The impact of "loose" restrictions in Sweden during the COVID-19 virus, compared to the neighbouring Scandinavian countries

Anie Kdlian

Lund University

1 Popular Summary

In Late 2019, a novel virus outbreak discovered in China. Soon this virus started to Spread to all over the world. This situation concerned the experts and soon a pandemic situation was declared by March-2020. Countries around the world tried to eliminate the risk of the pandemic by, partially following the World Health Organization's (WHO) recommendation and partially with performing some of their own policies. In northern Europe (in the Scandinavian region), a country called Sweden followed a different method when dealing with the pandemic situation. Many People called the Swedish approach as a "loose" method.

In this paper we had examined the Swedish approach, while comparing to some other Scandinavian countries; Denmark, Finland and Norway. During the period of time, from January-2020 until September-2022, has been highlighted four Covid-19 infection waves. The following figure illustrates the number of the new cases in the four Scandinavian countries; Denmark (red line), Finland (light blue line), Norway (dark blue line) and Sweden (yellow color line).
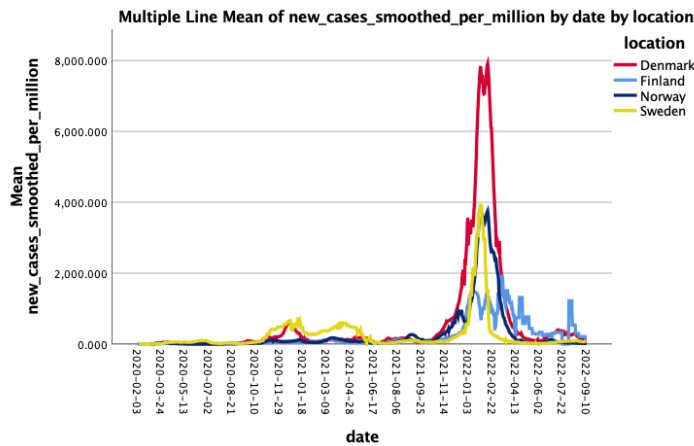

Figure 1: The Number of New Cases in the Scandinavian Countries

Data analysis was conducted on many Covid-related aspects, and obtained the following interesting results.

We can argue about the description of "loose" for restrictions in Sweden. As, according to the overall stringency in Sweden (by Summer-2022), it has been the highest total value in the Scandinavian region (illustrated in Figure (18). As the average of overall stringency is (41.9). While the lowest value of the average of overall stringency in Scandinavian region is in Finland (39.9).

Then, when comparing the total number of Covid cases in each of the four waves, within the Scandinavian countries. We observe that by 9_{th} of September-

2022, the total number of Covid cases in Sweden was less than the half of the total number of Covid cases in Denmark.

Further, we observe twelve different variants in Sweden. While, eleven variants were observed in both of the Scandinavian countries, Denmark and Norway. Yet, only ten variants were registered in Finland.

Moreover, the number of fully vaccinated people by 9_{th} of September-2022, is 73.21% of the total population in Sweden (is the lowest percentage in the Scandinavian region). While, 81.70% of the population is fully vaccinated in Denmark.

Then, the Excess mortality in Sweden was the highest when comparing to the other Scandinavian countries. Further, it is mainly increased during the beginning of the Covid-19 pandemic during year 2020.

Lastly, it is important refer to the differences in testing policies, which leads to some differences between the actual values and the visualized one.

2   Introduction

In December 2019, a novel coronavirus has been discovered in an outbreak within a city in China named Wuhan. There with, this coronavirus started to spread into all the different parts of our globe. By February-2020, this novel Corona virus type, was named as the $SARS - COV - 2$; Severe Acute Respiratory Syndrome Corona Virus 2, and the disease it causes called the $COVID - 19$ (World health organization, 2020)[31]. By mid of March-2020, this corona virus was already infected more than 118-thousand of people in 114 different countries. Therewith the World health organization announced a pandemic situation (World health organization, 2020) [34].

All Countries around the world, tried to minimize the risk of the virus in many different ways; partly by following the procedures recommended by the World Health Organization (WHO) and partly by performing their own methods that they believed to be best for their people and country. By that, many countries started taking some political actions in order to control the spread of the viral infection. Some Examples of the followed procedures are, closure of schools; closure of workplaces; public transport closure; public events cancellation; control the traveling accessibility for international and local flights; and also restrictions on public gathering and internal movements.

In the meanwhile, a country in northern Europe within the Scandinavian region, followed a different method. The Swedish health care, believed in the individual responsibility of the Swedish people and avoided the complete closure of the society.

Some people criticized and other praised the Swedish government's approach with the Covid-19 virus situation. In April 2020, a story in (FEE) Foundation for Economic Education (Jon Miltimore, 2020) [13], pointed to the anger against the Swedish method in the social networking service "Twitter" as :

> "Sweden is suddenly a punching bag on social media. What did the
> Swedes do to anger the Twittersphere?"

In May 2020,an article in The Guardian was been published about the Swedish model with title "Sweden's Covid-19 policy is a model for the right. It's also a deadly folly" [19].

In October 2020,an article in Science magazine called the Swedish policy as "Sweden's Gamble" [10].

The focus of this paper is to investigate the "loose" restrictions in Sweden, by comparing the stringency index of Sweden with some neighbouring countries in Scandinavian region, and assessing the outcomes of the Swedish approach in handling the Covid-19 situation compared to the neighbouring Scandinavians countries, like the number of Covid cases, the vaccination rate, the excess in the death numbers during the Covid-19 pandemic and others.

3 Background

3.1 The Scandinavian Region

In the early 18_{th} century, with the start of the joint championship movement between the Danish and the Swedish universities, a new word was arisen "Scandinavia". This word was specifically called after the territory of the championship place, which is "Skåne", the southernmost region of Sweden which is the closest Swedish province to Denmark. Geographically, Scandinavian countries are Denmark, Sweden and Norway. But Culturally, in addition to the three countries mentioned before there are three more countries Finland, Iceland and Faroe Islands.

Because of the strong connection between the Scandinavian countries; geographically and culturally (Wikipedia contributors,2022)[27].

Denmark, Finland and Norway were used as a referencing countries when analyzing the coronavirus situation and its impacts in Sweden.

3.2 The Covid-19 Virus and COVID-19 Variants

In China, a type of viral disease was discovered in the end of 2019 in a city called Wuhan. This Virus was characterized as a type of the Corona-viruses. The Corona viruses are RNA viruses, that attacks the respiratory tract in humans and causes infections within the respiratory tract [25].

By the start of the Year 2020, the Coronavirus has already started to spread into all the different parts of our globe. Soon after that it was already spreadout rapidly, causing brutal spread of disease-cases and even sometimes cause death. The SARS-CoV-2 variants were named by using the Greek alphabet letters;$\alpha, \beta, \delta, \gamma$, etc.

3.2.1 The variants of Covid "Variant of Concern"

Coronavirus has many different variants, as a result to the mutations in the virus. Some of the variants were considered as a variant of concern, as it had some significant impact on the viral-transmission, severity of infection and even sometimes causes weakness in body-immunity. Here are some of the variants of concern, that is categorized by The World Health Organization (European Centre for Disease Prevention and Control, updated 2022)[4], in a chronicle order of the documentation of the virus samples according to WHO (World Health Organization, 2022) [30].

- Beta Variant "B", May-2020, South Africa "Variant of Concern"

Beta variant was first discovered in South Africa in 2020, and was 50% more contagious than the original strain of coronavirus. This variant did concern the experts, because of its potency to evade the antibodies in the infected; therewith

it might lead to hospitalization and death (Katella, 2022) [15] .

- Alpha Variant "A", September-2020, United Kingdom "Variant of Concern"

Alpha variant was first discovered in Great Britain. This variant could transmit more faster, than the original Wuhan strain. The estimation of transmission is around 50% more than the original strain (Geddes, 2021) [16].

- Delta Variant "Δ", October-2020, India "Variant of Concern":

Delta variant was first detected in India, in October 2020 (WHO-Tracking SARS-CoV-2 variants, 2022) [31], and was categorized as a variant of concern. Delta believed to be more than twice as contagious as the other variants before. Delta is the dominant coronavirus in the infection until Omicron took place (Katella, 2022) [14].

- Gamma Variant "Γ", Nov-2020, Brazil "Variant of Concern"

Gamma variant was first discovered in a city named Manaus, in the states of Amazonas, in Brazil. This variant was more like the other two variances of concern Alpha and Beta, in the strong transmission force that lead into a global spreading of this variant of the COVID-19 virus (Global Virus Network, 2021) [9].

- Omicron variant "O", Nov-2021, South Africa "Variant of Concern":

Omicron variant was first reported in South Africa, in November 2021. This Variant is categorized as a variant of concern, as it had some unusual behaviour when comparing to the other variants. The large number of mutations, gives this variant a growth advantage that might consequently, increase the reinfection risk with this variant. Besides, the concern over the PCR test failure with a probability of one-third (World Health Organization, 2021) [32]. This makes it sometimes even harder to detect the infection and to prevent the spread of the virus.

3.3   The prevention methods

The World Health Organization recommends the following procedures, as a method of prevention on an individual level and also as a prevention for the spread of the virus (World Health Organization, 2022) [28]

3.3.1   Personal responsibility

Each individual is expected to:

- Keep a one-meter distance from the others,try to meet outdoors if possible, if this is not possible then try to have an open window.

- Avoid the three-C's, which are; closed spaces; crowded places and close contact.

- Wear a proper mask in crowded or poorly ventilated places.

- Cover both mouth and noise when sneezing, dispose any used tissues, and clean the hands.

- Keep good hygiene, clean regularly the hands with hand disinfection gel, or wash with soap and water.

- Clean and disinfect all the surfaces you regularly touch.

- In case of having some of the Covid-19 symptoms, avoid contact with other people and stay home for 10 days from the first symptom and until fully recovery. Besides, in case of heavy symptoms, seek medical help by first calling your local health center.

- Follow the country's vaccination guidelines.

- Keep yourself updated to the latest information and rules that concern the Covid-19 infection.

3.3.2   Wearing Proper Masks

Wearing the masks in a proper way means the following:
- The mask covers all the three areas on lower-face, nose, mouth and chin.
- Clean the hands whenever touching the mask, before wearing the mask,and even after taking off the mask.
- Store the mask in a plastic bag and wash the fabric bags after using it and throw the used medical mask in trash.
- Do not use masks with exhalation valves, as there is a risk of escaping the unfiltered breath out of mask.

3.4   The COVID-19 Vaccination Types

The following nine COVID-19 Vaccines have received WHO EUL approval by September 2022 (WHO, 2022) [33]
- Pfizer-BioNTech, approved on 31st December 2020.
- AstraZeneca, approved on 15th of February 2021.
- Janssen "Johnson and Johnson", approved on 12th of March 2021.
- Moderna-NIAID, approved on 30th of April 2021.
- Sinopharm BIBP, approved on 7th of May 2021.
- Sinovac-CoronaVac, approved on 1st of June 2021.
- Covaxin BBV152, approved on 3rd of November 2021.
- Covovax, approved on 17th of December 2021.
- Novavax - NVX-CoV2373/Nuvaxovid, approved on 20th of December 2021.

In the European Union only six of the vaccines above has been authorized by September 2022 to be used in EU, according to European Commission about vaccination information(European Commission, 2022) [5]

- Comirnaty (BioNTech and Pfizer)
- COVID-19 Vaccine Valneva
- Nuvaxovid (Novavax)
- Spikevax (Moderna)
- Vaxzevria (AstraZeneca)
- Jcovden (Janssen)

3.4.1 Pfizer-BioNTech Vaccine

Pfizer-BioNTech is an mRNA vaccine type. Vaccines of mRNA types, are considered safe and does not cause illness, because they don't use any live virus and does not make any change in our DNA (Centers for Disease Control and Prevention, 2022) [2].

3.4.2 Moderna COVID-19 vaccine

Moderna COVID-19 vaccine is an mRNA vaccine type. Just like the Pfizer vaccine, the messenger RNA (mRNA) vaccines, does not make any harm because it does not use any live virus. It triggers the immunity system by showing the spike protein on their surface, so the immunity system releases the antibodies to fight the "fake infection" (Centers for Disease Control and Prevention, 2022) [2].

3.4.3 Novavax COVID-19 vaccine

Novavax COVID-19 vaccine is a protine subunit vaccine.

3.4.4 Johnson Johnson's Janssen Vaccine (JJ/Janssen)

Johnson Johnson's Janssen Vaccine (JJ/Janssen) is a viral vector vaccine.

3.4.5 COVID-19 Vaccine Valneva

"The Valneva vaccine is a purified, inactivated, and adjuvanted whole virus SARS-CoV-2 vaccine." (WHO, 2022) [29]. This Vaccine has been proved to be effective on the individuals between 18 to 50 years old.

3.4.6 AstraZeneca vaccine- Vaxzevria

"Vaxzevria is made up of another virus (of the adenovirus family) that has been modified to contain the gene for making a protein from SARS-CoV-2, the virus that causes COVID-19." (European Medicines Agency, 2022) [6]

4 Data

About the data sources used in this paper. Three different sources for data-sets were used in the presented analysis.

4.1 Our World in Data data-set

Most of Covid related data is from the Our World in Data is a major source for most of the analysis.

Our world in Data is a project of a non-profit organization called Global Change Data Lab. The website is a result of a collaboration between the non-profit organization mentioned above with some of the scientific researchers of the Oxford university. The content of the website, is contributed by some of the scientific researchers of the oxford university. While the technical side of this website, such as publishing and maintaining all the tools and contents of the website is held by the non profit-organization Global Change Data Lab.

- The data source: Our World in Data (OWID)
- Data: Covid-19 data-set
- Geographical coverage: The four Nordic countries; Denmark, Finland, Norway, Sweden. Note that: The original data includes more countries, but only the above mentioned countries were chosen for the analytical purpose of this paper.
- Time span: between January-29-2020 and September-9-2022.
- Available at:(complete COVID-19 data-set is a collection of the COVID-19 data maintained by Our World in Data. It is updated daily and includes data on confirmed cases, deaths, hospitalizations, and testing.)
  https://github.com/owid/covid-19-data/tree/master/public/data
- Last modified: September-11-2022 (as it was uploaded from OWID dataset on 11_{th} of September 2022)
- Published by: "COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University. A raw data on confirmed cases and deaths for all countries is sourced from the COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University. complete COVID-19 data set is a collection of the COVID-19 data maintained by Our World in Data. It is updated daily and includes data on confirmed cases, deaths, hospitalizations, and testing."

4.1.1 Description of Some of the Used Variables in the Analysis

We used some of the 65 attributes in our analysis. Particularly, the location attribute as the he four Scandinavian countries; Denmark, Finland, Sweden and Norway.

Description of some of the variables that have been used in this paper's Analysis.

New Cases:

This indicates the daily cases of the reported number of newly Covid infected individuals, that has been registered within a particular day. Undoubtedly, there are some points that needs to be considered while dealing with the values. First, some cases might be not registered. Second, the registration process might vary, from a day to another. For example, during the weekends and holidays registration of the new cases might not been completed, and therefore the registration might be done afterwards.

New cases smoothed:

This indicates the mean of the new cases within the last week; seven days including the date of the indicated day. By using this value, we can have a better estimation for the new cases as it minimizes the error caused by the different measure significance from a day to another.

$$X_{N_{smoothed}} = \frac{\sum_{i=0}^{6} X_{N-i}}{7}$$

; as X_{N-i} is the number of the registered Covid new cases in a certain day $(N - i)$.

New cases smoothed per million:

The number of New cases is considered in proportion to the population number. When comparing the countries we need a normalized measure. Therefore we use the smoothed number per million people.

Stringency index:

This index is a measure of range from zero to hundred, as zero indicates no stringency at all, and hundred indicate the strictest. This stringency indicator is a composition of nine factors, which are the following. "school closures; workplace closures; cancellation of public events; restrictions on public gatherings; closures of public transport; stay-at-home requirements; public information campaigns; restrictions on internal movements; and international travel controls".

Excess mortality:

Excess mortality is an important measure in public health and epidemiology. As it is a measure of the difference between the estimated number of deaths and reported deaths.

Excess deaths = Reported deaths - Expected deaths

As the estimation of the number of deaths or what called "Expected deaths" in the formula above, has been calculated using Karlinsky and Kobak (2021) [1] As this model captures the seasonal variation and the trends that varies year to year trends.

The fitting regression model is calculated for each country by using the formula:

$$D_{t,Y} = \alpha_t + \beta.Y + \epsilon \; ;$$
$D_{t,Y}$: is the number of death observed in a period of time t (year or month) in the year Y

α_t is a fixed intercept for each period t

β is the linear slope across years

ϵ is a Gaussian noise $\epsilon \;\; N(0, \sigma^2)$.

New Deaths: The number of the new confirmed $COVID-19$ deaths, which is reported by a country on a certain day. Sometimes one certain day has a higher number of deaths, this might be because of the reporting didn't happen the day before; for example it was a Holiday.

New Deaths Smoothed:

As the reporting of the daily number of deaths might vary significantly, therefore a weekly average of the number of new Covid related cases.

Total Number of Deaths:

This indicates the cumulative sum of the daily number of deaths until the day α is Y_α

$$Y_\alpha = \sum_{i=0}^{\alpha-1} X_{\alpha-i}$$
;given $X_{\alpha-1}$ indicates the number of deaths on day $\alpha - 1$.

4.2   GISAID Data set of Variants

GISAID, or what is also known as "GISAID EpiFlu database", is a platform and a database for the influenza viruses and the Data of Coronavirus that causes COVID-19. GISAID is admistrated by German medical non-profit organization or what called Freunde von GISAID e.V., which is an organization that is oriented exclusively towards charity, science, and education purpose.

- The data source: GISAID database.

- Data: Covid variants counts.

- Geographical coverage: The four Nordic countries; Denmark, Finland, Norway, Sweden.
    Note that: The original data includes more countries, but only the above mentioned countries were chosen for the analytical purpose of this paper.

- Time span: between October-11-2020 to September-11-2022.

- The variables: A total of 12 variants with their mutations has been observed in the four Scandinavian countries; Denmark, Finland, Norway and Sweden .

4.2.1 The variants of Covid-19 that were detected in the Scandinavian Region

The variants of COVID that has been observed and recorded according to our data, between October-11-2020 and September-11-2022, are a total of 12 different variants. Five of the variants that were observed in the four Scandinavian countries; Denmark,Finland, Norway and Sweden, were labeled as a variant of concern. The variants that were been observed in the four Scandinavian countries are the following.

- **Omicron variant "O"; Variant of Concern**.
- **Delta Variant "Δ"; Variant of Concern**.
- **Alpha variant "A"; Variant of Concern**.
- **Beta variant "B"; Variant of Concern**.
- **Gamma variant "γ"; Variant of Concern**.
- **Epsilon variant "E"; Variant of Interest**.
- **Zeta variant "Z"; Variant of Interest**.
- **Eta variant "H"; Variant of Interest**.
- **Theta variant "Θ"; Variant of Interest**.
- **Iota variant "I"; Variant of Interest** .
- **Kappa variant "K"; Variant of Interest**.
- **Lambda variant "Λ"; Variant of Interest**.

4.2.2 The connection between the variants

In order to understand the variants of Covid-19 and their connections, The figure(2), describes the connection between the clades of SARS-COV-2. (Emma Hodcroft, 2022) [3].

Here comes a list of the Nextstrain clade with its corresponding WHO label, followed by Nextstrain clades figure.

Nexstrain Clade $\Longleftrightarrow$ WHO Label

$$20\text{I(Alpha, v1)} \Longleftrightarrow (\alpha)Alpha$$
$$20\text{H(Beta, v2)} \Longleftrightarrow (\beta)Beta$$
$$20\text{J(Gamma, 3)} \Longleftrightarrow (\gamma)Gamma$$
$$21\text{A(Delta)} \Longleftrightarrow (\delta)Delta$$
$$21\text{I(Delta)} \Longleftrightarrow (\delta)Delta$$
$$21\text{J(Delta)} \Longleftrightarrow (\delta)Delta$$
$$21\text{B(Kappa)} \Longleftrightarrow (\kappa)Kappa$$
$$21\text{C(Epsilon)} \Longleftrightarrow (\epsilon)Epsilon$$
$$21\text{D(Eta)} \Longleftrightarrow (\eta)Eta$$
$$21\text{F(Iota)} \Longleftrightarrow (\iota)Iota$$
$$21\text{G(Lambda)} \Longleftrightarrow (\lambda)Lambda$$
$$21\text{H(MU)} \Longleftrightarrow (\mu)MU$$

$$21K \text{ (Omicron)} \iff (o)Omicron$$
$$21L \text{ (Omicron)} \iff (o)Omicron$$
$$22A \text{ (Omicron)} \iff (o)Omicron$$
$$22B \text{ (Omicron)} \iff (o)Omicron$$
$$22C \text{ (Omicron)} \iff ((o)Omicron$$
$$22D \text{ (Omicron)} \iff (o)Omicron$$
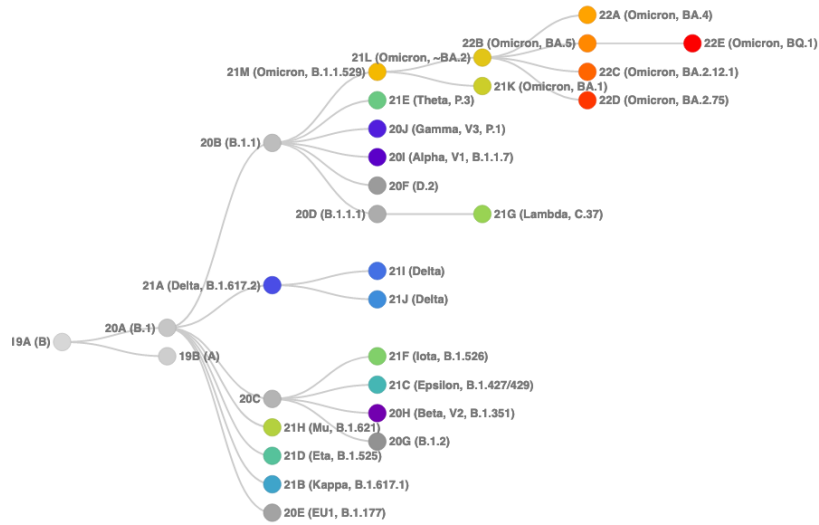$$22E \text{ (Omicron)} \iff (o)Omicron$$

Figure 2: "Phylogenetic relationships of Nextstrain SARS-CoV-2 clades". This figure credits are to "NextStrain.org"

4.3 Eurostat number of death data-set

To understand the excess death caused during the Covid-19 pandemic situation, we try first to visualize the long term pattern for the number of crude deaths before Covid and during some period of Covid. Therefore, we visualize the data for the number of deaths, from 2010 until 2021.

The data for the number of death and the the number of crude death rate in European countries, is downloaded from Eurostat website. Eurostat is the statistical office of the European Union, and here comes some facts about the data set we used.

- Data source: Eurostat.

- Geographical coverage: Denmark, Finland, Norway and Sweden.

- Time span: between 2010 and 2021.

- Frequency: yearly value.

- $https://ec.europa.eu/eurostat/databrowser/view/TPS00029/default/table?lang = encategory = demo.demo_ind$

-Available variables: "Death number" and the "Crude death rate per thousand person".

Death number: is the number of the registered deaths within a year in a certain country.

Crude death rate per thousand person: is the ratio of the number of the deaths registered during a year to the average number of the population during that same year. we have the value expressed per thousand people.

5 Method

5.1 The Graphical Analysis Tool

The Analysis was conducted using the SPSS tools; Statistical Product and Service Solutions tools.

5.2 The Major Waves of Coronavirus

The total time span of the used data, is from January-2020 until start of September-2022. But, to be able to detect the patterns, we try to isolate the active periods of time, to extract some patterns and indicators. Therefore we divide the total period into the four waves of infection in each country. It should be noted that each Covid infection wave start and duration varies somewhat between the four Scandinavian countries.

Here comes more specification about the four waves in the four countries.

5.2.1 First wave of Covid-19

We notice that the first case is Scandinavia starts in Finland. There after almost a month a Covid case appears in Denmark, then after three days Covid starts in Sweden, and almost a week after the infection starts in Norway.

The first wave dates are specified from articles and papers regarding the first wave in each one of the countries.

Not only the start date for the first wave is different in each of the Scandinavian countries, but also the length of the first wave is different among them. As Sweden has the longest duration of the first wave;almost six months, while Norway has shortest duration of the first wave; i.e the half of Sweden's wave duration.

Here are the estimated dates for COVID-19 infections first wave in the Scandinavian countries.

Denmark: 27-February-2020 until 08-July-2020 (BMC Infectious disease, 2021) [12]

Finland: 29-January-2020 until 30-June-2020 (Pia Polsa, Petteri Repo and University He, 2022) [21]

Norway: 09-March-2020 until 23-June-2020 (Tidsskr Nor Legeforen, 2022) [17]

Sweden: 01-March-2020 until 31-August-2020 (Covid-19-pandemin i Sverige, 2022) [26]

5.2.2 Second Wave of Covid-19

The second wave dates in each of the Scandinavian countries, are defined partially by using dates from some published papers and others by estimating from the daily numbers of Covid cases in the data.

Denmark: 02-September-2020 until 15-February-2021.

Finland : 20-September-2020 until 08-January-2021 (Birgitte Kjos Fonn and Nathalie Hyde-Clarke, 2021) [8].

Norway : 21-September-2020 until 28-February-2021 (Tidsskr Nor Legeforen, 2022) [17].

Sweden: 01-September-2020 until 31-January-2021 (Covid-19-pandemin i Sverige, 2022) [26]

5.2.3 Third Wave of Covid-19

The dates of the third wave has been estimated from the data, besides some dated mentioned in some published articles regarding the third wave.

Denmark: 16-February-2021 until 24-June-2021

Finland: 16-February-2021 until 30-April-2021

Norway: 01-March-2021 until 28-June-2021 (Tidsskr Nor Legeforen, 2022) [17].

Sweden: 01-February-2021 until 10-June-2021 (Covid-19-pandemin i Sverige, 2022) [26]

5.2.4 Fourth Wave of Covid-19

The dates of Sweden were declared in a statistical paper that the Swedish public health published in 2022 regarding the fourth wave and as for the other countries the estimation was made from the available data.

Denmark: 01-November-2021 until 30-April-2022

Finland: 01-November-2021 until 30-May-2022

Norway:01-November-2021 until 30-April-2022

Sweden: 22-November-2021 until 10-April-2022 (Folkhälsomyndigheten, 2022) [7].

5.3 Time Series Analysis

In order to find the similarities and differences between the four Scandinavian countries in the number of deaths. We will create time series for the differences.

Time series of first order differences between the numbers of deaths has been created, and then the method repeated again to have time series for points of the second order differences, which has a period of four weeks. This method will eliminate all the external factors that might effect our curve, in order to see if there is any similar behavior between the countries.

Thus, we will define the Covid infection wave with its corresponding Time series that we created, to examine if there is a correlation between the number of Covid-cases and the number of deaths. Also, we will examine the oscillation of the waves in each country, to define the countries with similar patterns.

6 Analysis

This paper's main concern is to understand the overall situation of Covid-19 in Sweden compared to the neighbour countries in the Scandinavian region; Denmark; Finland; and Norway. We will analyze the data and define the similarities and differences in the Covid-19 related responses in the four countries of the Scandinavian region. Besides, we will examine the levels of restrictions that were followed in each of the four Scandinavian countries mentioned above.

Corona-type viruses are a seasonal viruses, therefore to understand the impact of the disease in a better way, we will analyze by defining and isolating the periods/seasons with a high number of infections.

These Covid-19 infection seasons are called the waves; as it looks like a wave that increases until it gets to a peak then it decreases again.

We divide the total time span of the Covid-19 infection between the years 2020 and until the 10_{th} of September-10 of 2022, check in the "Appendix of Graphs" in this paper, figure (23), into four waves of Covid infections.

The dates of the waves are defined according to two different criteria. Firstly, some Covid related published papers about the waves in the countries. Secondly, from visualizing the data of the daily Covid cases of infection. These are more specified in the "Method" part of this paper.

It is also important to understand that there might be some actual cases that were not recorded, and therewith, some loss in the actual data is possible. Besides, different Covid-19 testing policies were followed in the different countries. Therefore using some normalized values will give us a better estimation and will reduces the error factor, hence smoother estimation to our data.

In the following subsections of this part we will analyze some of the aspects of Covid in the countries; Denmark, Finland, Norway and Sweden.

Note that: Due to some differences in testing policies, there might be some differences between the real (actual) values and the values in the Analysis.

6.1 The Total Number of Daily COVID-19 Cases

The daily cases of Covid-19 were reported on daily and semi-daily bases. For example, no reporting was done on weekends and holidays. Besides, the reporting style differ a bit between the countries. As the actual number of infected individuals are much higher than the number of the recorded infection cases. Therefore, with the more number of testing, we get a bigger sample of data and a more unbiased data.

This can be easily seen from figure(3), as the number of tests per case in Sweden is the lowest in the Scandinavian region.
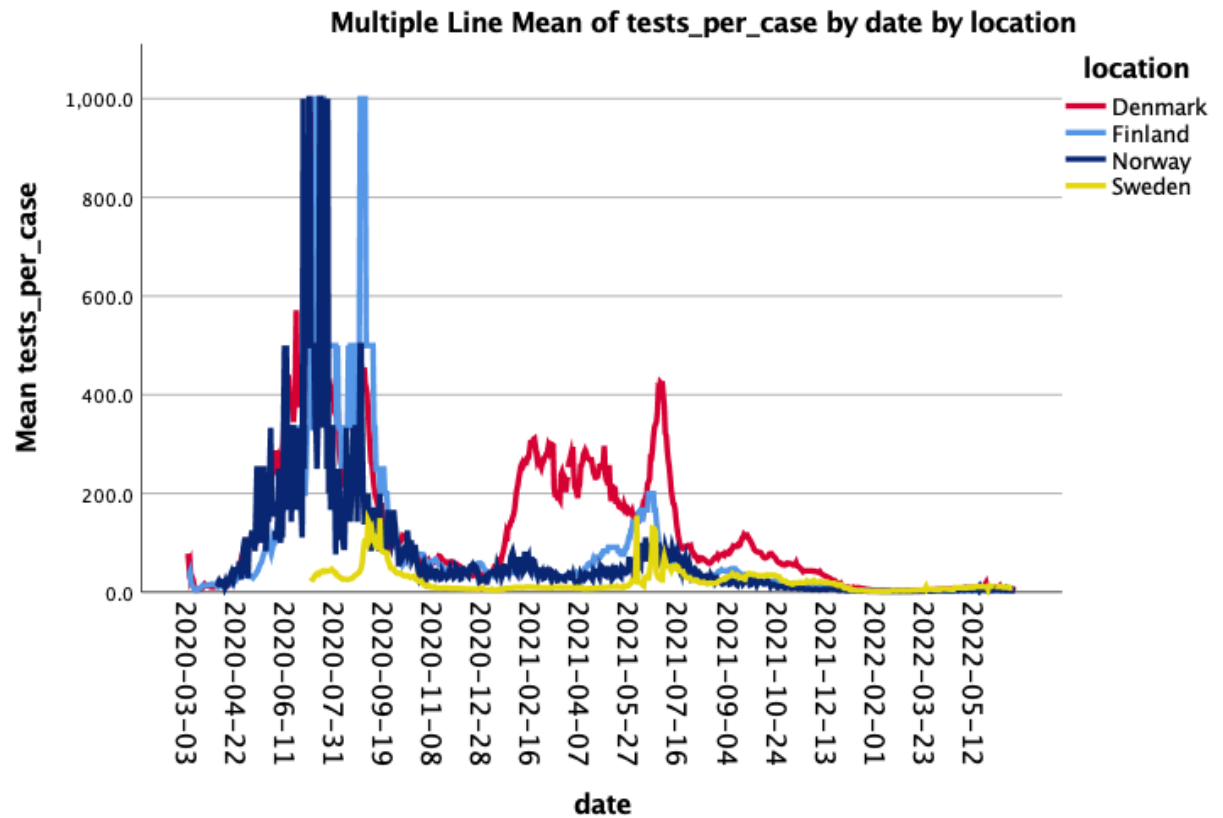
Figure 3: The number of tests that were done per Covid Case

According to OWID data-set, the number of the total registered Covid cases per million people, from January-2020 until the beginning of September-2022, as in figure (4), is the highest in Denmark, as the registered number of the cases of Covid infection by end of August-2022, is 560 000 cases per million people. The second highest infection of Covid is registered in Norway, a total of roughly 270 000 cases of Covid-infection per million people. Then comes the total number of Covid-infection in Sweden of almost 245 000 infections per million people. While Finland had the lowest number of total Covid registered cases in the four Scandinavian countries, which is roughly about 230 000 cases per million.
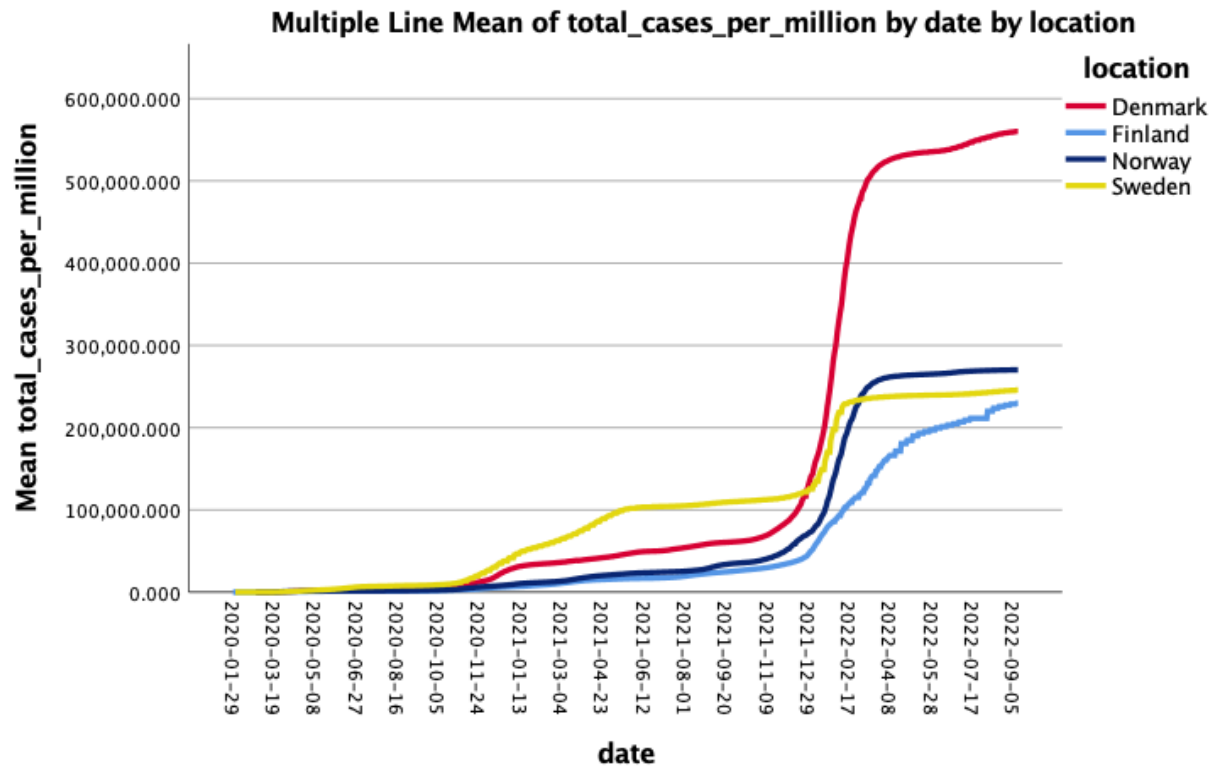
Figure 4: The number of total cases from January-2020 to 10-September-2022, in the Scandinavian Countries

In the following parts we will analyze the daily infection cases per million people of Covid-19 that was registered during each wave of the total four waves.

6.1.1 Covid New Cases in the First Wave

The number of daily Covid cases during the first wave is visualized in the following figure (6, 5).
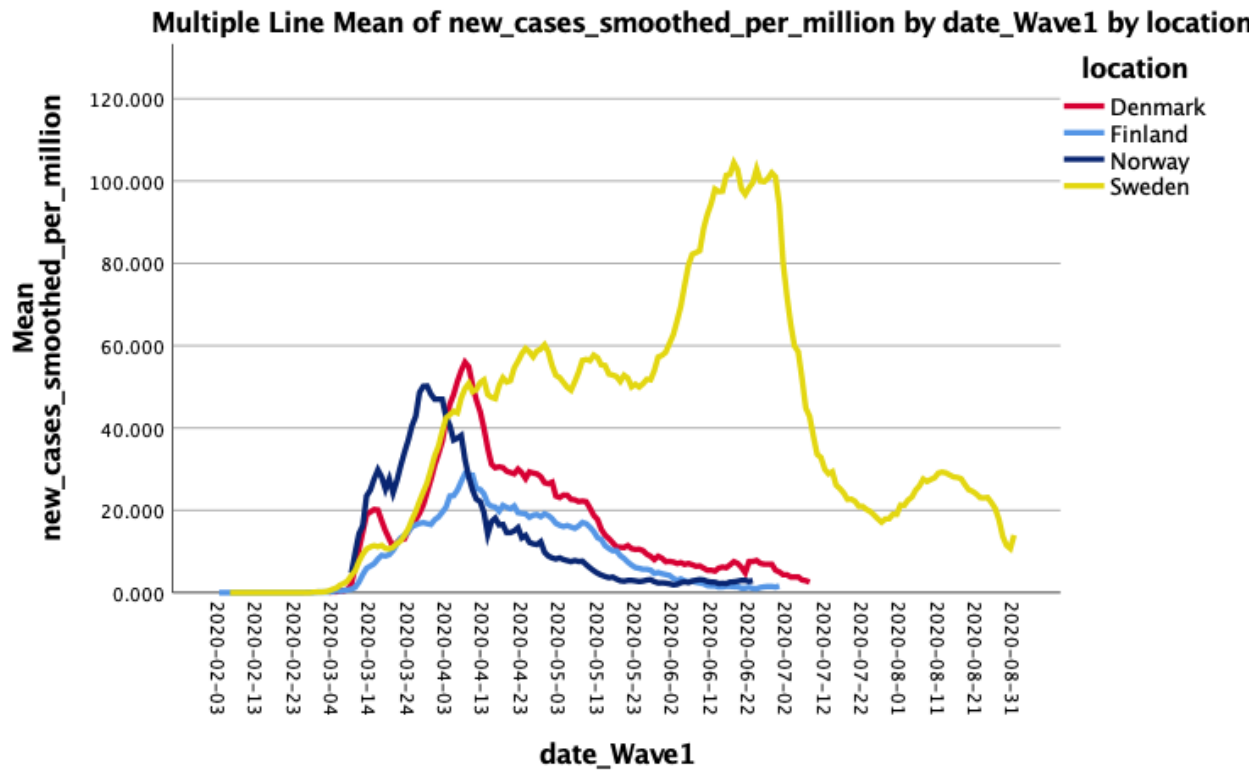
Figure 5: The Number of New Cases during the First Wave in the Scandinavian Countries.

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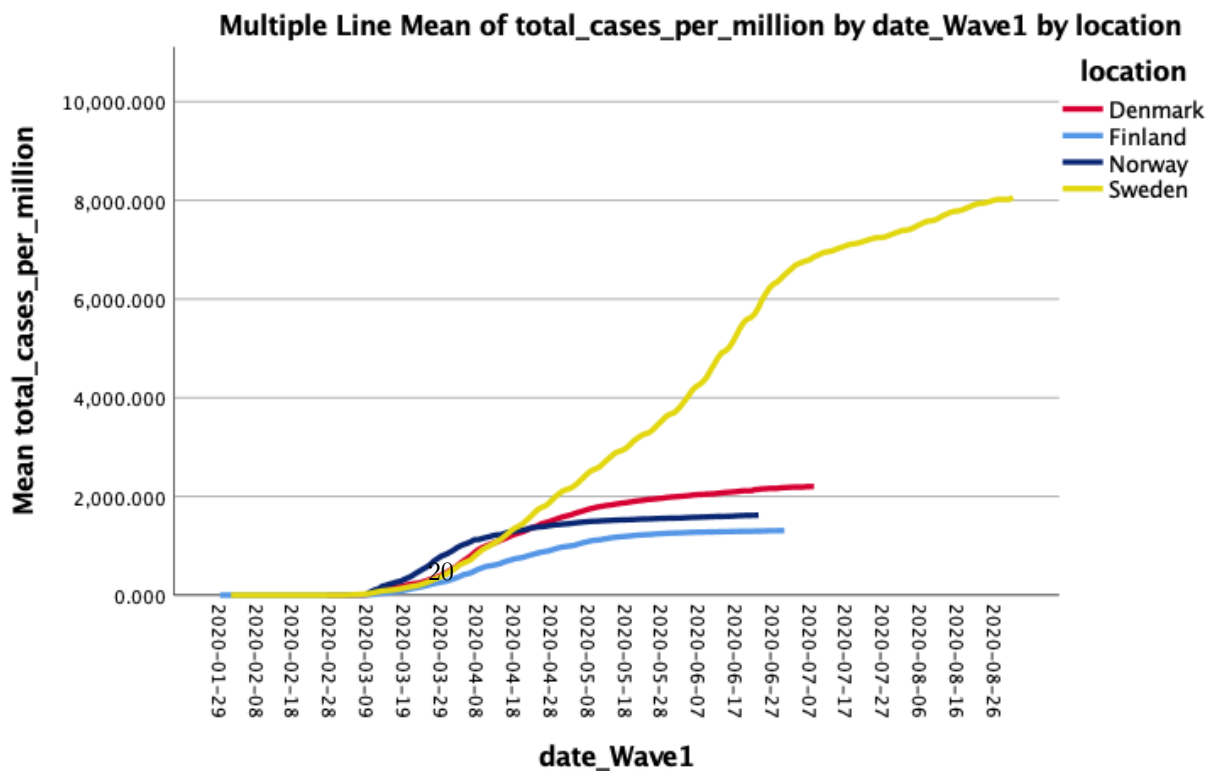
Here comes the number of the cases of infection that is caused during the first wave of Covid infection in the Scandinavian countries.

Denmark: the total number of new cases per million by the end of the first wave, within a period of a bit over five months of time, is roughly 2 200 cases per million inhabitant.

Finland: the total number of new cases per million by the end of the first wave, within a period of a total of five months of time, is roughly 1 300 cases per million inhabitant.

Norway: the total number of new cases per million by the end of the first wave, within a period of almost four months of time, is roughly 1 600 cases per million inhabitant.

Sweden: the total number of new cases per million by the end of the first wave, within a period of six months of time, is roughly 8 000 cases per million inhabitant.

6.1.2   Covid New Cases in the Second Wave

The number of daily Covid cases during the second wave is visualized in the following figure (7).
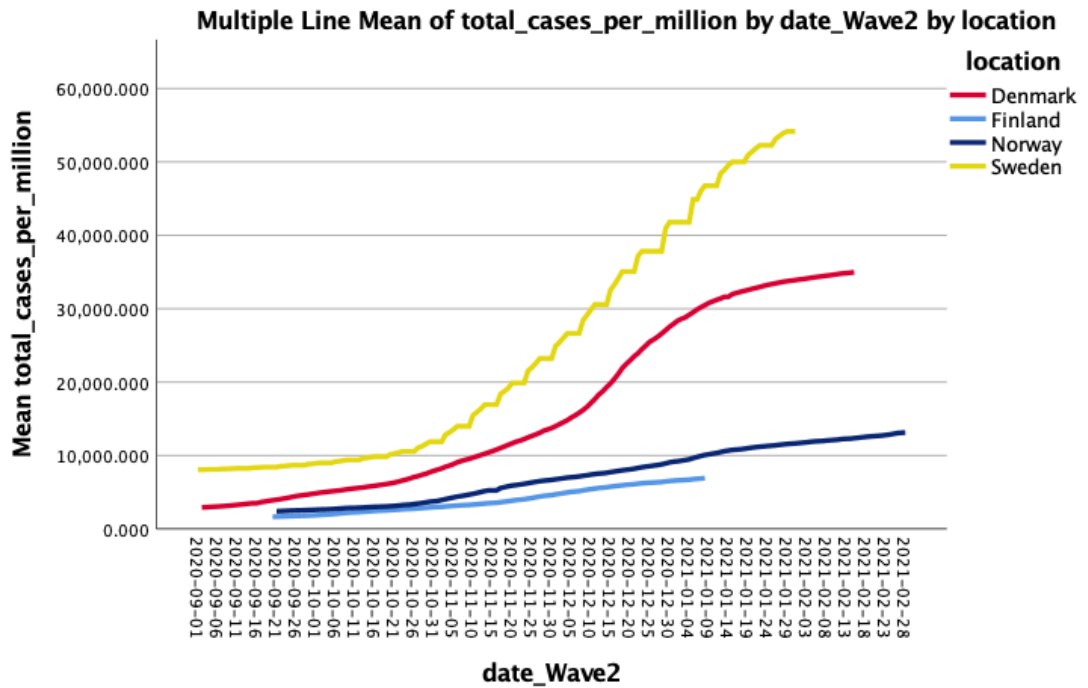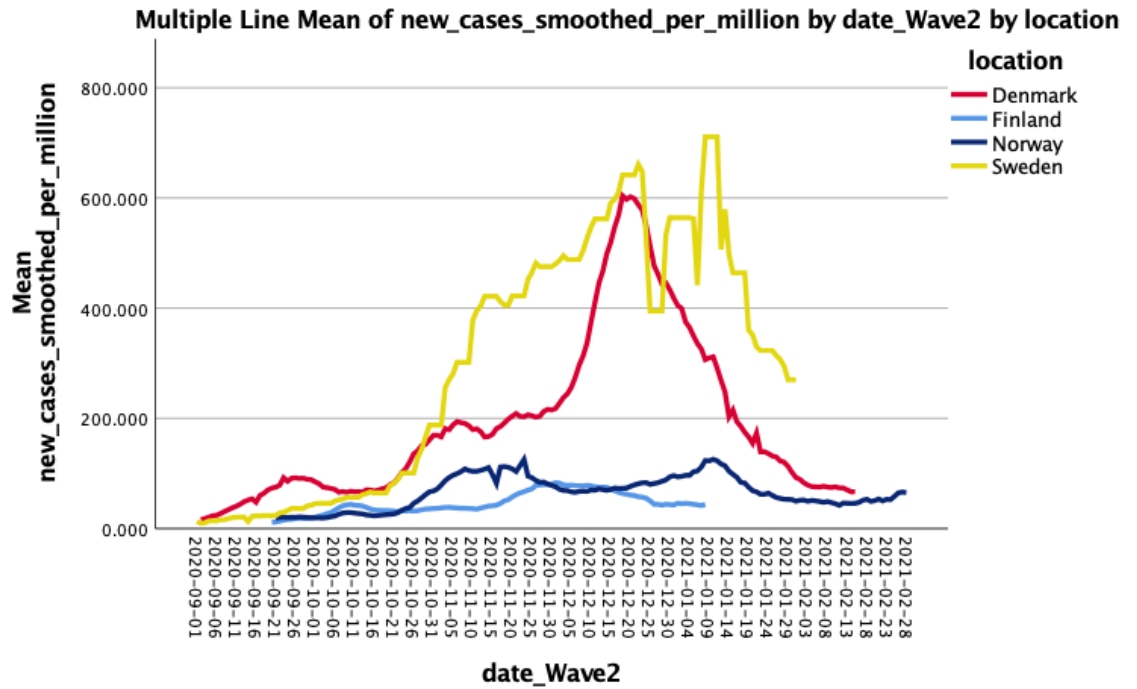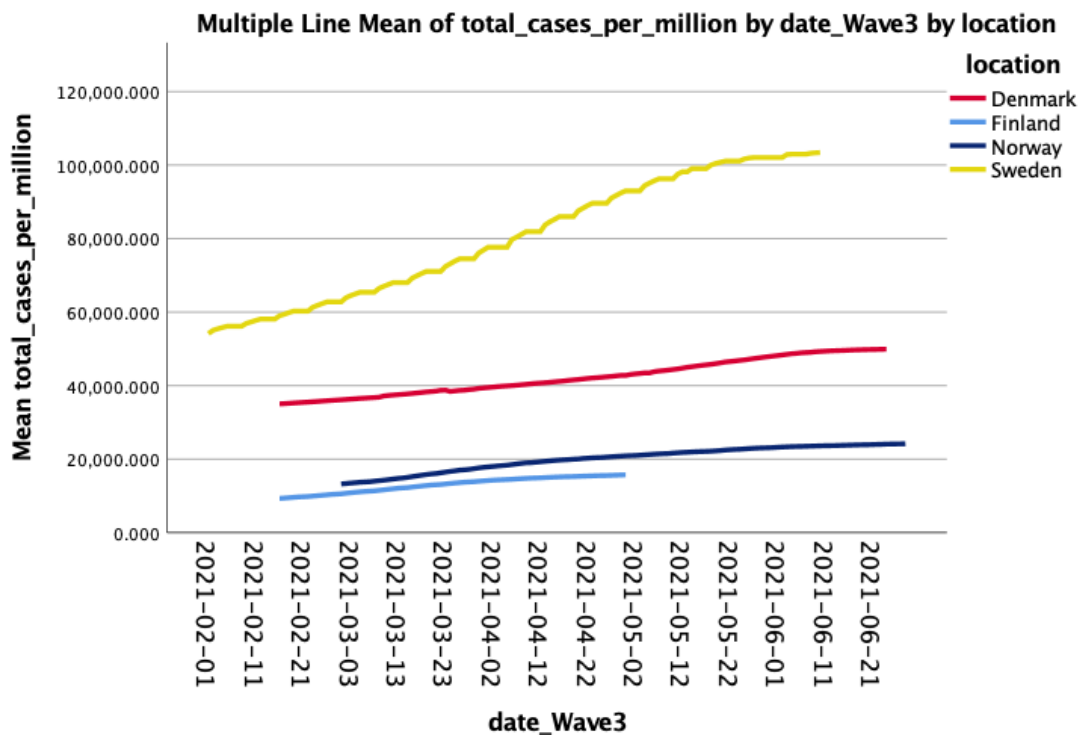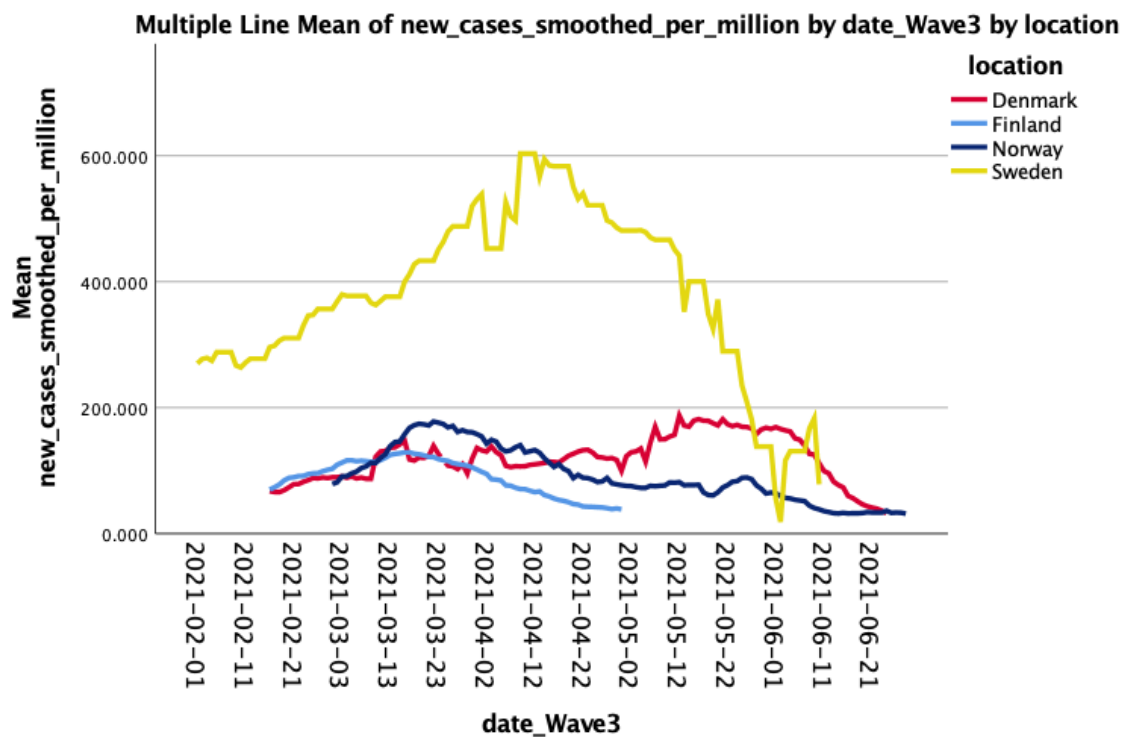
Figure 7: Upper figure: The Number of New Cases during the Second Wave in the Scandinavian Countries. Lower figure: The total number of Covid cases during the Second Wave in the Scandinavian Countries.

Here comes the number of the cases of infection that is caused during the second wave of Covid infection in the Scandinavian countries.

Finland: the total number of the Covid-19 registered cases that were caused by the second wave in Finland; which lasted almost four months of a time, is almost 5 300 new Covid infection cases per million inhabitant.

Norway: the total number of the Covid-19 registered cases that were caused by the second wave in Norway; which lasted roughly a five months of a time, is almost 11 000 new Covid infection cases per million inhabitant.

Sweden: the total number of the Covid-19 registered cases that were caused by the second wave in Sweden; which lasted for five months, is roughly 46 000 new Covid infection cases per million inhabitant.

6.1.3   Covid New Cases in the Third Wave

The number of daily Covid cases during the third wave is visualized in the following figure (8).

Figure 8: Upper figure: The Number of New Cases during the Third Wave in the Scandinavian Countries. Lower figure: The total number of Covid cases during the Third Wave in the Scandinavian Countries.

Here comes the number of the cases of infection that is caused during the third wave of Covid infection in the Scandinavian countries.

Denmark: the total number of the Covid-19 registered cases that were caused by the third wave in Denmark; which lasted four months of time, is almost 15 000 cases of Covid infection per million inhabitant.

Finland: the total number of the Covid-19 registered cases that were caused by the third wave in Finland; which lasted roughly two months of time, is almost 6 500 cases of Covid infection per million inhabitant.

Norway: the total number of the Covid-19 registered cases that were caused by the third wave in Norway; which lasted almost four months of time, is almost 11 000 cases of Covid infection per million inhabitant.

Sweden: the total number of the Covid-19 registered cases that were caused by the third wave in Sweden; which lasted roughly four months of time, is roughly 49 000 cases of Covid infection per million inhabitant.

6.1.4   Covid New Cases in the Fourth Wave

The number of daily Covid cases during the fourth wave is visualized in the following figure (9).
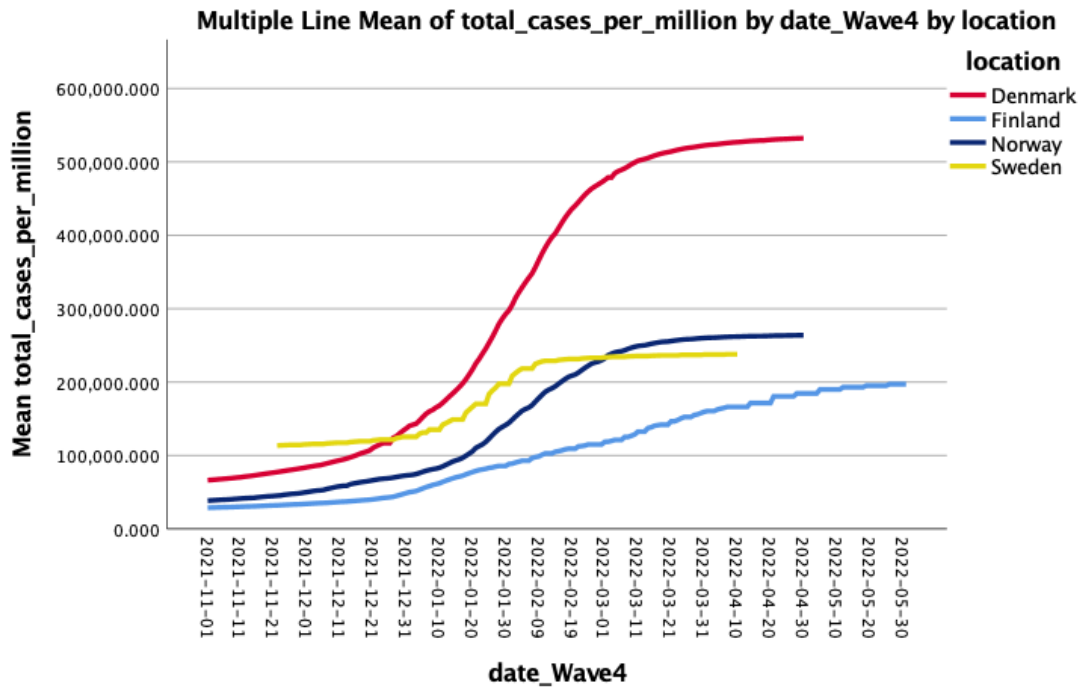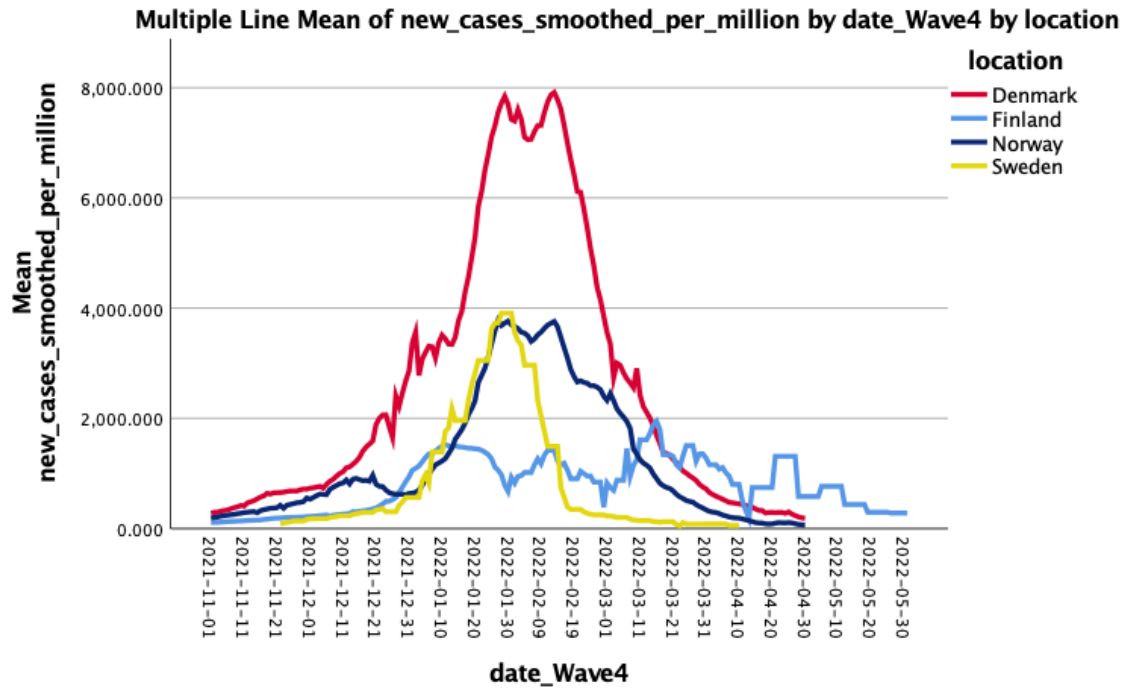
Figure 9: Upper figure: The Number of New Cases during the Fourth Wave in the Scandinavian Countries. Lower figure: The total number of Covid cases during the Fourth Wave in the Scandinavian Countries.

Here comes the number of the cases of infection that is caused during the fourth wave of Covid infection in the Scandinavian countries.

Denmark: the total number of the Covid-19 registered cases that were caused by the fourth wave in Denmark; which lasted six months of time, is almost 466 000 cases of Covid infection per million inhabitant.

Finland: the total number of the Covid-19 registered cases that were caused by the fourth wave in Finland; which lasted seven months of time, is almost 156 000 cases of Covid infection per million inhabitant.

Norway: the total number of the Covid-19 registered cases that were caused by the fourth wave in Norway; which lasted six months of time, is roughly 225 000 cases of Covid infection per million inhabitant.

Sweden: the total number of the Covid-19 registered cases that were caused by the fourth wave in Sweden; which lasted roughly four months of time, is almost 125 000 cases of Covid infection per million inhabitant.

6.2 The variants of Covid

The data used, for the variants are registered by GISAID; which has been already introduced in the method part of this paper. We have a total of 12 different variants that were observed and registered in the four Scandinavian countries; Denmark, Finland, Norway and Sweden.

Four of the variant are labeled as variants of concern (VOC). The four variants of concern that were observed in the Scandinavian region until the start of September-2022, are Alpha, Beta, Delta, Gamma and Omicron.

The data of variants has the registry of the variants from the middle of October-2020 until the start of September-2022. Therewith, we have only the registered variants from the second half of the second wave and afterwards.

Now, we will analyze the variants that were observed in the different Scandinavian countries.

6.2.1 The counts of the different variants in Scandinavian countries

During the time span of the registry of the variants (October-11-2020 to September-11-2022), we see that the dominating Variants in all of the four countries are the three variants of concern; Alpha, Beta and Omicron. There is more specified figures about the variants in the fourth wave (figure 28), third wave (figure 27) and the second part of the second wave (figure 26) in the ""Appendix of Graphs" of this paper.
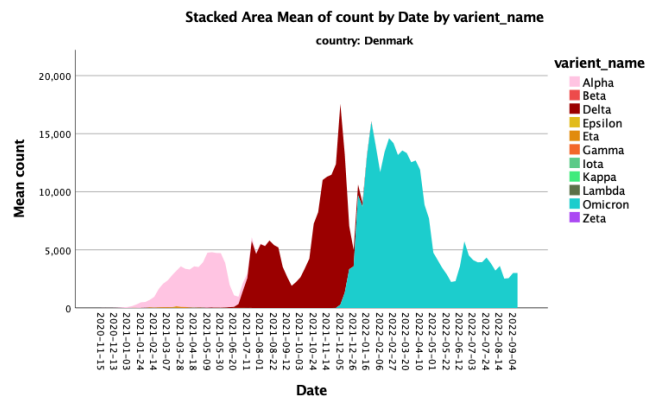

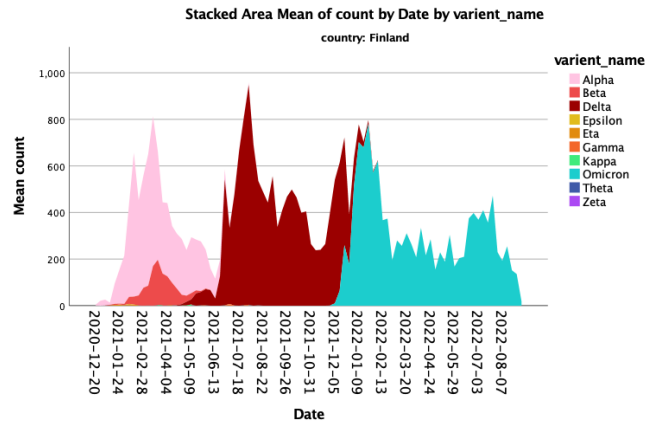Figure 10: The variants count in Denmark

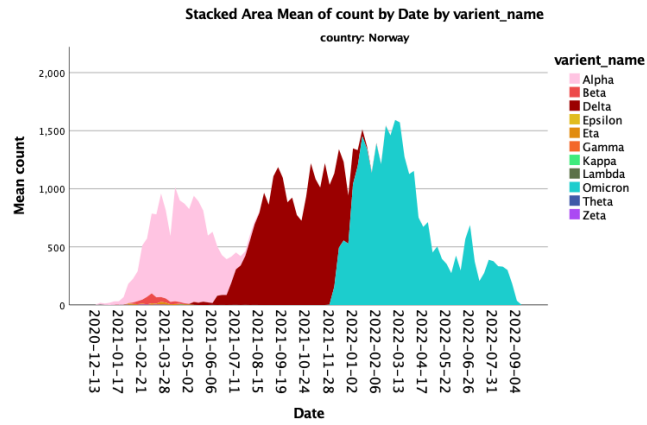Figure 11: The variants of Covid-19 observed in Finland

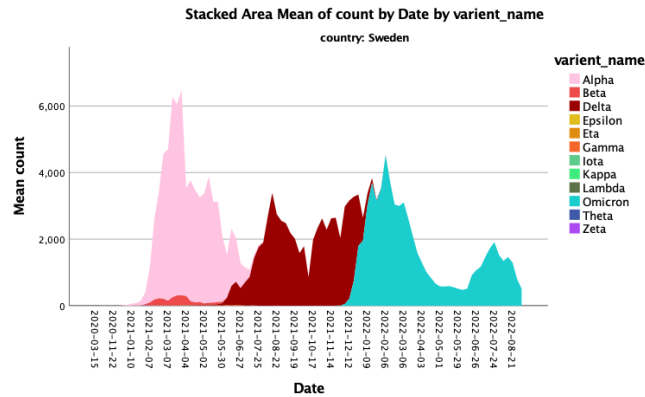Figure 12: The variants of Covid-19 observed in Norway

Figure 13: The variants of Covid-19 observed in Sweden.

By 11-th of September-2022, the total registered number of infected cases with the variants in each of the four Scandinavian countries are as the following.

- The **Alpha variant** has caused 63 823 cases of infection in Denmark, 6 793 cases in Finland, 14 316 cases in Norway, and 68 635 cases in Sweden.

- The **Delta variant** has caused 160 424 cases of infection in Denmark, 13 325 cases in Finland, 22 154 cases in Norway, and 58 816 cases in Sweden.

- The **Omicron variant** has caused 289 432 cases of infection in Denmark, 12 297 cases in Finland, 29 131 cases in Norway, and 64 686 cases in Sweden.

- The **Beta variant** has caused 130 cases of infection in Denmark, 1 198 cases in Finland, 442 cases in Norway, and 2 633 cases in Sweden.

- The **Gamma variant** has caused 66 cases of infection in Denmark, 20 cases in Finland, 13 cases in Norway, and 185 cases in Sweden.

- The **Epsilon variant** has caused 37 cases of infection in Denmark, 2 cases in Finland, 4 cases in Norway, and 2 cases in Sweden.

- The **Zeta variant** has caused 21 cases of infection in Denmark, only 1 case in Finland, 27 cases in Norway, and 18 cases in Sweden.

- The **Eta variant** has caused 614 cases of infection in Denmark, 28 cases in Finland, 122 cases in Norway, and 16 cases in Sweden.

- The **Theta variant** has caused No-cases of infection in Denmark, only 1 case in Finland, 3 cases in Norway, and 2 cases in Sweden.

- The **Iota variant** has caused 8 cases of infection in Denmark, no-cases in Finland, no-cases in Norway, and 4 cases in Sweden.

- The **Kappa variant** has caused 28 cases of infection in Denmark, 11 cases in Finland, 4 cases in Norway, and 5 cases in Sweden.

- The **Lambda variant** has caused 9 cases of infection in Denmark, no-cases in Finland, only 1 case in Norway, and 4 cases in Sweden.

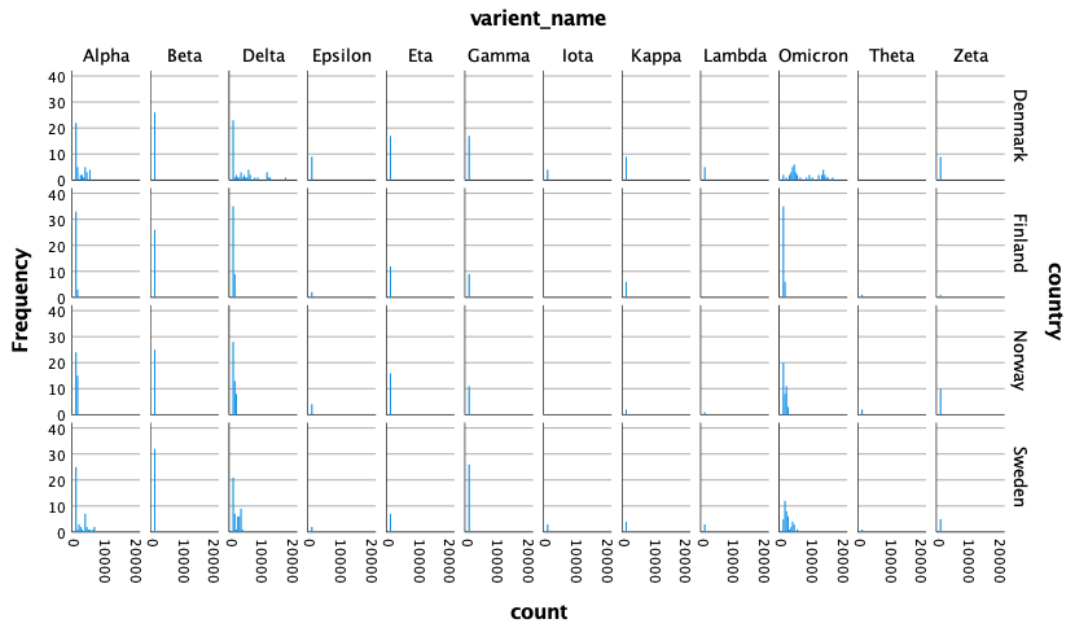Check the following figure (14), for the frequencies of the variants in the four countries.

Figure 14: The frequencies of the variants in each of the four Scandinavian countries.

6.2.2 The most dominant variants in the Scandinavian countries

In general we see that there are three variants of concern that are the most dominant variants in the Scandinavian region. These variants are Alpha-variant, Delta-variant and Omicron-variant. After comparing the numbers of infections with each variant-type within the four countries, we notice the dominant variants as the follow.

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Alpha was the dominant variant in Sweden. As the number of infections with this variant was the highest among the total of 12 variants that were observed in Sweden.

Delta variant was the dominant variant in Finland. As the number of infections with this variant was the highest among the total of 10 variants that were observed in Finland.

Omicron variant was the dominant variant in both of the Scandinavian countries Denmark and Norway. As The number of infections with this variant was the highest among the total of 11 variants that were observed in each of the two countries; Denmark and Norway .
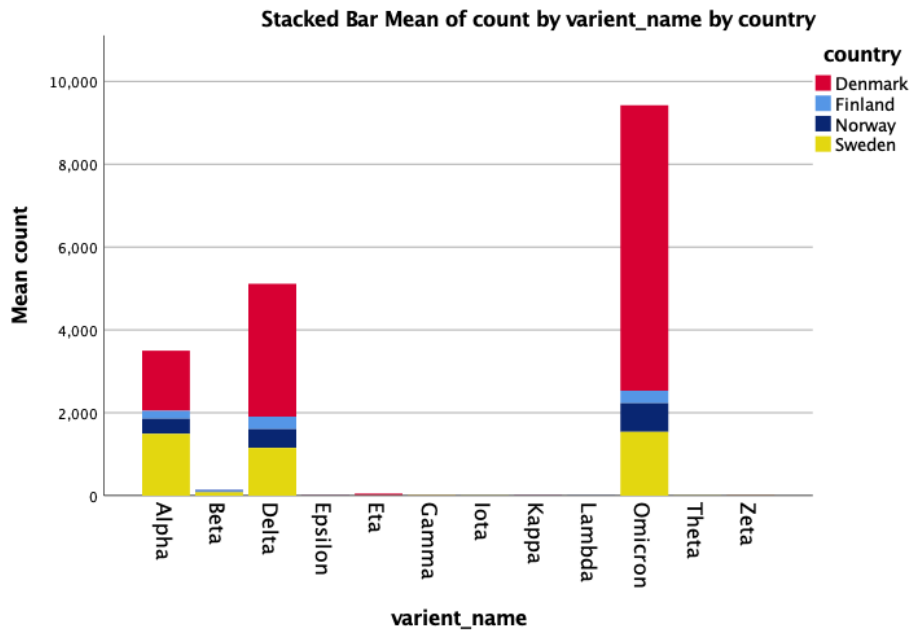

Figure 15: The variants of Covid in the Scandinavian countries

The figure (15) above, visualizes each variant type with a separate bar, colored by the country, and the height of the colored bars represents the total number of infection with that specified variant.

6.3 The number of the fully Vaccinated People

The vaccination in the Scandinavian countries Started by the start of the year 2021. The reporting system for the vaccinations were different in the countries. As, Denmark reported the vaccination on a daily base, and the last date for

A fully vaccinated person is the individual that has received all the prescribed doses according to the vaccination protocol.

The number of the people that were fully vaccinated, according to OWID dataset (uploaded from OWID dataset on 11_{th} of September 2022), are given as the follow.

- The vaccination reporting in Denmark started on 29-December-2020, there after a reporting for the number of vaccinated people in the country was done on a daily base, and by 04-September-2022, the total number of fully vaccinated people in Denmark was, 4 782 914 fully vaccinated people.

- The vaccination reporting in Finland started on 17-January-2021, there after a reporting for the number of vaccinated people in the country was done on a weekly base first then it became to have more irregular pattern for reporting, and by 07-September-2022, the total number of fully vaccinated people in Finland was, 4 341 757 fully vaccinated people.

- The vaccination reporting in Norway started on 06-January-2021, there after a reporting for the number of vaccinated people in the country was done on a daily base, and by 08-September-2022, the total number of fully vaccinated people in Norway was, 4 052 011 fully vaccinated people.

- The vaccination reporting in Sweden started on 17-January-2021, there after a reporting for the number of vaccinated people in the country was done on a weekly base, and by 08-September-2022, the total number of fully vaccinated people in Sweden was, 7 663 019 fully vaccinated people.

But the Population varies within the countries. Sweden has the highest population number within the Scandinavian region. The population in Sweden is over 10 million inhabitant. While, Denmark has a population of 5,9 million inhabitant, Finland is about 5,5 million inhabitant, and in Norway the population number is 5,4 million inhabitant.

Hence, the percentage of the number of fully vaccinated people in each of the four countries, are given as the follow (by 9_{th} of September 2022):

- Denmark: 81.70% of the population in Denmark are fully vaccinated.
- Finland: 78.43% of the population in Finland are fully vaccinated.
- Norway: 75% of the population in Norway are fully vaccinated.
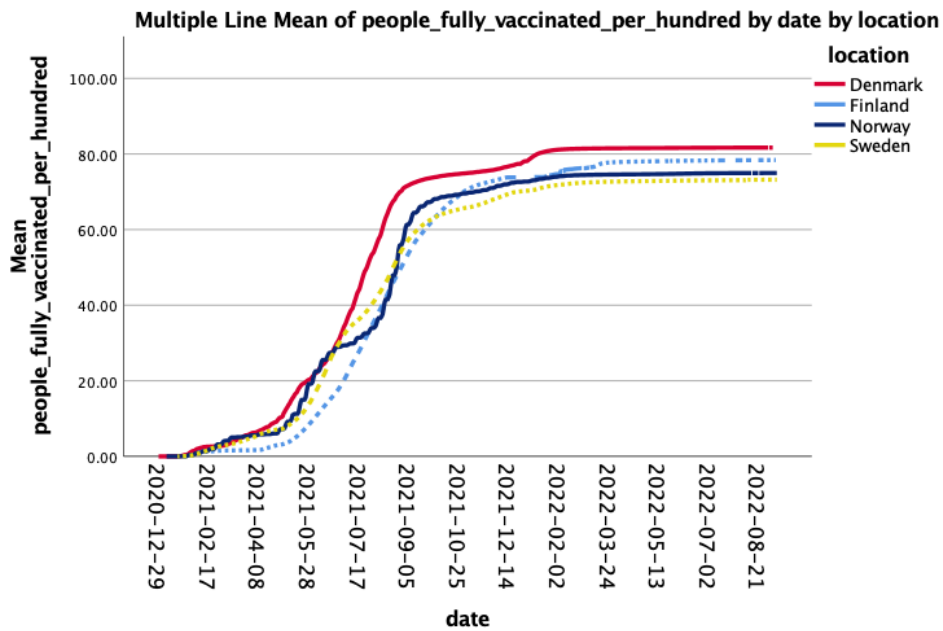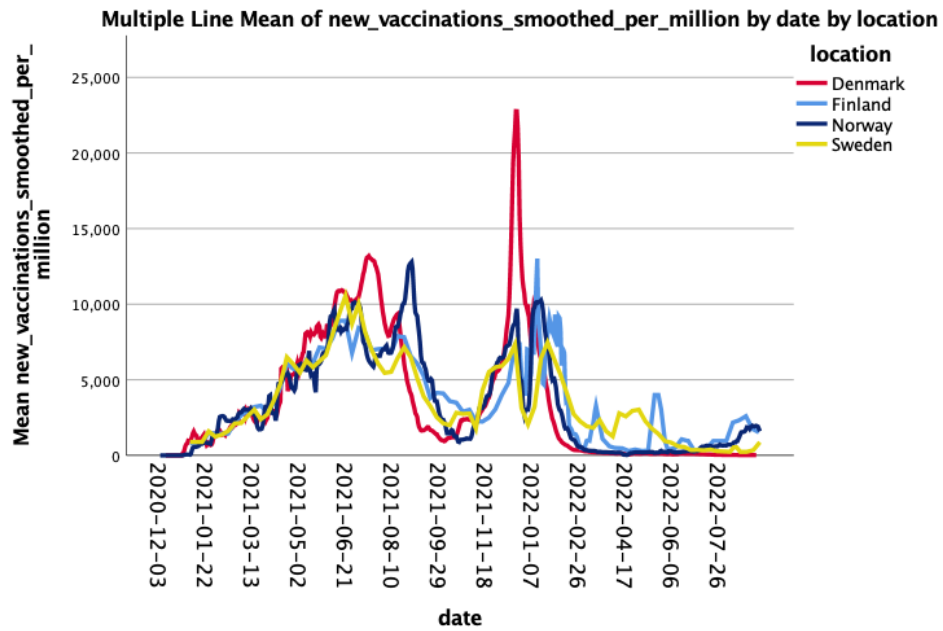- Sweden: 73.21% of the population in Sweden are fully vaccinated.

Figure 16: Upper figure:The number of Covid-19 new vaccinations per million, by 9_{th} of September 2022, in the four Scandinavian countries. Lower figure: The number of fully vaccinated people against Covid-19, by 9_{th} of September 2022, in the four Scandinavian countries.

Hence, the number of vaccinated people per hundred is the highest in Denmark. While Sweden has the lowest number of vaccinated people per hundred.

6.4 The Stringency Index

Stringency Index is the index that indicates the strictness of a government policy. This strictness is a weigh average of nine indicators.
The indicators are according to (Thomas Hale, Noam Angrist, Rafael Goldszmidt, Beatriz Kira, Anna Petherick, Toby Phillips, Samuel Webster, Emily Cameron-Blake, Laura Hallas, Saptarshi Majumdar, and Helen Tatlow, 2021) [11] as follows.

1- "school closures"
2-"workplace closures"
3-"cancellation of public events"
4-"restrictions on public gatherings"
5-"closures of public transport"
6-"stay-at-home requirements"
7-"public information campaigns"
8-"restrictions on internal movements"
9-"international travel controls"

This stringency indicator (that is the average of the nine indicators above), has the range of [0-100]; as 0 indicates no restriction and 100 indicates the strictest response.

Descriptive Statistics

location		N	Minimum	Maximum	Mean	Std. Deviation
Denmark	stringency_index	905	11.11	72.22	41.3003	20.57544
	Valid N (listwise)	905				
Finland	stringency_index	934	5.56	71.30	38.8672	13.51963
	Valid N (listwise)	934				
Norway	stringency_index	910	11.11	79.63	40.9734	21.53144
	Valid N (listwise)	910				
Sweden	stringency_index	920	5.56	69.44	41.8972	22.77484
	Valid N (listwise)	920				

Figure 17: The descriptive statistics of the stringency index.

By observing the figures (17 and 18) and also from the date, we get the following observations.

The stringency in each of the four countries in the Scandinavian region started by the start of the first case (according to the data). The start date of the first Covid case in Finland is on 29_{th} of January-2020 and three days after Covid first case appeared in Sweden, on the 1_{st} of February-2020. In both of those countries; Finland and Sweden, the stringency indicator has the same first value; by the start of the first case in Finland and three days after by the start of the first case in Sweden was 5.58 the value indicator for the stringency index.

Following this, almost four weeks later the First case of Covid infection was found in the other two countries . On the 26_{th} of February-2020 the first case of Covid infection was found in Norway and a day after on the 27_{th} of February-2020 the first case of Covid infection was found in Denmark. In both of those latter mentioned countries; Norway and Denmark, the stringency overall indicator has the same start value by the start of the first case, as the stringency indicator had the value 11.11 .

From one hand, the minimum stringency, of 5.8, by the start of the first case in both the countries Sweden and Finland. On the other hand, both Denmark and Norway had the minimum stringency of 11.11 by the start of their first Covid infection case appearance.

Besides, from the descriptive statistics in figure (17),when comparing the maximum stringency level. We found the maximum stringency level in Sweden was been the lowest among the Scandinavian countries, a value of 69,44%.
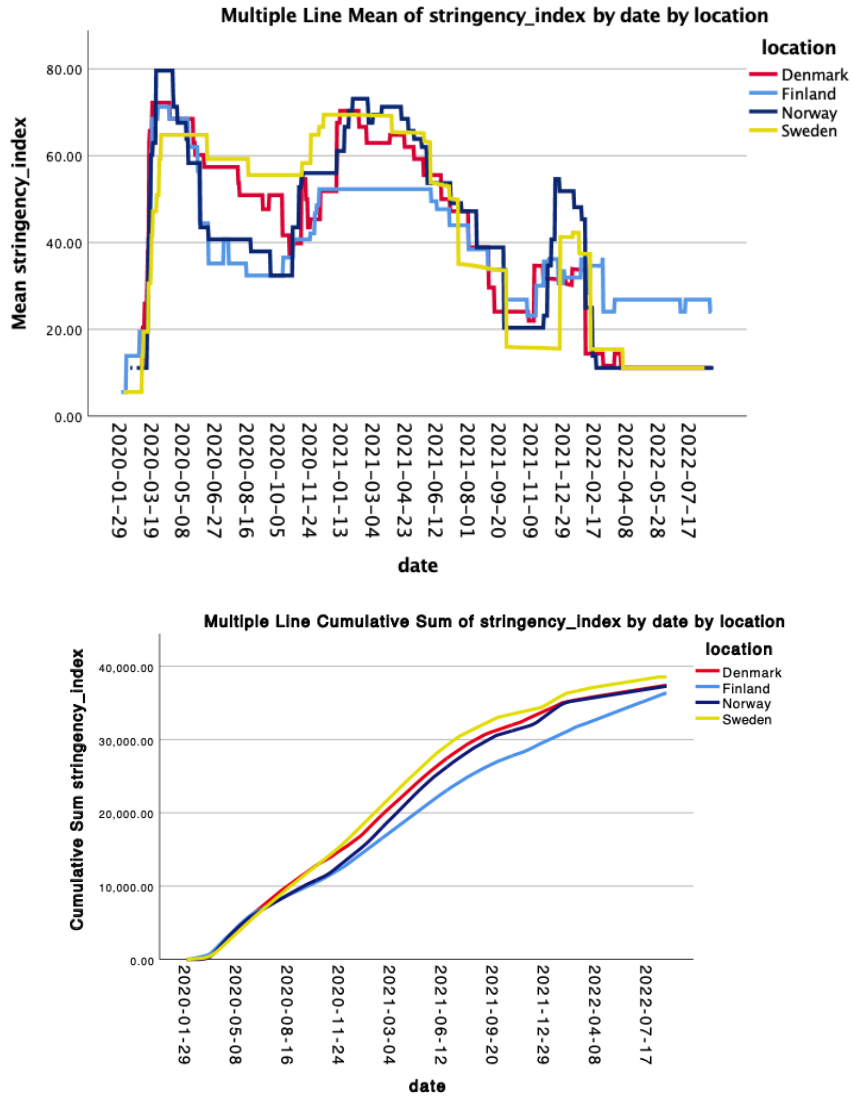
Figure 18: Upper figure: Stringency index in Scandinavian countries. Lower figure: Cumulative sum of stringency index in Scandinavian countries.

Whereas,in Norway it had been the highest among the Scandinavian countries, with a value of 79.63% of the stringency index.

Finally, when comparing the statistical mean between the four countries. we see that the overall stringency average in Sweden from years 2020 until summer of 2022 is the highest (41.9). While Denmark had a so close average (41.3) of stringency index to Sweden, which indicates that only the distribution of stringency in both of the countries (Denmark and Sweden) was different while the overall mean is so close. Finland had the lowest average of stringency (39.9) among the Scandinavian four countries; Denmark, Finland, Norway and Sweden.

Overall all the four Scandinavian countries on average were so close as we have a small average range; between 38.9 and 41.9 .

6.5 Covid-19 Pandemic Effect on the Number of Death and the Excess Mortality Measure

In order to understand the number of deaths caused by the pandemic. We will examine from three aspects.

First, the number of crude deaths, before the Covid-infection. Second, the number of deaths during Covid-19 phase. Third, the number of excess mortality during Covid-19 phase

6.5.1 The crude death before Covid and during the first two year of pandemic(with focus on Sweden)

To understand the effect caused by Covid-19 on the number of deaths within each of the countries. We understand the situation of the reported death number of death before Covid-19 (without the pandemic effect). Therefore we plotted, the crude death numbers in the countries Denmark, Finland, Norway and Sweden. The data source is Eurostat, and it covers the years 2010 to 2021.

As we explained before (in the Data part of this paper), the crude death rate is the ratio of the registered number of deaths during a year to the average of the population of the country. We have the Crude death rate presented per million inhabitant in figure (19).
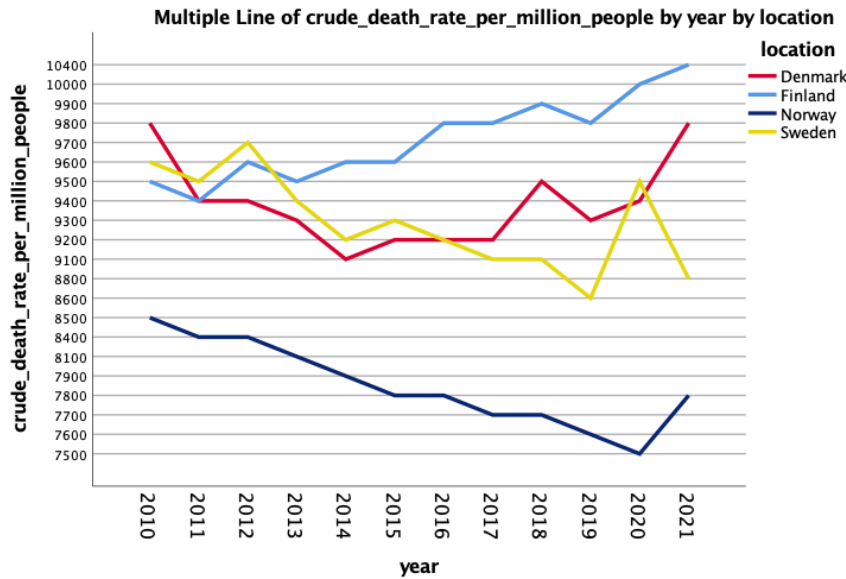
Figure 19: The crude death rate in the Scandinavian region for a period of 10 years of time, before the Coronavirus pandemic and during the first two years period of time of the Covid-19 pandemic

From the figure (19) above, we notice that there is a huge decrease in the number of crude death rate in Sweden. This might be a result to many different things like better health care system, better life style and many other factors. One of the factors that might be important to pay attention to, is that the the number of birth between the years 1927-1941 was significantly low; as there has been less than 100 000 child birth per year (Statistics Sweden, 2020) [23]. While in 1940s the children birth number was been increased to 120 000 child birth per year. According to Statistics Sweden, the common age for death in year 2019 has been at age of 88; the men common death age was 86 and women common death age 90. Which indicates that the people who died in 2019 of ages 86 for men and 90 for women corresponds to the dates of birth between 1929 to 1933; these years had a significant low number of birth.

According to the data of "Our World in Data", during the years 2020 to 2022; the pandemic years, we have the life expectancy age in Sweden (82.80), is the highest, then comes Norway (82.40), there after comes Finland (81.91), and the lowest life expectancy age is in Denmark (80.90).

Therewith, for Sweden, the people who died at age of the life expectancy age 82-83, in the years of pandemic. These people were born in the years 1937 and 1940. Therefore for the same reason mentioned above for year 2019, the death rate is expected also to be less and might increase the following years (by year 2023, as in year 1940, an increase in the number of birth happened with 20%) .
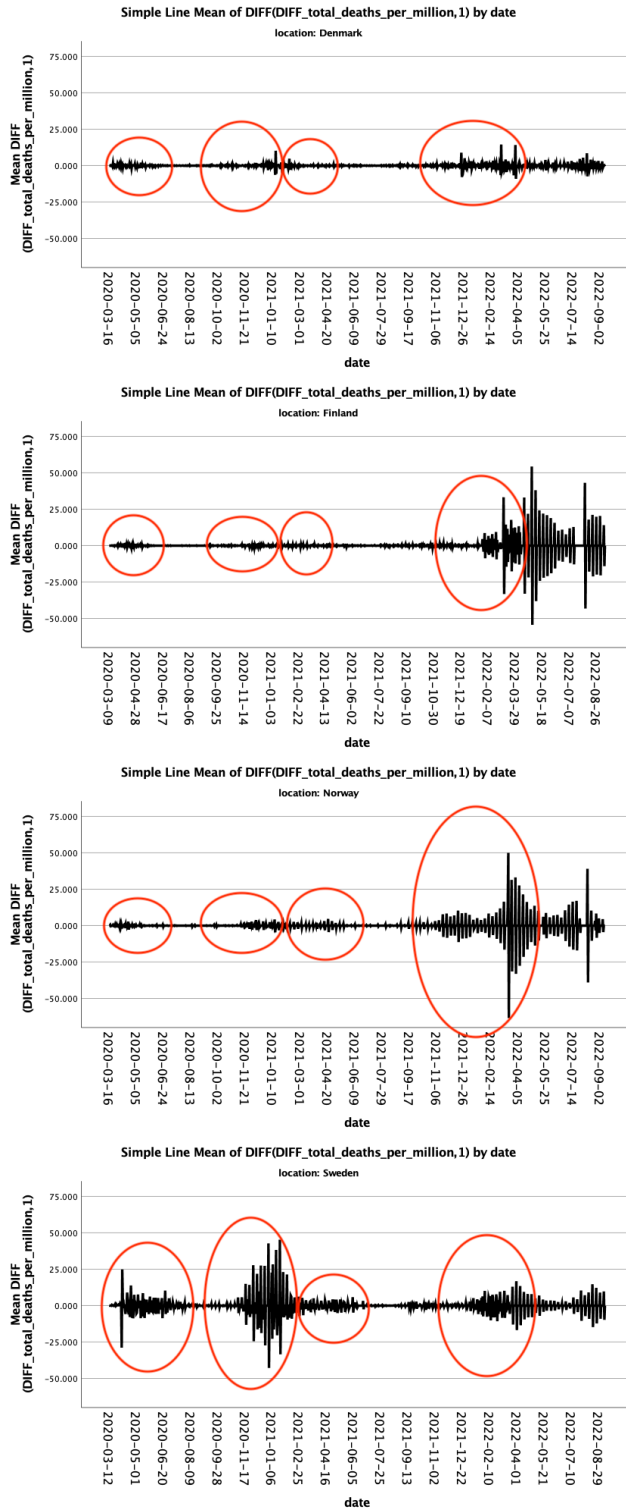
40

Figure 20: Time series of second order differences between total number of deaths per million within each country by date. (the circles define the four waves of Covid from left to right.)

6.5.2 The number of death in the Scandinavian countries during Covid-19 Pandemic

The number of death did vary among the different countries and during the different periods of Covid-19 infection. To examine further the similarities and differences of the number of deaths among the countries and along the different waves of Covid, we use Time series Analysis. We start by creating Time series of first order of differences, then we repeat the method above on the latent time series, to get the time series of the second order of differences. The time series of second order of differences has a period of four weeks, and using this method of time series will eliminate all the external factors that might effect our curve, in order to define any similar behavior between the countries.

The figures (20) above shows that there is a seasonal change in the number of deaths, as the time series oscillates a lot during some period of time (infection seasons) and we observe the following about the number of Covid-19 death per million in the Scandinavian countries. We clearly see, the four waves of infection in each of the countries, and the four waves are defined in (red) circles. The behaviour of the number of deaths in Sweden differs a lot from the other three countries, As the first wave and mostly the Second caused most of the Covid deaths, Thereafter the third and fourth waves were milder. this is clear from the oscillation during the waves. In the other three countries; Denmark, Norway, and Finland, The number of deaths were the most during the fourth wave. Both Finland and Norway had a similar behaviour overall, as the the first three waves caused Covid deaths in a mild way. We notice the high altitude in the fourth wave in both of the time series graphs of Finland and Norway. The low maximum altitude (less than the half of the maximum altitude of the other Scandinavian countries) within the second degree differences of total death number per million in Denmark, indicated that the situation in Denmark with the number of death was much milder than the situation in the other Scandinavian countries.

In Denmark Covid death numbers were high a bit during the first wave, then the death number got even higher during the second wave, the third wave was mild, while the fourth wave caused the highest number of death cases.

By looking to the time Series figures (20), we notice that within the time series of all of the four countries, there a period that oscillates a lot after the fourth wave. The latter, indicates that the Covid infection cases is not over and also the death cases are increasing, and this might mean another wave for Covid infection which obviously from the high altitude in Both Finland and Norway causing some cases of death.

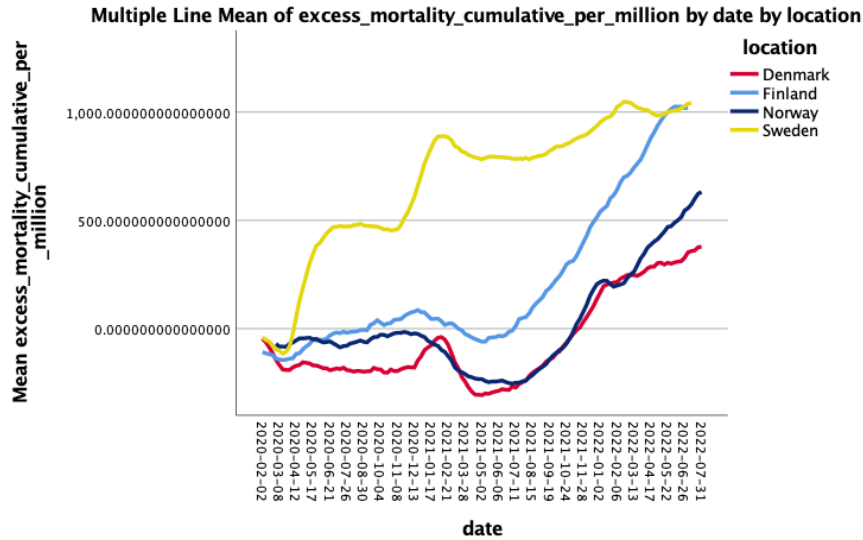### 6.5.3   the number of excess mortality during the pandemic

Figure 21: The number of excess mortality in the Scandinavian countries during Covid-19.

Excess mortality is an important measure that is used in epidemiology. It helps to evaluate the pandemic situation impact on the number of the registered death during an epidemic in comparison with the years before the pandemic.

To estimate the impact of the different waves, we will define a new value for the change in the specified wave in the specified country. This measure will be calculated from the values of the Cumulative Excess mortality, to define the growth (In case of increment in death numbers) or the as the follow

$$\frac{"TheLastExcessMortalityValueOfTheWave" - "TheFirstExcessMortalityValueOfTheWave"}{"TotalNumberOfMeasurements"}$$

Things to consider when reading/interpreting the excess mortality values and understanding its graphs.

- A negative excess mortality value means that the reported death number is less than the expected death number during that period of time, when comparing to the same period of time in the last five years before the pandemic (Years from 2015 until 2019).

- The excess mortality in each country is presented as a weekly value, also the cumulative is calculated per week.

-The value of the excess death is defined using the following formula,

Excess deaths = Reported deaths - Expected deaths.

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- The number of the registry count of the weekly excess mortality values for each country is different from each other; i.e. there is 131 registered weekly values for Denmark while 127 value is registered for Norway. Here are some specifications about the registered data.

Denmark :
First value registered: 02-February-2020
Last value registered: 31-July-2022
The number count: 131 Weeks values.

Finland :
First value registered: 02-February-2020
Last value registered: 03-July-2022
The number count: 127 Weeks values.

Norway :
First value registered: 01-March-2020
Last value registered: 31-July-2022
The number count: 127 Weeks values.

Sweden :
First value registered: 02-February-2020
Last value registered: 10-July-2022
The number count: 128 Weeks values.

The excess mortality growth at the end of each wave is as the follow.

- Here is the value that represents the difference in the cumulative excess mortality per million in each of the four countries, by the end of the first wave.

Denmark: -2.137
Finland: 3.894
Norway: 0.864
Sweden: 21.163

- Here is the value that represents the difference in the cumulative excess mortality per million in each of the four countries, by the end of the second wave.

Denmark: 5.934
Finland: 2.007
Norway: -4.528
Sweden: 17.841

- Here is the value that represents the difference in the cumulative excess mortality per million in each of the four countries, by the end of the third wave.

Denmark: -10.927
Finland: -6.459
Norway: -5.759
Sweden: -4.75

- Here is the value that represents the difference in the cumulative excess mortality per million in each of the four countries, by the end of the fourth wave.

Denmark: 12.873
Finland: 23.308
Norway: 16.964
Sweden: 5.881

We use the clustered bar count to visualize the difference in the cumulative excess mortality per million in each of the four countries by the end of each wave.

Having, each cluster represent a wave and each bar color represent the country and the height of the bar represent the growth in the excess mortality measure.

During the first wave, the excess mortality in Sweden is the highest, thereafter comes the Finland, then Norway and Denmark is the lowest in excess mortality. Denmark has a negative excess mortality value which indicates that the first wave did not cause any excess in the death the numbers from the expected value; i.e. 2.137 less cases were reported per million, than the expected number.

During the second wave, the excess mortality in Sweden again is the highest, thereafter comes Denmark, then Finland, while Norway has the lowest excess mortality measure in the Scandinavian region caused by the second wave. the negative excess mortality value in Norway, indicates that the second wave did not cause any excess in the number of death than what was expected; i.e. 4.528 less cases were reported per million, than the expected number.

During the third wave, none of the countries had an excess in the number of deaths. As all of the four countries had a negative excess mortality value. Which indicates that the third wave did not cause any excess cases of deaths

than the expected in all four Scandinavian countries.

The fourth wave, caused the most excess in the number of deaths. Finland had suffered the most in the Scandinavian region, with an excess mortality number of 23.308 excess death cases per million people. There after comes Norway with the excess number of 16.984 excess death cases per million people. Then Denmark with number of 12.873 excess death cases per million people. The least excess in the number of mortality (by the end of fourth wave) per million is in Sweden with 5.881 excess death cases per million people.

Overall, the number of excess mortality by July-2022 is the highest in Sweden, as the cumulative excess mortality sum per million people is 1042.142). Then comes Finland with 1020.666 cumulative excess mortality sum per million people. There after comes Norway with 631.499 cumulative excess mortality sum per million people. The least suffered with excess death in the Scandinavian region until July-2022 is Denmark , with 378.666 cumulative excess mortality sum per million people.
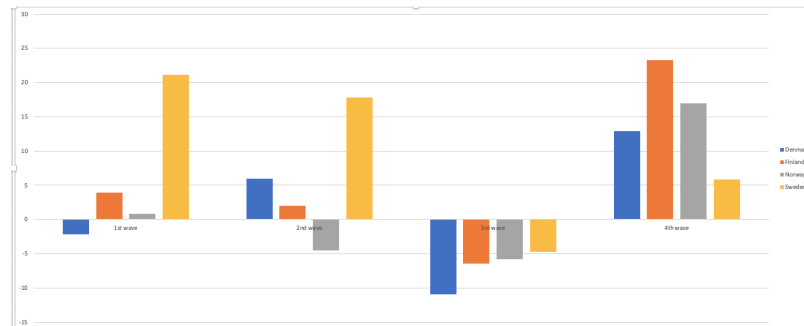

Figure 22: The difference in the cumulative excess mortality per million by the end of each wave.

7 Results

Here comes the results of the Analysis part.

7.1 The Total Number of Daily COVID-19 Cases

The novel Corona virus outbreak started to spread out from Wuhan, a country in China at the end of year 2019. Soon it started to spread both on a local level; within China, and also on an international level; to all rest of the world.

Therewith, by the start of the year 2020, there were already many cases of this novel corona virus had been observed in many European countries. In Scandinavian region, the first case of this Wuhan coronavirus was registered in Finland on 29_{th} of January, year 2020. Thereafter a case in Sweden was been observed on the 1_{st} of February. Later by the 26_{th} of February,in Norway a case of infection was been registered, and a day after a case of this virus infection was registered in Denmark.

During the time span of January-2020 until August-2022, a total of four waves of Covid-19 infections were observed and registered in the Scandinavian region.

The first wave was the longest and caused the highest number of corona virus infection cases in Sweden. As it lasted about six months (March to August, year 2020), and caused roughly 8000 cases of Covid per million inhabitant.

Then, comes Denmark with both the duration of roughly five months for the first wave and with the number of Covid new cases, roughly 2200 cases of Covid infection per million inhabitant.

The first wave in Norway was the shortest, as it lasted almost for a four months and caused 1600 cases of Covid per million people. While, Finland had the lowest number of Covid infection cases in the Scandinavian region, with roughly 1300 cases of Covid infections by million inhabitant. Even if the duration of the first wave was five months, a bit longer than the first wave in Norway.

The second wave lasted the longest time in Denmark, as it lasted less than six months (2-September-2020 until 15-February-2021). Thereafter comes Norway, as the second wave lasted roughly five months (21-September-2020 until 28-February-2021). Then Sweden, as the second wave lasted five months (1-September-2020 until 31-January-2021). The shortest Second wave in the Scandinavian region was in Finland, as it lasted for almost four months (20-September-2020 until 8-January-2021).

The highest number of the virus infections during the second wave was in Sweden, as the number of Covid infections was roughly 46 000 cases per million inhabitant. Then Denmark comes with roughly 32 000 cases of Covid infection per million inhabitant. There after comes Norway with almost 11 000 cases of Covid infection per million inhabitant. The lowest number of Covid infections during the second wave is in Finland, almost 5 300 cases of Covid per million

people were registered during the second wave of Covid.

The third wave was the longest and caused the highest number of corona virus infection cases in Sweden. As it lasted roughly four months (1-February-2021 until 10-June-2021), and caused roughly 49 000 cases of Covid infections per million inhabitant.

Then, comes Denmark with both the duration of four months for the third wave (16-February-2021 until 24-June-2021). Also with the number of Covid new cases, almost 15 000 cases of Covid infection per million inhabitant.

There after comes Norway with both the number of infection, 11 000 cases of Covid infections by million inhabitant, and the duration of almost four months for the third wave(1-March-2021 until 28-June-2021).

The Shortest third Covid wave and the lowest number of infection per million was in Finland. Finland had roughly two months of duration for the third wave (16-February-2021 until 30-April-2021), and the number of Covid cases were almost 6 500 cases per million inhabitant.

The fourth wave was the longest and caused the highest number of the virus infections in Denmark.

As it lasted for six months (1-November-2021 until 30-April-2022), and caused almost 466 000 cases of Covid infections per million inhabitant.

Then comes Norway as the fourth wave lasted for six months(1-November-2021 until 30-April-2022), and caused roughly 225 000 cases of Covid infections per million inhabitant.

After that comes Finland, with seven months duration for the fourth wave (1-November-2021 until 30-May-2022), and roughly 156 000 cases of Covid infections per million inhabitant.

Last, comes Sweden with the duration of the fourth wave, of roughly four months (22-November-2021 until 10-April-2022), and roughly 125 000 cases of Covid infections per million inhabitant.

In general, during the time phase of January-2020 until 9_{th} of September-2022. The total number of Covid-19 cases per million in the Scandinavian region was as the following.

The highest number of infections, by 9_{th} of September-2022 was registered in Denmark, of total 560 000 cases per million people. The second highest registered total number of Covid cases was registered in Norway, of 270 000 Covid cases per million people. Then comes Sweden, with almost 245 000 cases of infections per million people. While the lowest number of Covid cases was in Finland, which is roughly 230 000 Covid-19 cases per million people

It is important to notice that, the numbers might not be so accurate, specially towards the end of the fourth wave. Because, some of the countries started to test less often and therefore some of the cases were not detected nor recorded.

7.2 The Variants of Covid

A total of 12 variants were observed in the Scandinavian region. Five of these variants were observed as variants of Concern.

In Sweden a total of 12 variants had been observed until the end of August 2022. In Denmark 11 variants of Covid had observed, only the variant Theta was not observed in Denmark. In Finland 10 variants types were observed, Iota and Lambda were not observed in Finland. In Norway 11 variants types were observed, Iota variant was not observed in Norway.

Only Three of these variants of concern caused high number of infections within the Scandinavian region. The three variants of concern that were dominant in the Scandinavian region were Alpha, Delta and Omicron.

When observing the number of infections caused by the variants, we notice that Omicron variant is the variant that caused absolutely the highest number of infections in the Scandinavian region. As the highest number of a single variant cases is in Denmark, with Omicron variant, a total of 289432 registered infection cases.

Denmark :had Omicron cases the highest, as 289432 cases of Covid infections in Denmark was registered by 9_{th} of September 2022. Besides 160424 Covid cases with Delta variant , and 63823 cases of Covid infections with Alpha variant.

Finland: the number of Covid infections with the variant Delta was the highest, as 13325 of the Covid infections were registered by 9_{th} of September 2022. While the variants Omicron had caused 12297 of infections and Alpha variant caused 6793 cases of infections.

Norway: the number of Covid infections with the variant Omicron was the highest, as 29131 of the Covid infections were registered by 9_{th} of September 2022. While the variants Delta had caused 22154 of infections and Alpha variant caused 14316 cases of infections.

Sweden: the number of Covid infections with the variant Alpha was the highest, as 68635 of the Covid infections were registered by 9_{th} of September 2022. While the variant of type Omicron had caused 64686 of infections and the variant of type Delta caused 58816 cases of infections.

The numbers of the cases of the variants in proportion to the population number per hundred are as the follow.

In **Denmark**, almost 5% of the population was infected with the variant **Omicron**. Besides, almost 3% of the population in Denmark was infected with Delta variant and 1% with Alpha variant.

In **Finland**, the variant **Delta** caused infections of roughly 0.2% of the population. Besides, almost 0.2% of infections with Alpha variant, and 0.1% of the population got infected with Alpha variant.

In **Norway**, the variant **Omicron** caused infection with roughly 0.5% of the population. Besides, 0.4% of infections with Delta variant, and 0.3% of the population got infected with Alpha variant.

In **Sweden**,the variant **Alpha** caused infection with almost 0.7% of the population. Besides, roughly 0.6% of infections with Omicron variant, and almost 0.6% of the population got infected with Delta variant.

Note that: There might be some people that were been infected more than once with some different variants. Therefore when we say for example 5% of the people were infected with Omicron variant and 1% with alpha variant, this might also include some of the population that were infected with the Alpha-variant might also got infected with the Omicron-variant (as there is approximately a year of time, which means that cases of re-infection might happens.).

7.3 The Number of the Fully Vaccinated People

During the phase of the second wave of Covid infections. The vaccination with Covid started; with the people with higher risk of severe symptoms when getting a Covid-19 virus infection.

According to the data, the percentage of fully vaccinated people in the four Scandinavian countries, until 9-September-2022,are as the follow:

Denmark 81.70% of the population is fully vaccinated.
Finland 78.43% of the population is fully vaccinated.
Norway 75% of the population is fully vaccinated.
Sweden 73.21% of the population is fully vaccinated.

More figures about the vaccination in the Scandinavian countries are added in the "Appendix of Graphs" part at the end of this paper, check figures (29, 30, 31).

7.4 The Stringency Index

The Stringency in Sweden started with a low level of restriction; a level of 5.58%, and did not exceed the level of 69.44%. But The overall statistical mean of the stringency index was the highest in Sweden, when comparing to the neighbour countries in the Scandinavian region. There with, we might argue that the restrictions in Sweden was not overall "loose", as it might be at some points a bit looser than it's neighbours. As Sweden did stay on a low restriction level of 5.58 until 1_{st} of March. While Finland increased the restrictions to a level of 19.44 of stringency. By that time, both Denmark and Norway were on 11.11 a level of stringency as it was through the beginning phase of Covid-19 infections.

The restriction in Sweden can be divided into these five phases:

- First phase, the low restriction phase. This phase started with a restriction level of 5.58 and continued constantly on that level until 1_{st} of March-2020.

- Second phase, the restrictions level started to increase. This phase started by the end of the first phase and lasted until 14_{th}] of December-2022. It was a

phase of rapid increase in the restrictions. During this phase the index for the stringency got to level of 69.44, an increase of 63.88% through 289 days.

- Third phase, a phase of high restrictions. This phase started by the end of the second phase. For a consecutive 54 days the restriction stayed on a level of 69.44.

- Fourth phase, the phase of decreasing the restrictions. This phase started by the end of the third phase. This phase lasted for 321 days and the restrictions decreased slowly to get a level of 15.56, by the end of this phase (22-December-2021).

- Fifth phase, this started before Christmas celebrations in Sweden (December-2021). On 23_{rd} of December, the restriction increased from 15.56 to 41.31 suddenly in one day. Then the restrictions started to slowly decrease, until it got to a level of stringency 11.11 (over 229 days), on 8_{th} of August-2022.

More about the stringency in the Scandinavian countries is at the "Appendix of Graphs" of this paper, check the figures (32, 33, 34 , 35).

7.5 Covid-19 Pandemic Effect on the Number of Death and the Excess Mortality Measure

From the Eurostat number of deaths, data-set we see that the crude death rate after year 2014, has been the highest within the Scandinavian region in Finland and the lowest in Norway.

Years 2014 and 2015, Sweden was the second highest in the number of crude deaths in Scandinavia, followed by Denmark. While in year 2016 both Sweden and Denmark had an equal crude death rate. After that the number of crude death rate in Sweden went lower, suddenly in year 2020; the first year of Covid-19 pandemic, the crude number of deaths in Sweden went higher than Denmark and the year Sweden's death rate after went back to be lower than Denmark.

From the OWID data set, and by applying time series of the second order differences on the number of deaths per million. We notice that from January-2020 until September-2022, the behaviour of Finland and Norway were Similar. When comparing the number of deaths; as the death rate in both of the countries is the highest during the fourth wave .

While Sweden had a totally different behaviour, as the first and mostly second wave caused a high death rate, and the fourth wave was much milder. In Denmark, most of the death rate was during the fourth wave, but the situation was relatively the milder in the Scandinavian region, until begining of September-2022.

Further observing the excess mortality numbers, we notice that Sweden did suffer the most, while the third wave did not cause any excess deaths. On the other hand, the fourth wave did cause some of excess death cases as the total excess mortality caused by the fourth wave is less than 30% of the excess mortality cases caused by the first wave.

There after, comes the number of the excess mortality in Finland, The fourth wave did cause most of the excess deaths in Finland, also the first wave did cause some excess in the mortality rate and even the second wave cause a bit less.

Then Comes Finland, The third wave caused most of the excess death, and the first wave caused some increase in the excess death rate.

Denmark had the lowest excess mortality numbers in the Scandinavian region. Most of the excess in the number of the deaths were caused by the fourth wave and some excess death cases were caused by the second wave.

8 Discussion

From one side, the the statistical mean of the stringency index, was the highest in Sweden, when comparing to the other three Scandinavian countries. But, on the other hand, the maximum limit for the stringency index that Sweden reached was the lowest in the Scandinavian region. For example, the maximum stringency level between the years 2020 and Sep-2022, was the lowest in Sweden when comparing to the neighbour countries in the Scandinavian region. As the maximum level of stringency Sweden has reached only 87.2% of the maximum stringency level of Norway, also got to 96.2% of the maximum stringency level of Denmark, and 97.4% of the maximum stringency level of Finland.

Among the Scandinavian countries, Sweden had the highest number of death and excess mortality. This is due to the Fact that most of the death cases were in the beginning of the pandemic, during both the first wave; that was between 01-March-2020 and 31-August-2020, and the second waves of Covid-19; that was between 01-September-2020 and 31-January-2021.

Roughly, 7000 more people died when comparing to the years 2015-2019, as most of the death cases (60%) accrued during the first half of the year, while the other 40% death cases happened in the second half of the same year.

The crude death rate shows that in 2019 there was a decrease in the number of the deaths. This decrease in the number of deaths, might be a response to the the significant low number of birth during the years 1927 until 1941 in Sweden, besides the age expectancy in Sweden which is 82.80. All that, leads to a drop in the number of deaths in the corresponding years between the years 2019 and 2023. However, the peak that we got in the year 2020 was due to the pandemic situation, and the number of deaths in Sweden decreased back in year 2021.

The variants of the first Covid-19 infections wave is not registered. While after 11_{th} of October-2020, we have during the second wave, Alpha variant was the dominant variant in Sweden. For further understanding, check "Appendix of Graphs" of this paper, for figure (26). The estimation of transmission with the Alpha variant twas around 50% more than the original strain, this caused an increase in the number of infections in Sweden.

The problem with the excess deaths from Covid was huge in Sweden, this happened most during the year 2020. There are many factors that might have contributed in the increase of the death numbers.

One of the factors for the excess deaths during Covid-19 pandemic is that, the population of foreign-born people which in year 2020 were estimated to be 20% of the total population in Sweden (Statistics Sweden,2022) [22]. The number of the foreign born in Sweden is the highest among the Scandinavian countries.

Moreover, according to the Organisation for Economic Co-operation and Development (OECD), in the other three Scandinavian countries the percentage of

the foreign born people in their population by the end of 2021 was as the follow, in Norway 16.1% of the population, in Denmark 10.5% of the population, and in Finland 7.3% of the population.(Economic Co-operation and Development, 2022) [20].

The country of birth is a significant factor in the number of deaths in year 2020 in Sweden. Therefore at, the death percentage was disproportionately high among people in Sweden that were born in countries like, Turkey, Syria, Somalia, Iraq, Iran, Greece and Chili. (The National Board of Social Affairs and Health in Sweden, 2021) [24]. The percentage of dead people due to Covid, varied depending on the birth country. As 50% of the deceased in year 2020 who were born in Somalia, were dead from Covid. While only 10% of the deceased in the same year, that were born in Sweden, were dead from Covid-19.

Another factor is that, in the beginning of the pandemic the situation was foggy. Therewith, some people were extra alert and scared, while there were some people that did not give much attention to the situation. As the risk estimation was different among people. An example of that is an incident that happened in a municipality in Sweden. The number of infections did suddenly increased in a municipality in Sweden, When a group of people went to visit a sick person; as visiting sick people is considered to be an important social duty for some communities.

Also the factor of the problem in the elderly houses in Sweden. As during the first half of the year 2020, a problem of rapid spread in the elderly care in Sweden, because of, a failure in the health care assistants system. An article in the SVT-news; the Swedish television news was published in April-2020, about 150 death cases in the elderly care in Stockholm Region (SVT-news, 2020)[18]

By that the Covid-19 infection started to smuggle into the elderly care through the assistant staff. With that, a rapid increase in the number of death reported. As we have fragile group of people against the coronavirus.

The number of fully vaccinated people is the lowest in Sweden, only 73.11% of the population was fully vaccinated by 9-September-2022. While in Denmark 81.86% of the population is fully vaccinated. But on the other hand the excess mortality in the fourth wave in Denmark was twice the the excess mortality in Sweden. Moreover, the excess mortality during the fourth wave in Finland was almost four times of the number of excess mortality in Sweden during the fourth wave.

Finally, the situation of Covid is not easy to asses. Because of, the large number of factors, that effects the outcome results, directly and indirectly. As we don't have only single factors, sometimes a composition of two factors of more (The positive or negative correlation among factors), might bring to life a new factor.

Epidemiology challenges are many, like collecting standardizing data, accuracy of the collected data. Therefore, Analyzing the data that were collected with different perspectives or (and) the rules for measuring were not standardized, leads us to some level of uncertainty in the results. Therefore all the results are relevant to the data accuracy, but the fact of having a big number of data points, gives us gives us a better accuracy for the presented result.

9   Conclusion

When assessing the stringency index in Sweden was not in general "loose". As, it had the highest statistical mean when comparing to its neighbours in Scandinavia. but on the other hand, we can't affirm that the restrictions were stringent . Because of, some factors like the maximum stringency level that Sweden reached was the lowest among the Scandinavian countries. Besides, during many periods of time, the restrictions in Sweden were weaker than the restrictions of its Scandinavian neighbours.

The number of Covid cases, might have been high during the first two waves of Covid in Sweden. While, the number of cases per million has been second last, between 1-February-2020 and 10-September-2022, when Denmark had the highest numbers per million people, and the cases per million in Sweden were almost only 44% of the total number of Covid infections per million in Denmark.

The number of excess mortality was the highest in Sweden, excess mortality was estimated as roughly one-thousand people per million (0.1%). Most of the death cases were caused by the first and the second waves, which lead to an increase in the excess mortality measure year 2020.

Both first and second waved did caused most of the death cases. Moreover,it had also cause an increase in the excess mortality measure. Therefore mostly the main strain of Covid-19 caused the high death numbers and thereafter came the variant Alpha that was a dominant variant in Sweden, that caused many number of Covid cases and also deaths.

In Sweden, 73.21% of the Swedish population was fully vaccinated (by 10-September-2022), Which was the lowest vaccination percentage in the Scandinavian region. while the highest percentage of fully vaccinated people was in Denmark, with a percentage of 81.70% of the Danish population. But in spite of the fact that the number of fully vaccinated people achieve only (almost) 90% of the the vaccination level of Denmark. We had, the number of the excess mortality caused by the fourth wave, was as half as the number (even less than half) of the excess mortality in Denmark caused by the the fourth wave. This might have been a result due to many different factors. One possible factor is that, Sweden was already had a prior period with excess mortality (during the first and the second waves). Another factor might be that the people in Sweden started to adapt and act more responsibly. Because of the policy applied in Sweden, the obligation of Personal responsibility ; as people were encouraged to be more self responsible by recommendations with some proper actions in many different situations and cases, for over almost two years of time. So even after the pandemic situation title was withdrawn. Many individuals are still sometimes working from home, specially in case of tiny flue symptom, and still greeting each others without much of physical contact. Generally speaking, It is not easy to forget the habits that we gain over time, especially when the consequences might effect the health of ours and the people we care about.

Finally, This paper did analyze the first four waves of Covid in the Scandinavian countries and could present some general outline for the situation in Sweden in particular and in the Scandinavian countries in general. But, with the increase of the numbers of Covid infection now, by the end of year 2022, the corona virus effect is not over. With that, more of work will need to be done with the more data we get, to be able to reveal as much as possible about the situation during a pandemic, for a better future for the human kind.

10 Appendix of Graphs

10.1 New Daily COVID Cases in the Scandinavian Countries
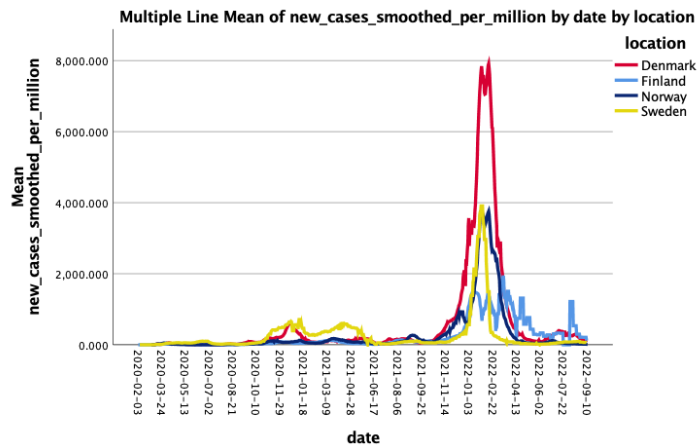
Figure 23: The Number of New Cases in the Scandinavian Countries

- Total Covid cases in the Scandinavian countries, during the time period January-2020 until September-2022.
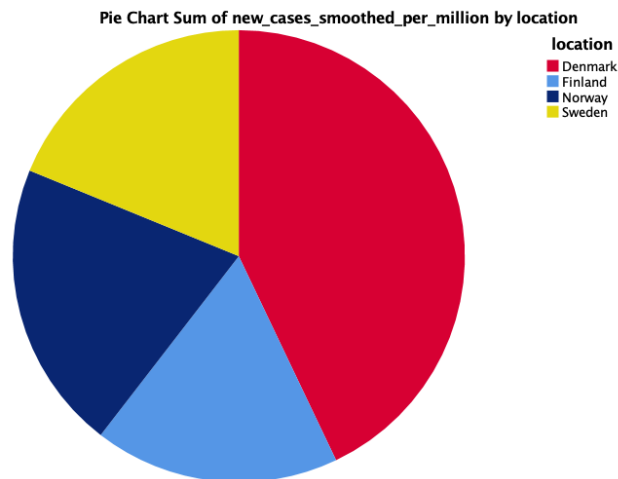
Figure 24: The Number of total Covid Cases in the Scandinavian Countries during January-2020 to September-2022.

- The total number of cases per million in the Scandinavian countries by the end of each wave.
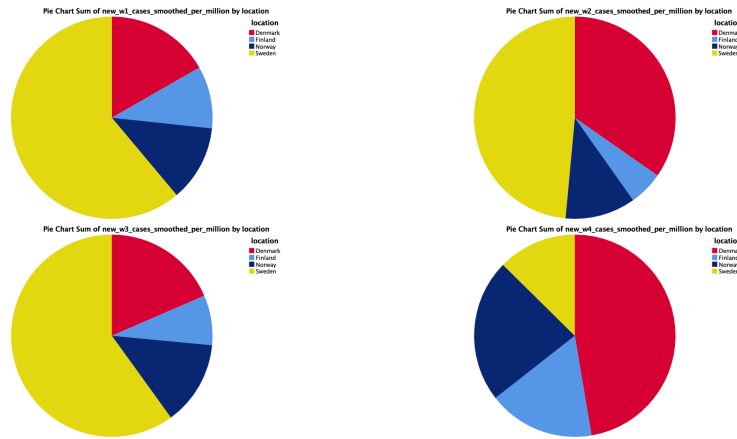
Figure 25: The total number of Covid cases in the different Scandinavian countries, by the end of each wave.

10.2 The variants in the Scandinavian countries during the waves

I- The variants in the Scandinavian countries during the Second wave
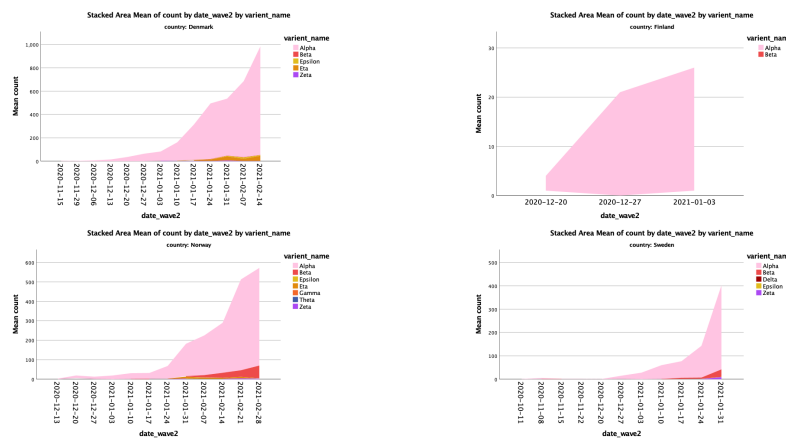
Figure 26: The variants during the second wave in the four Scandinavian countries.
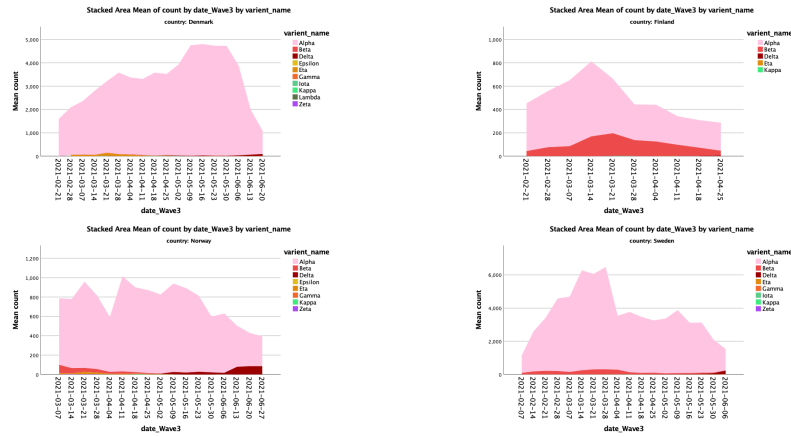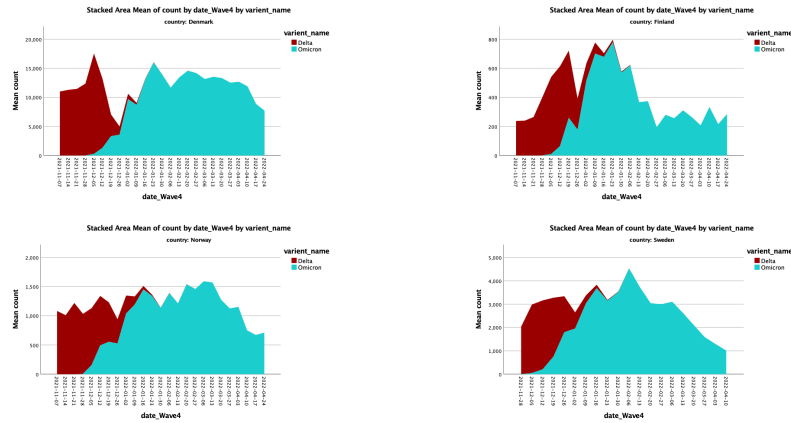
II-The variants of Covid-19 during the third wave

Figure 27: The variants during the third wave in the four Scandinavian countries.

III-The variants of Covid-19 during the fourth wave

Figure 28: The variants during the fourth wave in the four Scandinavian countries.

10.3 The vaccination capacity during each wave

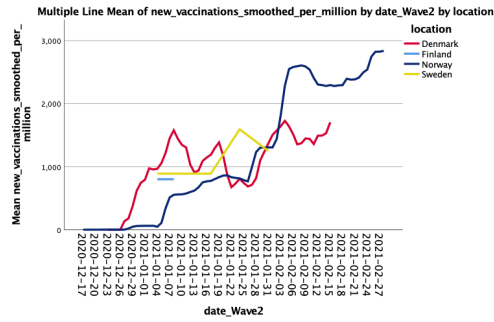- **The vaccination during the second wave**

Figure 29: The number of new vaccination per million in the Scandinavian countries during the second wave.
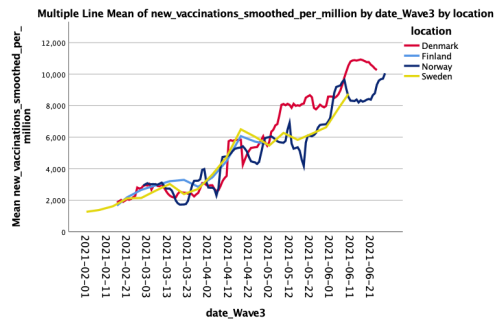
- **The vaccination during the third wave**

Figure 30: The number of new vaccination per million in the Scandinavian countries during the third wave.
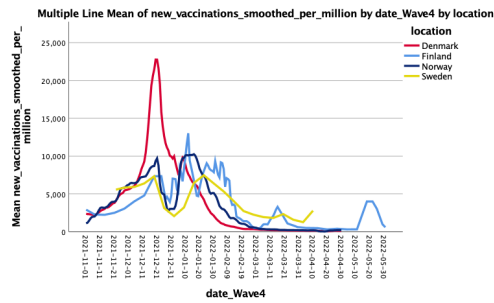
- The vaccination during the fourth wave

Figure 31: The number of new vaccination per million in the Scandinavian countries during the fourth wave.

10.4 The stringency index during the different waves

- Stringency index in the Scandinavian countries during the first wave

Figure 32: Left figure:Stringency index in Scandinavian countries during the first wave.Right figure:Cumulative sum of stringency index in Scandinavian countries.

- The stringency index in the Scandinavian countries during the second wave

Figure 33: Left figure:Stringency index in Scandinavian countries during the second wave.Right figure:Cumulative sum of stringency index in Scandinavian countries during the second wave.

- The stringency index in the Scandinavian countries during the third wave

Figure 34: Left figure:Stringency index in Scandinavian countries during the third wave.Right figure:Cumulative sum of stringency index in Scandinavian countries during the third wave.

- The stringency index in the Scandinavian countries during the fourth wave

Figure 35: Left figure:Stringency index in Scandinavian countries during the fourth wave.Right figure:Cumulative sum of stringency index in Scandinavian countries during the fourth wave.
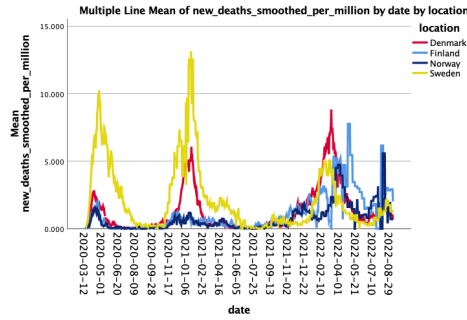
10.5 New deaths

Figure 36: The number of new deaths smoothed per million in Scandinavia
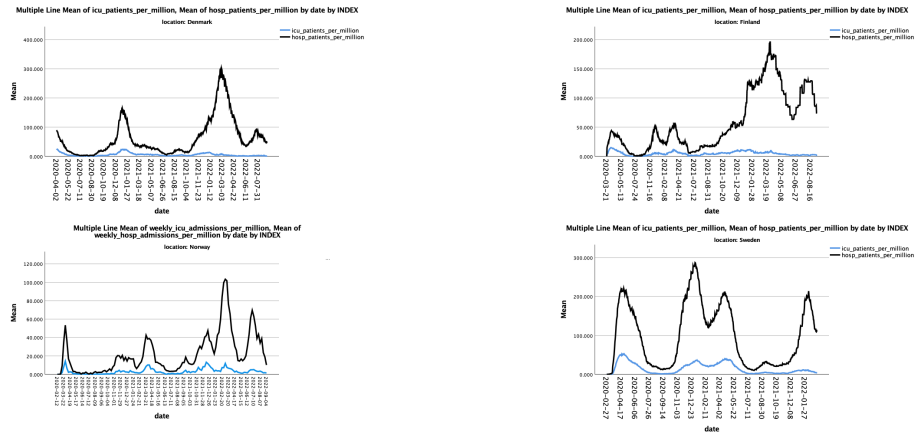
10.6 Hospitalized and ICU patients

Figure 37: The number of hospital admissions and ICU patients in each of the Scandinavian countries.

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