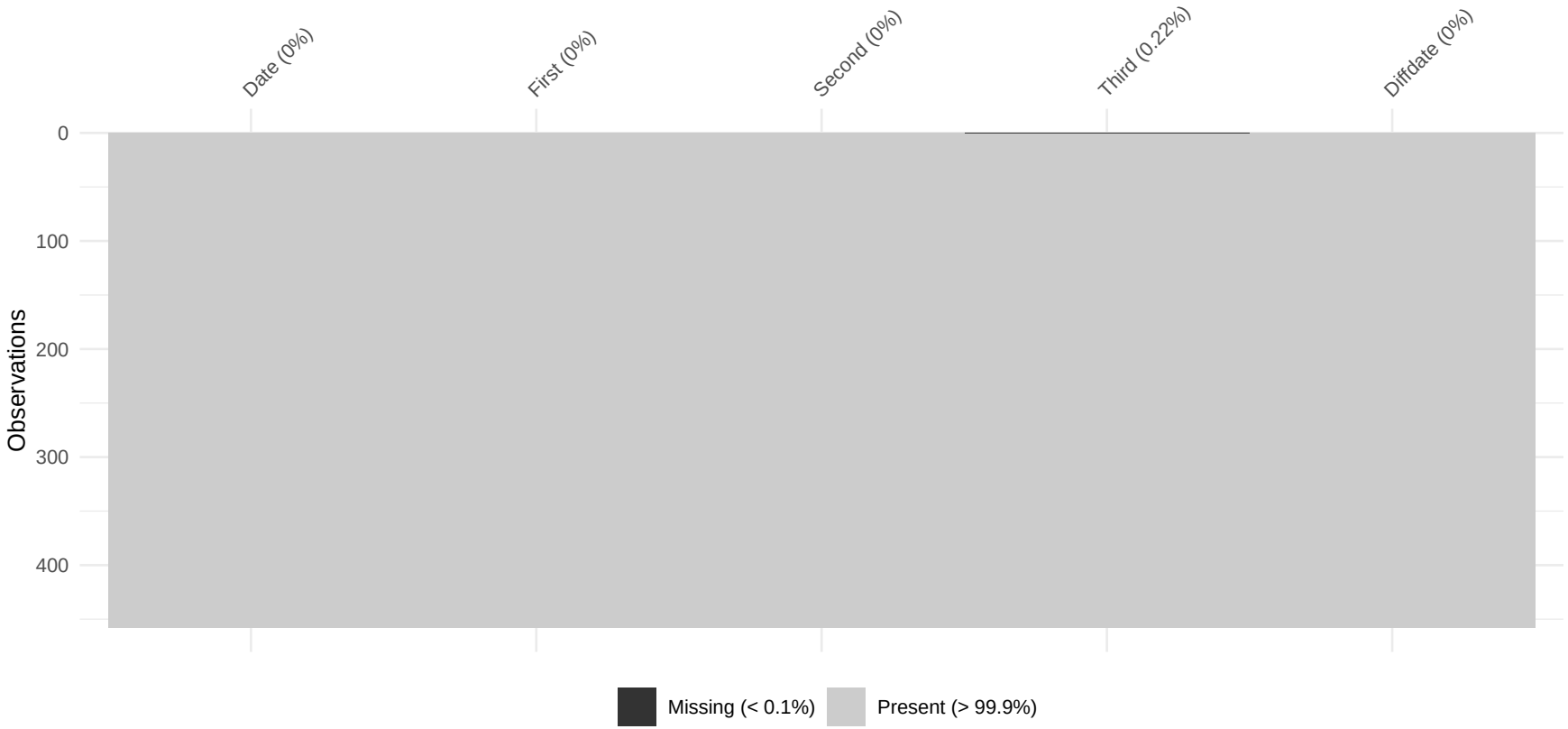
I want to be sure that the file has statistics for every day.

The difference between dates is 1. So, we have full statistics by date.

### 3.3.1 Missing values

Do we have missing values?

| | |
|---|---|
| Date | 0 |
| First | 0 |
| Second | 0 |
| Third | 1 |
| Diffdate | 0 |

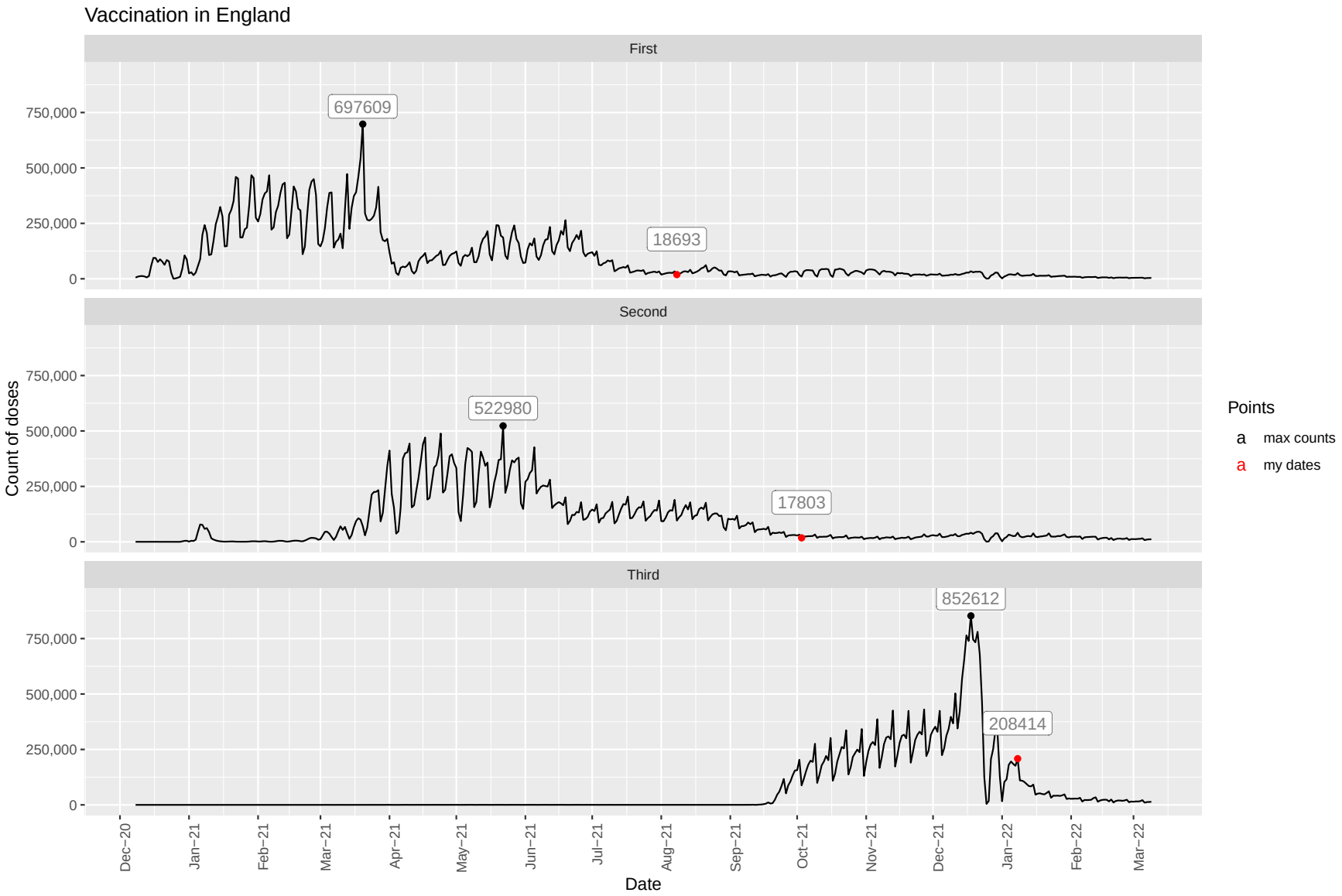



Yes, we have missing values in the column "Third". In this case, missing values and zeroes are equivalent.

Replace by zero.

### 3.3.2 Question 1

How many people got their jabs with me?


Vaccination in England
First
Second
Third
697609
18693
522980
17803
852612
208414
750,000
500,000
250,000
0
Count of doses
Dec−20
Jan−21
Feb−21
Mar−21
Apr−21
May−21
Jun−21
Jul−21
Aug−21
Sep−21
Oct−21
Nov−21
Dec−21
Jan−22
Feb−22
Mar−22
Date
Points
a max counts
a my dates

# 4 Modeling

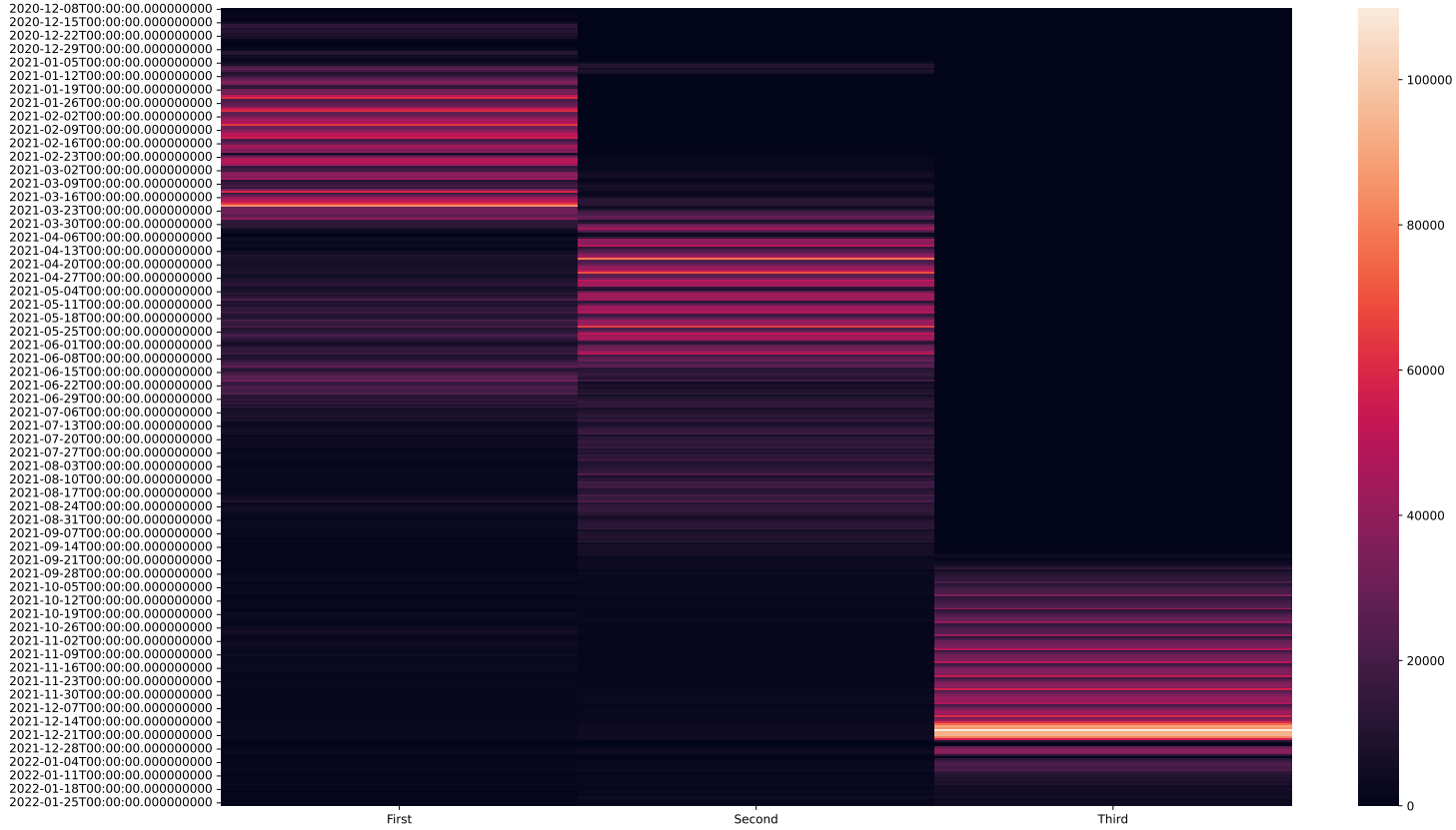
So, I am curious. Can I predict vaccination data?

## 4.1 South West

### 4.1.1 Looking at and Modifying the dataset

I will work with the South West's vaccination data.

| | First | Second | Third |
|---|---|---|---|
| 2022-01-26 | 986 | 2520 | 4034 |
| 2022-01-25 | 899 | 1845 | 4283 |
| 2022-01-24 | 723 | 1445 | 3441 |
| 2022-01-23 | 1035 | 3007 | 3439 |
| 2022-01-22 | 1822 | 4709 | 5896 |
| 2022-01-21 | 1085 | 2362 | 4944 |
| 2022-01-20 | 1152 | 2330 | 5058 |
| 2022-01-19 | 1083 | 2524 | 5017 |
| 2022-01-18 | 1298 | 2126 | 5359 |
| 2022-01-17 | 946 | 1699 | 4374 |




### 4.1.2 Getting features

As we discuss earlier 3.1, there are waves. So, the count of jabs depends on dates.

Let's get features: 1) Year 2) Month 3) Day etc.

| | First | Second | Third | Year | Month | Day | DayOfYear | Weekday | Quarter | IsMonthStart | IsMonthEnd |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2022-01-26 | 986 | 2520 | 4034 | 2022 | 1 | 26 | 26 | 2 | 1 | FALSE | FALSE |
| 2022-01-25 | 899 | 1845 | 4283 | 2022 | 1 | 25 | 25 | 1 | 1 | FALSE | FALSE |
| 2022-01-24 | 723 | 1445 | 3441 | 2022 | 1 | 24 | 24 | 0 | 1 | FALSE | FALSE |
| 2022-01-23 | 1035 | 3007 | 3439 | 2022 | 1 | 23 | 23 | 6 | 1 | FALSE | FALSE |
| 2022-01-22 | 1822 | 4709 | 5896 | 2022 | 1 | 22 | 22 | 5 | 1 | FALSE | FALSE |
| 2022-01-21 | 1085 | 2362 | 4944 | 2022 | 1 | 21 | 21 | 4 | 1 | FALSE | FALSE |
| 2022-01-20 | 1152 | 2330 | 5058 | 2022 | 1 | 20 | 20 | 3 | 1 | FALSE | FALSE |
| 2022-01-19 | 1083 | 2524 | 5017 | 2022 | 1 | 19 | 19 | 2 | 1 | FALSE | FALSE |
| 2022-01-18 | 1298 | 2126 | 5359 | 2022 | 1 | 18 | 18 | 1 | 1 | FALSE | FALSE |
| 2022-01-17 | 946 | 1699 | 4374 | 2022 | 1 | 17 | 17 | 0 | 1 | FALSE | FALSE |

#### 4.1.3 Choosing a model

First of all, I am going to use Regression Machine Learning models:

- Decision Tree
- Random Forest.

What is my plan?

1. Read data

I already did this step.

2. Understand statistics about the data

It will be helpful to choose the right features for better results.

- Work with missing data and categorical variables
- Work with outliers or not completed data.

5. Store prediction target (y) in a Series, selecting multiple features by providing a list of column names inside brackets, define X (subset with features), check the X summary.
6. Choose the library

7. Build and use the model

- What type of model will it be?
- Capture patterns from provided data.
- Predict
- Evaluate = Determine how accurate the model's predictions are

Let's look at the dataset carefully.

#### 4.1.4 Exploring the dataset

In the previous chapter 3.1, we already looked at the South West's data. Do we need to know something else? Yes.

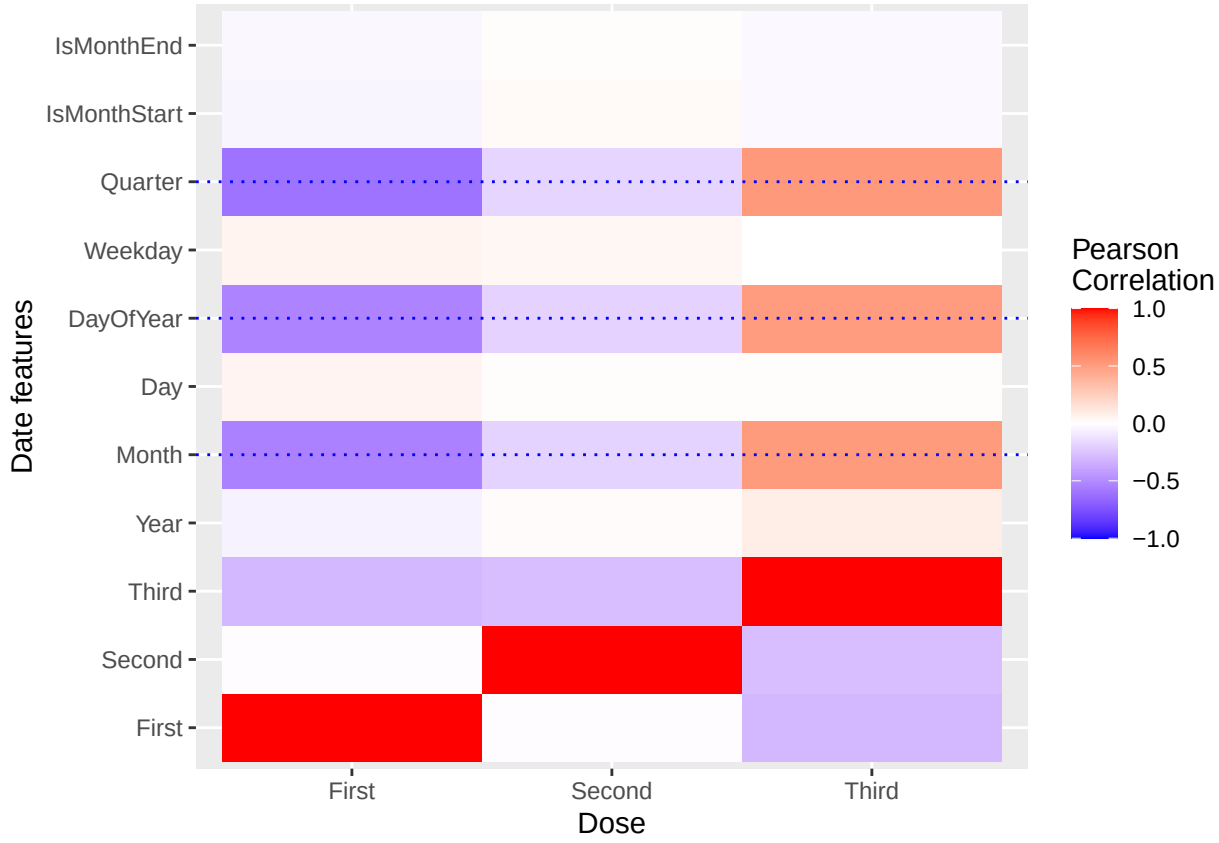
**4.1.4.1 Data types** It is important to know which types of data columns have. Sometimes we don't realise what we see: the string or the number.

| | |
|---|---|
| First | double |
| Second | double |
| Third | double |
| Year | double |
| Month | double |
| Day | double |
| DayOfYear | double |
| Weekday | double |
| Quarter | double |
| IsMonthStart | logical |
| IsMonthEnd | logical |

The good news is I don't need to convert my variables because they fit into Regression Machine Learning models.

We will move on to correlations.

**4.1.4.2 Correlations** What do we need to remember? Correlation does not imply causation. So, the columns that have a strong relationship may show low accuracy in the model.




In the table below, we can see the numeric values.

| | | |
|---|---|---|
| First | Month | -0.5432969 |
| Second | Month | -0.1888013 |
| Third | Month | 0.5158655 |
| First | DayOfYear | -0.5343244 |
| Second | DayOfYear | -0.1901012 |
| Third | DayOfYear | 0.5133313 |
| First | Quarter | -0.6070344 |
| Second | Quarter | -0.1799906 |
| Third | Quarter | 0.5244181 |

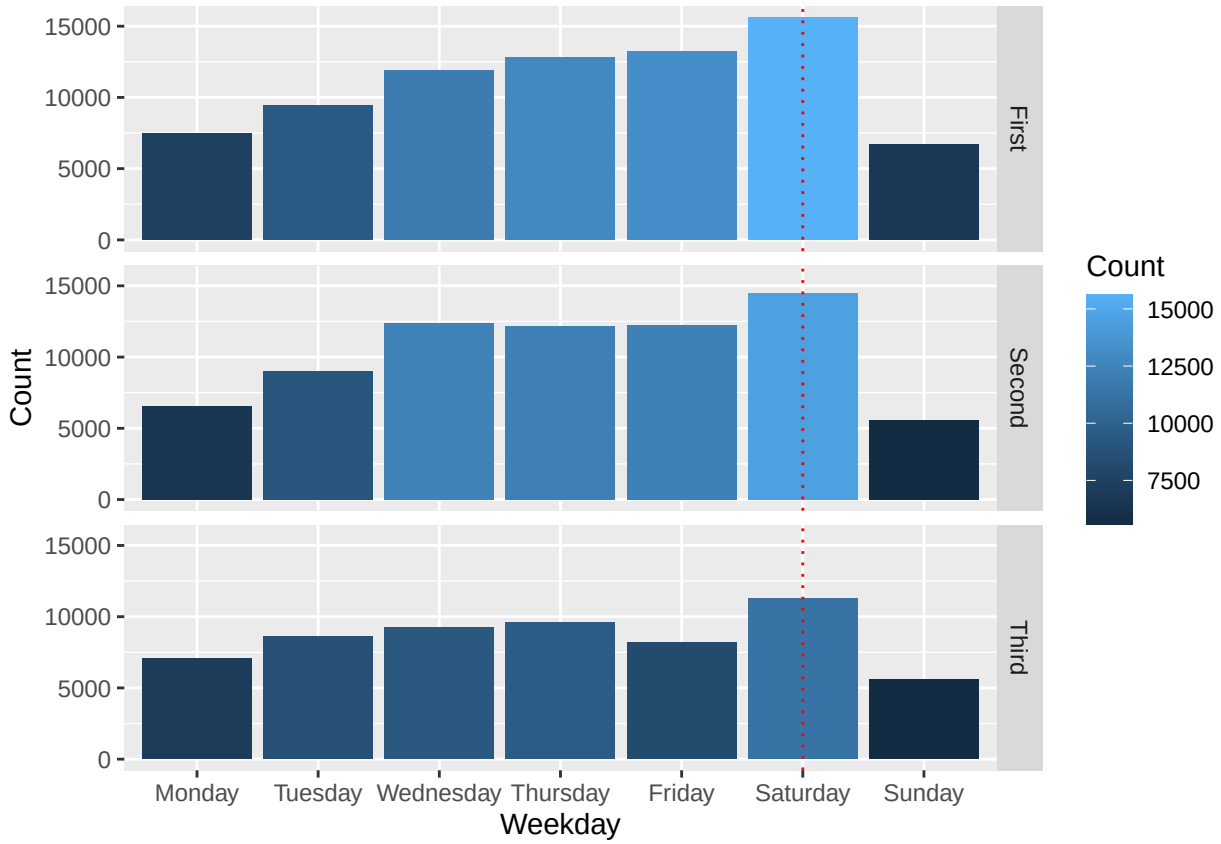
As we can see, the column “First” has a strong relationship with

- “Quarter”,
- “DayOfYear”,
- “Month”.

At the same time, the column “Second” doesn’t have strong relationships; but we can use the same columns.

**4.1.4.3 Question 2** As you remember, I have a question. When do people prefer to get a jab: weekdays or weekends/Saturdays or Sundays? It may be helpful to choose the right features.

Let's answer.




So, most of South West's people prefer to get a jab on Saturdays. That is not illogical because, for example, for me, the side effects go away during the weekend.

**4.1.4.4 Missing values** As we already saw in the previous chapter 3.1, the column "Third" has missing values, but we can replace them with zeroes. Do we have the dates when nobody got the jab?

Calculate a count of dates in the dataset.

```
## 415
```

Calculate a count of dates between maximum and minimum dates.

```
## 415
```

There are no missing dates.

So, we have finished the dataset exploring. The next steps are about the models.

#### 4.1.5 Splitting sets, training a Machine Learning Model and Evaluating performance

**Define necessary variables**

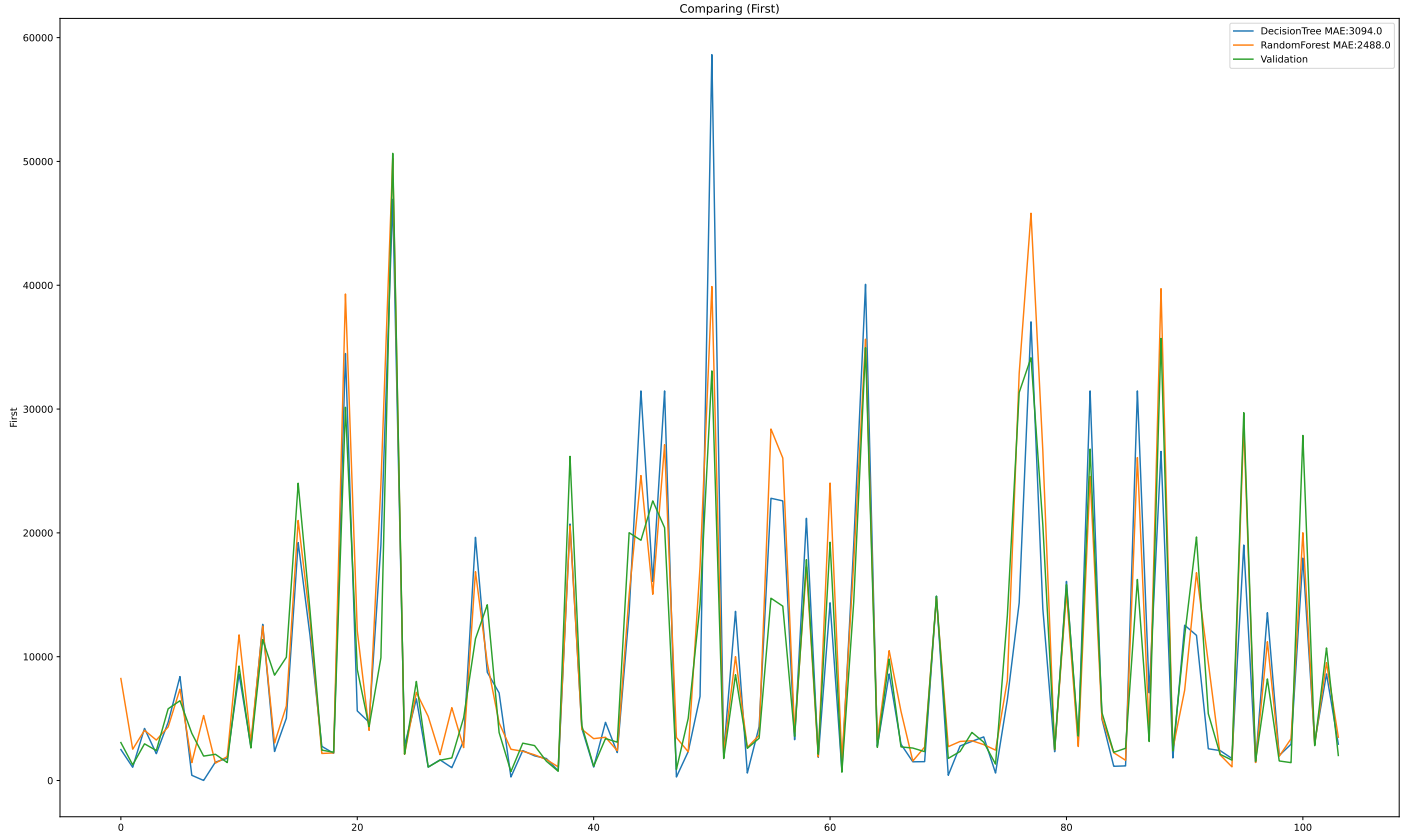
First of all, I will use all columns that I have.

| |
|---|
| Year |
| Month |
| Day |
| DayOfYear |
| Weekday |
| Quarter |
| IsMonthStart |
| IsMonthEnd |

**Prepare sets and train models using parameters.**

The first column that I will predict is “First”.

Finally, look at the result.

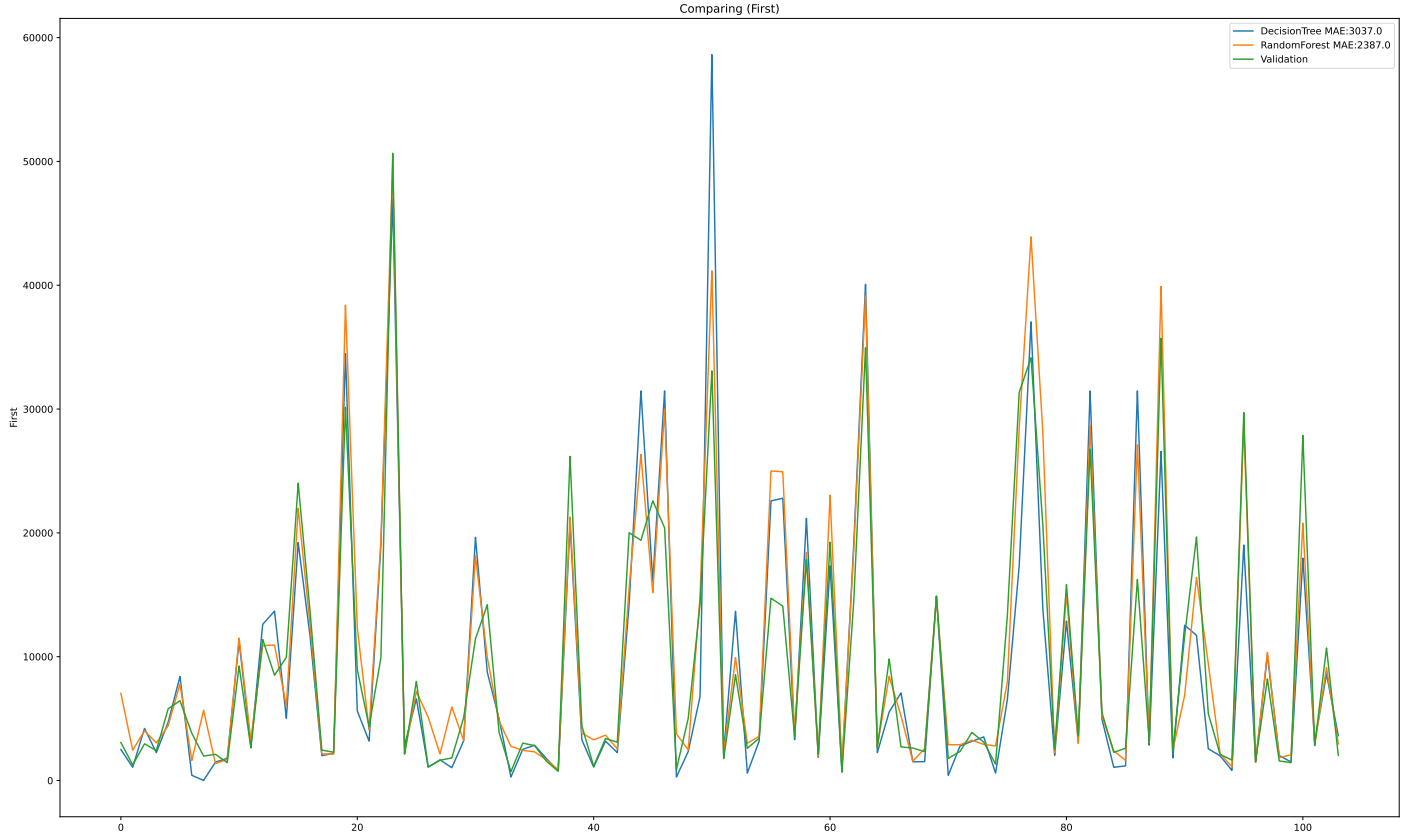



In my opinion, the result is good.

- The waves were recognized.
- The extreme values are bigger than in real data.

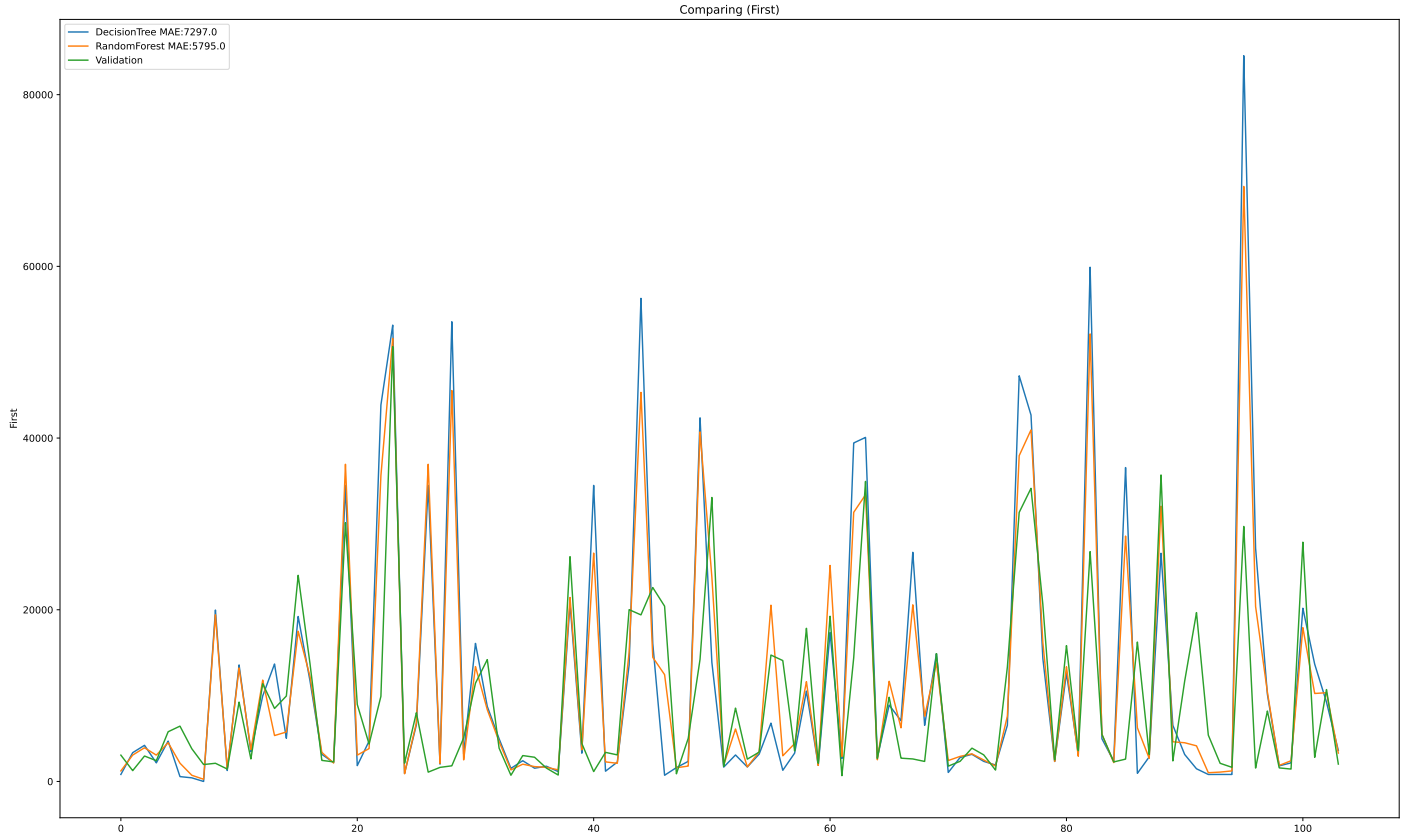
Let's work with the columns that I chose during the dataset exploring.

- "Weekday" that we discussed in this chapter influences the wave during the week.
- "Year" is the logical key because of the vaccination steps.
- DayOfYear was chosen because of the dependency on dates.




The result is better a little, but extreme values are disappointing.

Also, I suggest checking the model with columns that we discussed during the correlations search.




Not so good.

A combination of the following features give us the best result: Weekday, Year, DayOfYear.

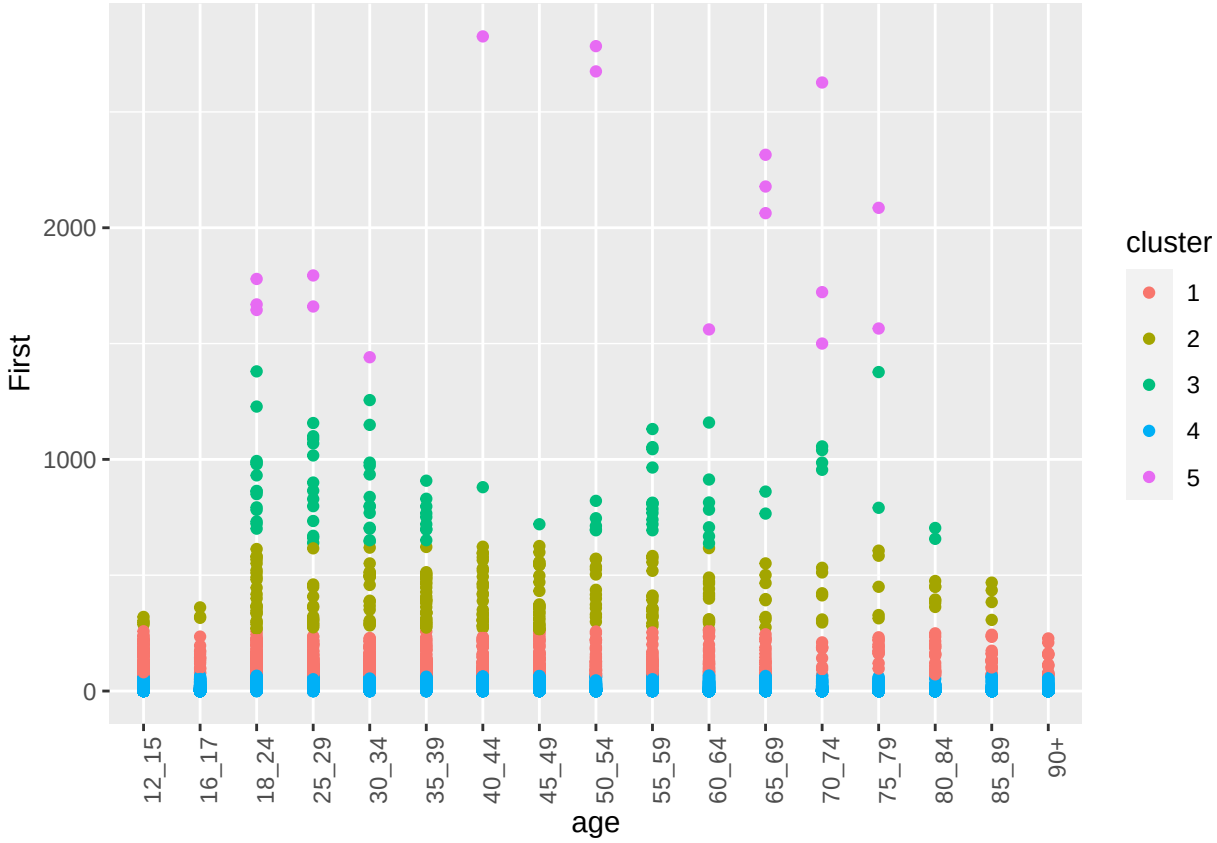
We can also look at the models for the Second and Third doses. But now I suggest moving on. Maybe in the future, I will find more fitting models.

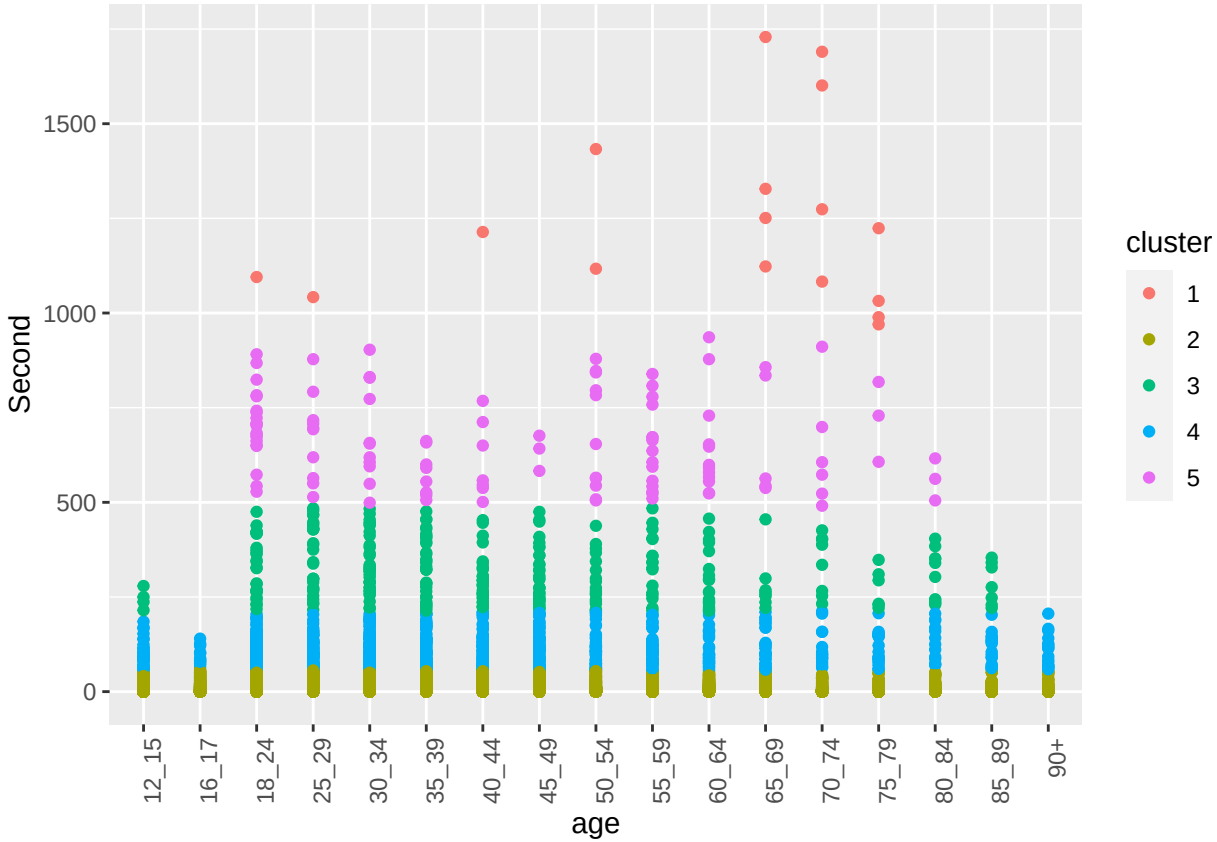
## 4.2 Bristol

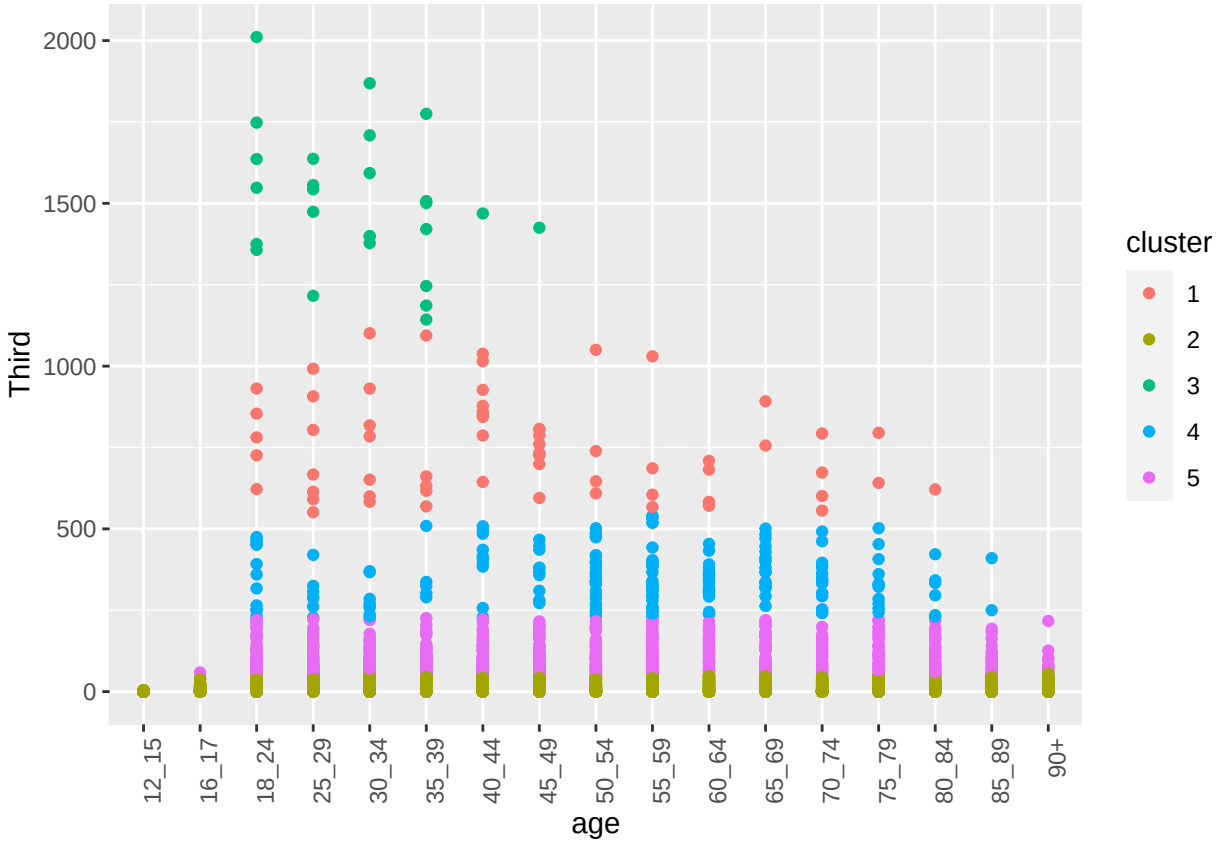
Add the column "Age" for the model using Ordinal Encoding and look at the dataset.

| age | date | First | Second | Third | Age |
|---|---|---|---|---|---|
| 12_15 | 2022-03-24 | 6 | 34 | 0 | 1 |
| 16_17 | 2022-03-24 | 0 | 7 | 23 | 2 |
| 18_24 | 2022-03-24 | 13 | 15 | 30 | 3 |
| 25_29 | 2022-03-24 | 3 | 11 | 14 | 4 |
| 30_34 | 2022-03-24 | 0 | 5 | 13 | 5 |
| 35_39 | 2022-03-24 | 1 | 3 | 7 | 6 |

I am going to use the k-means clustering model.




Second
1500
1000
500
0
12_15
16_17
18_24
25_29
30_34
35_39
40_44
45_49
50_54
55_59
60_64
65_69
70_74
75_79
80_84
85_89
90+
age
cluster
1
2
3
4
5



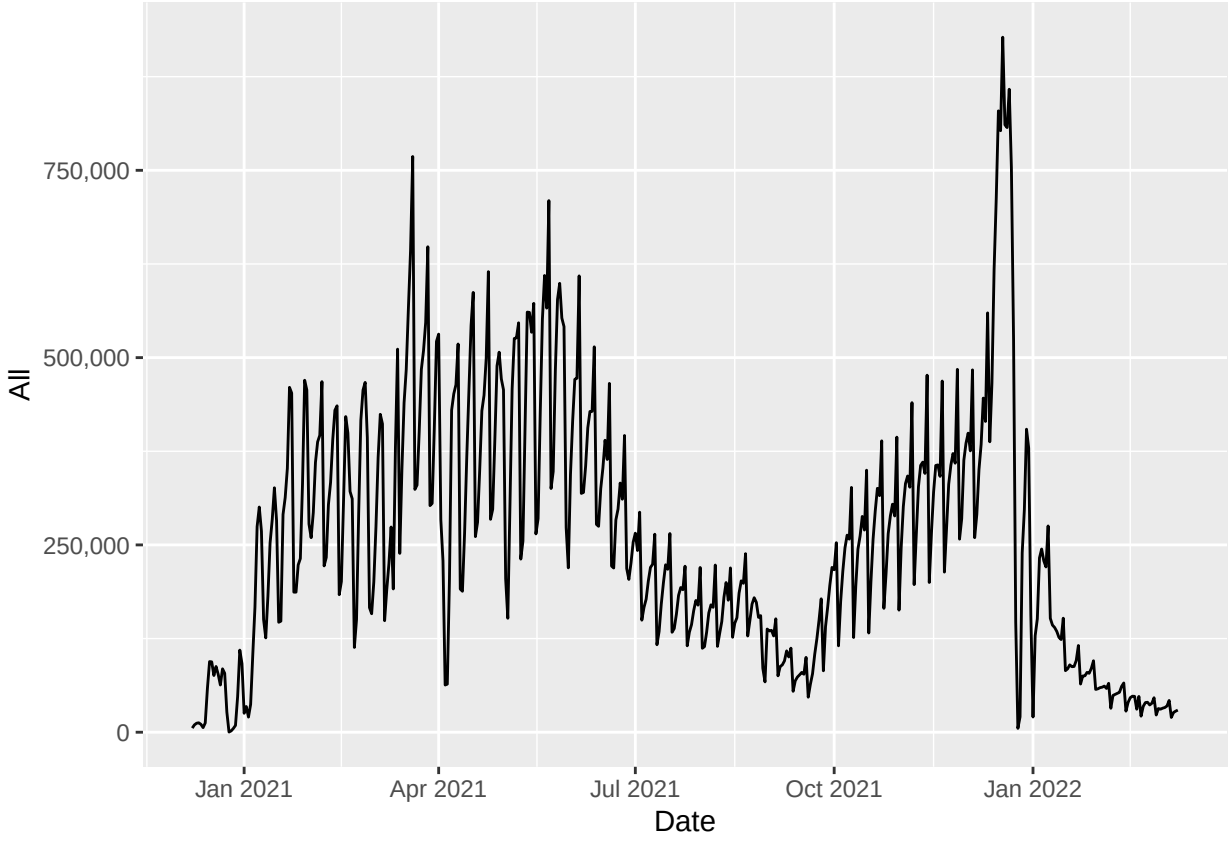

As we can see, sometimes a lot of people in the same age group got their jabs together. This fact may be useful for modeling.

## 4.3 England

Look at the dataset.

| | Date | First | Second | Third | All |
|---|---|---|---|---|---|
| 457 | 2020-12-08 | 5370 | 146 | 0 | 5516 |
| 456 | 2020-12-09 | 9648 | 137 | 2 | 9787 |
| 455 | 2020-12-10 | 11888 | 119 | 1 | 12008 |
| 454 | 2020-12-11 | 12516 | 82 | 1 | 12599 |
| 453 | 2020-12-12 | 10565 | 23 | 3 | 10591 |
| 452 | 2020-12-13 | 6134 | 30 | 0 | 6164 |

Look at the plot for the sum of doses counts.



What can we say?

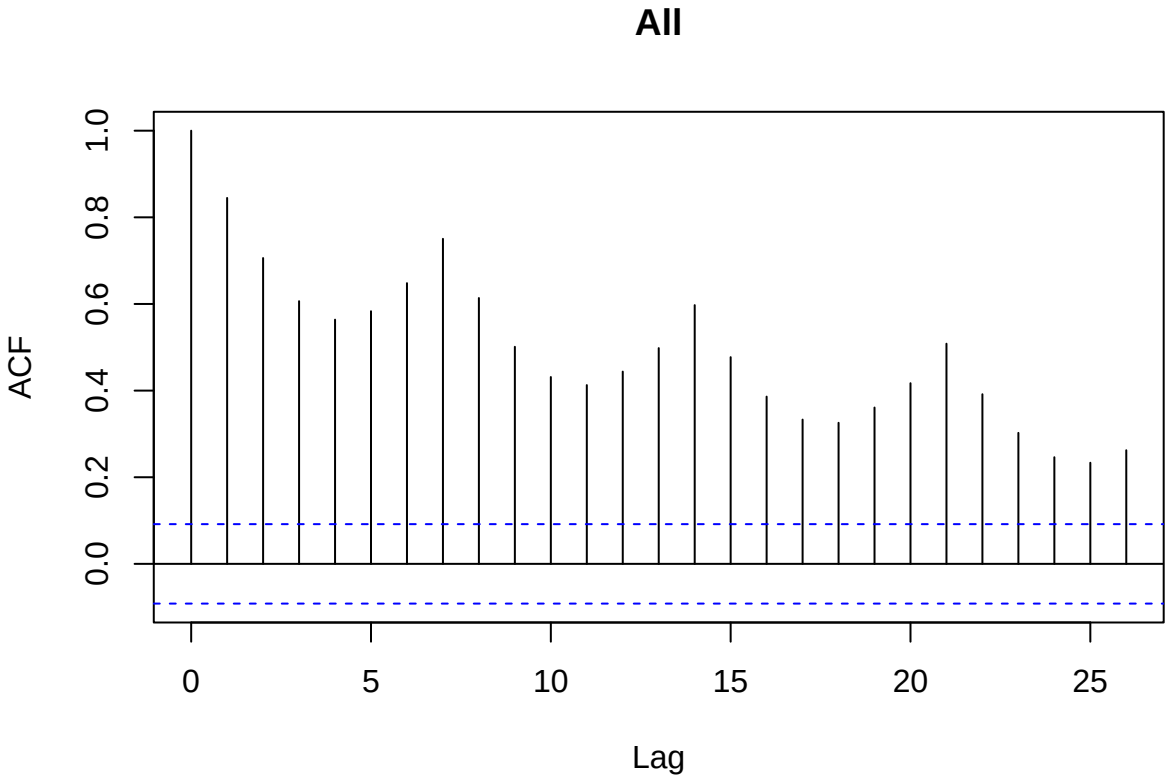
There is a not stationary time series, as the series wanders up and down for long periods.

I am going to use an ARIMA model.

ARIMA(5, 1, 3)

- 5 – is the order of Auto-regressive or linear model
- 1 – difference value to make the time series stationary from non-stationary.
- 3 – is the order of Moving Average/ number of lagged values

If the data is stationary, then d=0. So, I was right earlier.

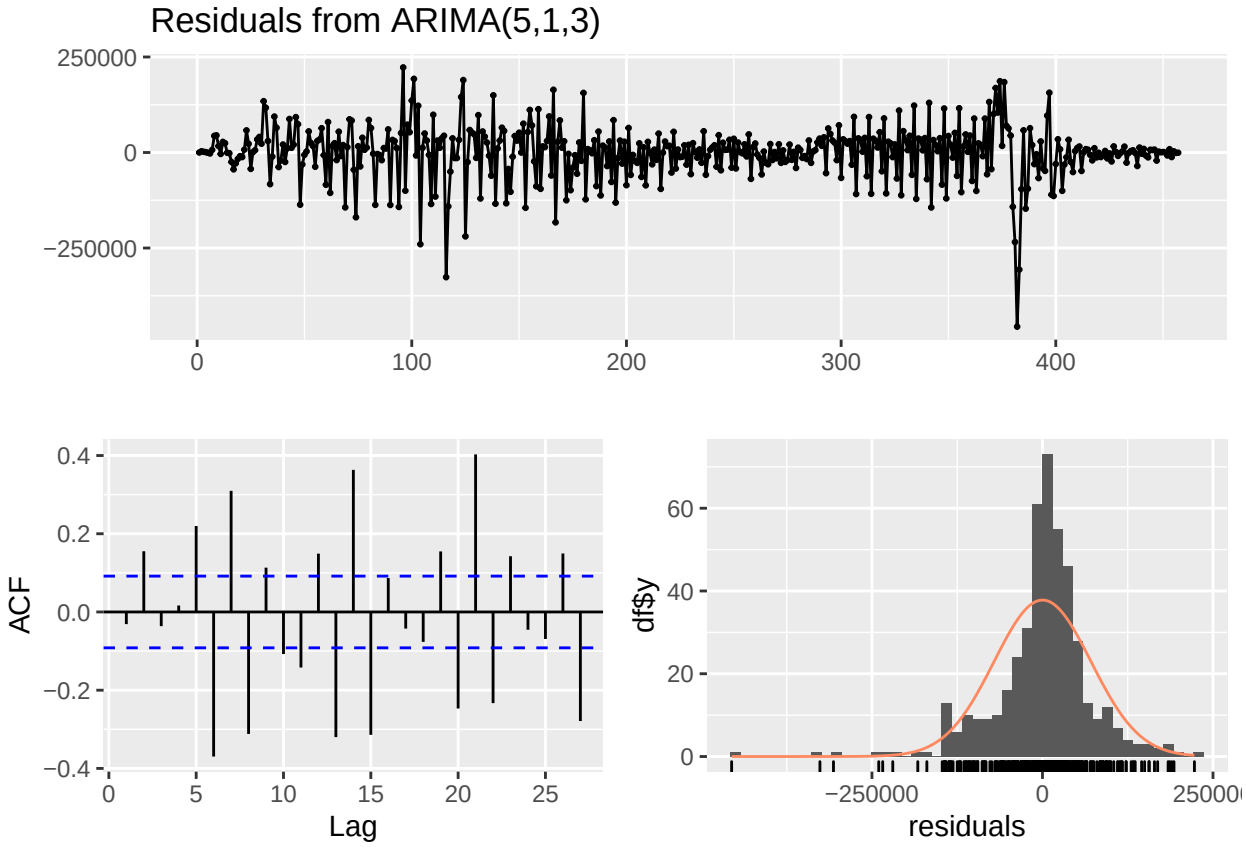



As we know, the autocorrelation function (ACF) assesses the correlation between observations in a time series for a set of lags. In an ACF plot, each bar represents the size and direction of the correlation. Bars that extend across the blue line are statistically significant.

So,

- this ACF plot indicates that these time series data are not random.
- the autocorrelations decline slowly.
- When a time series has both a trend and seasonality, the ACF plot displays a mixture of both effects. Notice how you can see the wavy correlations for the seasonal pattern and the slowly diminishing lags of a trend.

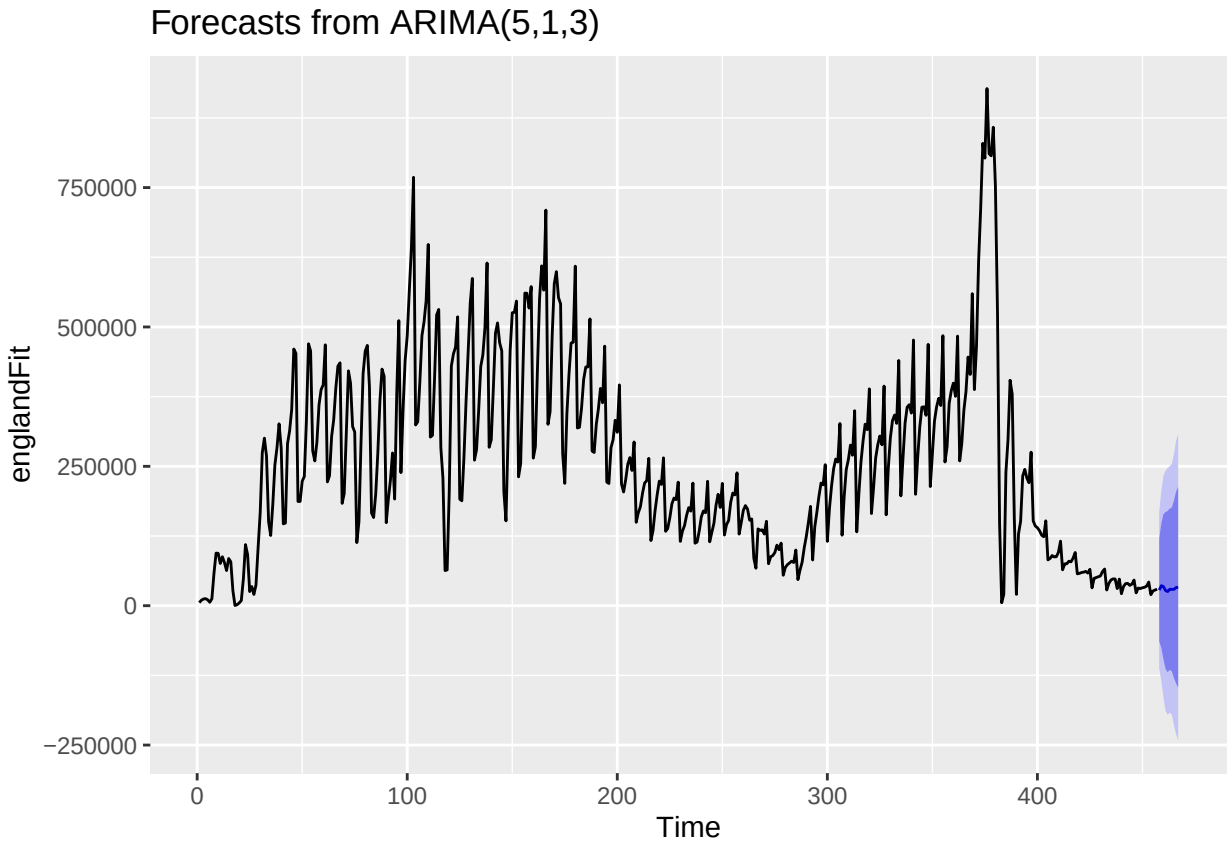
Look at the residuals that tell us a story about the model performance.




```
##
##  Ljung-Box test
```

```
##
## data:  Residuals from ARIMA(5,1,3)
## Q* = 209.31, df = 3, p-value < 2.2e-16
##
## Model df: 8.   Total lags used: 11
```

The first plot shows us that the difference between the observations and the corresponding fitted values is not fine.




I am not impressed because there are negative values. But I am sure that this may be corrected by using not auto.arima. What do I need to think about? Is how to explain to the model that the second dose is two months after the First, and the Third one is three or six months after the Second. Maybe I can find the explanatory variable for that.