Czech University of Life Sciences Prague

Faculty of Economics and Management

Department of Information Technologies

Bachelor Thesis

Analysis of Covid-19 Restrictions Efficiency

Ekaterina Yakina

CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Economics and Management

BACHELOR THESIS ASSIGNMENT

Ekaterina Yakina

Informatics

Thesis title

Analysis of Covid-19 Restrictions Efficiency

Objectives of thesis

The main objective is to compare the impact of restrictions and methods of controlling the spread of COVID-19 disease in different countries. The partial objectives are:
– Collect information on what kind of restrictions have been applied in chosen countries
– Gather data on the number of cases before and after restrictions were imposed
– Analyze the effect of restrictions on number of COVID-19 cases in observed time period

Methodology

Methodology of the theoretical part will be based on studying available information sources. In the practical part data will be collected regarding development of number of cases in chosen countries. Information about applied restrictions will be gathered and based on statistical analysis of the data the effect of restrictions will be evaluated. Final conclusions will be made based on synthesis of knowledge obtained in the theoretical part and the results of the practical part.

The proposed extent of the thesis

40-50

Keywords

Data analysis, covid-19, restrictions, pandemic, disease spread, statistical analysis

Recommended information sources

Flaxman, S., Mishra, S., Gandy, A. et al. Estimating the effects of non-pharmaceutical interventions on COVID-19 in Europe [online]. Nature 584, 257–261 (2020). Available at: https://doi.org/10.1038/s41586-020-2405-7

Jack Schijven, Lucie C. Vermeulen, Arno Swart, Adam Meijer, Erwin Duizer, and Ana Maria de Roda Husman. Quantitative Microbial Risk Assessment for Airborne Transmission of SARS-CoV-2 via Breathing, Speaking, Singing, Coughing, and Sneezing. [online] Environmental Health Perspectives 129:4, (2021). Available at: https://doi.org/10.1289/EHP7886

JENNIFER Peat, BELINDA Barton . Medical Statistics: A Guide to SPSS, Data Analysis and Critical Appraisal. John Wiley & Sons, Incorporated, 2005. ISBN: 1118589939

Expected date of thesis defence

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The Bachelor Thesis Supervisor

Ing. Jan Pavlík

Supervising department

Department of Information Technologies

Electronic approval: 17. 8. 2021

doc. Ing. Jiří Vaněk, Ph.D.

Head of department

Electronic approval: 5. 10. 2021

Ing. Martin Pelikán, Ph.D.

Dean

Prague on 30. 11. 2023

Declaration

I declare that I have worked on my bachelor thesis titled "Analysis of Covid-19 Restrictions Efficiency" by myself and I have used only the sources mentioned at the end of the thesis. As the author of the bachelor thesis, I declare that the thesis does not break any copyrights.

In Prague on 30.11.2023 ___________________________

Acknowledgement

I want to express my gratitude to my supervisor, Ing. Jan Pavlík, for the invaluable help, support, advice, ideas, and guidance provided during the entire thesis process.

Analysis of Covid-19 Restrictions Efficiency

Abstract

This thesis analyses the impact of covid restrictions in the Czech Republic, Germany and the Netherlands on the dynamics of the spread of the disease. The main research question is whether these restrictions have a positive impact on reducing the number of new cases of the disease. To achieve this goal, an analysis of the restrictions applied in these countries was carried out, the time periods for their introduction were determined, and their effect was assessed in the context of containing the spread of the disease.

Keywords: Data analysis, covid-19, restrictions, pandemic, disease spread, statistical analysis

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List of Abbreviations

COVID-19	Coronavirus disease 2019
IgM	Immunoglobulin M
IgG	Immunoglobulin G
PCR	Polymerase chain reaction
SARS-CoV-2	Severe acute respiratory syndrome coronavirus 2
WHO	World Health Organization

1 Introduction

On December 31, 2019, the World Health Organization received a report of cases of pneumonia caused by an unknown pathogen. On January 3 the following year, Chinese authorities reported 44 cases of pneumonia in Wuhan, Hubei. The virus affected by the new coronavirus was named SARS-CoV-2 and was previously unknown.

On January 30, 2020, the epidemic caused WHO to declare a public health emergency of international concern, and on February 28, 2020, the global risk assessment level was high to very high. On March 11 of the same year, the epidemic was declared a pandemic.

One of the main threats of the pandemic is the possibility of overwhelming the health care system due to the large number of infected people, which could lead to an increase in hospitalizations and deaths. Healthcare may not be prepared for so many critically ill patients. Therefore, the main strategy to combat the pandemic has become not only treating the infection, but also slowing its spread in order to relieve the burden on the healthcare system and provide care to more people.

To contain the virus outbreak, many countries have introduced a series of much needed but extremely difficult measures known as lockdowns. These measures included self-isolation, quarantine, border closures, restricted air travel between countries, curfews, social distancing and mandatory testing.
In this work, we will analyse the key quarantine restrictions adopted in various countries and examine their impact on the spread of COVID-19.

2 Objectives and Methodology

2.1 Objectives

This bachelor's thesis consists of a thorough comparison of individual measures taken in response to the global COVID-19 pandemic in three countries - the Czech Republic, Germany and the Netherlands. The main task is to analyse the restrictions that were designed to slow and control the spread of the virus. This main goal includes several key sub-goals aimed at achieving completeness of the study:

- Collection of information about what restrictions and when were applied in selected countries.
- Analyse the impact of restrictions on the number of cases of COVID-19 infection for a selected period of time.

2.2 Methodology

The research project is structured into two parts: a literature review and a practical practical part. In the theoretical segment, drawing from literature, is presented an overview of the pandemic issue. This includes an exploration of the disease transmission mechanisms, WHO's primary epidemiological recommendations for disease control and prevention, and an elucidation of key terminologies associated with COVID-19.

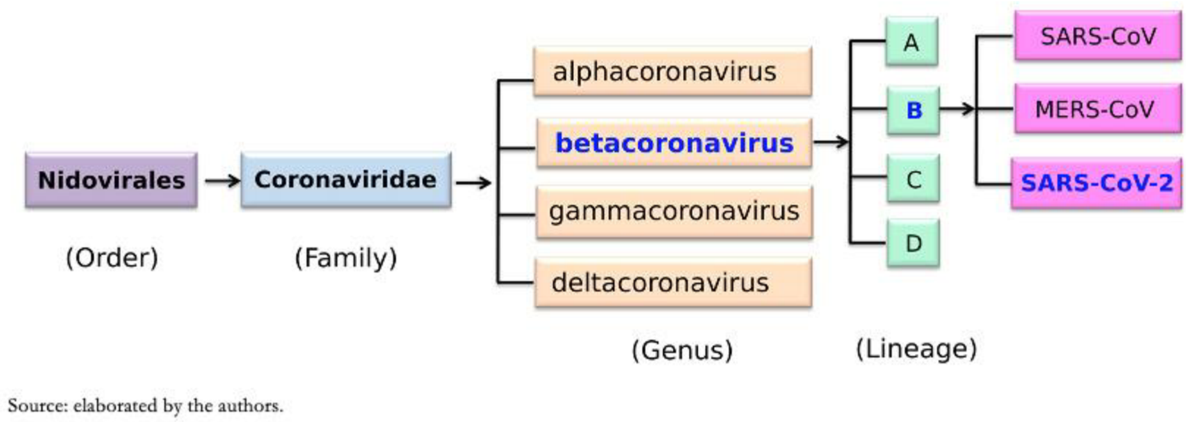
Transitioning to the practical part, the study involves the meticulous collection of data pertaining to the trajectory of COVID-19 cases in selected countries, both preceding and following the implementation of preventive measures. The focus is on quantifying the number of infections during these specific periods. Subsequently, a statistical analysis of the collected data will be conducted to assess the impact of the imposed restrictions.

The combination of the results of the theoretical and practical aspects will enable the formulation of comprehensive conclusions. By combining the received data in the theoretical segment and the insights derived from the practical analysis, the study aims to provide an understanding of the effectiveness of the implemented measures in controlling and preventing the spread of COVID-19. This integrated approach seeks to offer valuable insights into the broader dynamics of pandemics and their management strategies.

3 Literature Review

3.1 Coronavirus

The origins of the coronavirus can be traced from the late 1920s when the first documented instance emerged as a contagious avian influenza virus. This virus belongs to the family Coronaviridae, a term encompassing four distinct virus families, each varying in its level of harm to humans. Common carriers of this virus include mice, cats, and various other species (Singhal, 2020).



Picture 1 Taxonomic classification of coronavirus

Source: https://www.medwave.cl/revisiones/revisionclinica/8037.html?lang=en

COVID-19, caused by the coronavirus, shares similarities with the flu but can manifest in more severe ways. Typical symptoms include fever, fatigue, and cough, mirroring those of influenza. It's worth noting that some individuals may experience a mild progression of the disease or may remain asymptomatic altogether (Menni, Valdes, Freidin, Sudre, Nguyen, Drew, 2020). The incubation period for the COVID-19 virus is generally considered to be between few days and two weeks. (Lauer, Grantz, Bi, Jones, Zheng, Meredith, 2020)

Among the ongoing pandemic, significant efforts have been directed towards vaccine development. Several vaccines are currently available, representing a crucial advancement in collective response to the virus. These vaccines play a pivotal role in mitigating the impact of COVID-19, offering effective prevention and control measures.

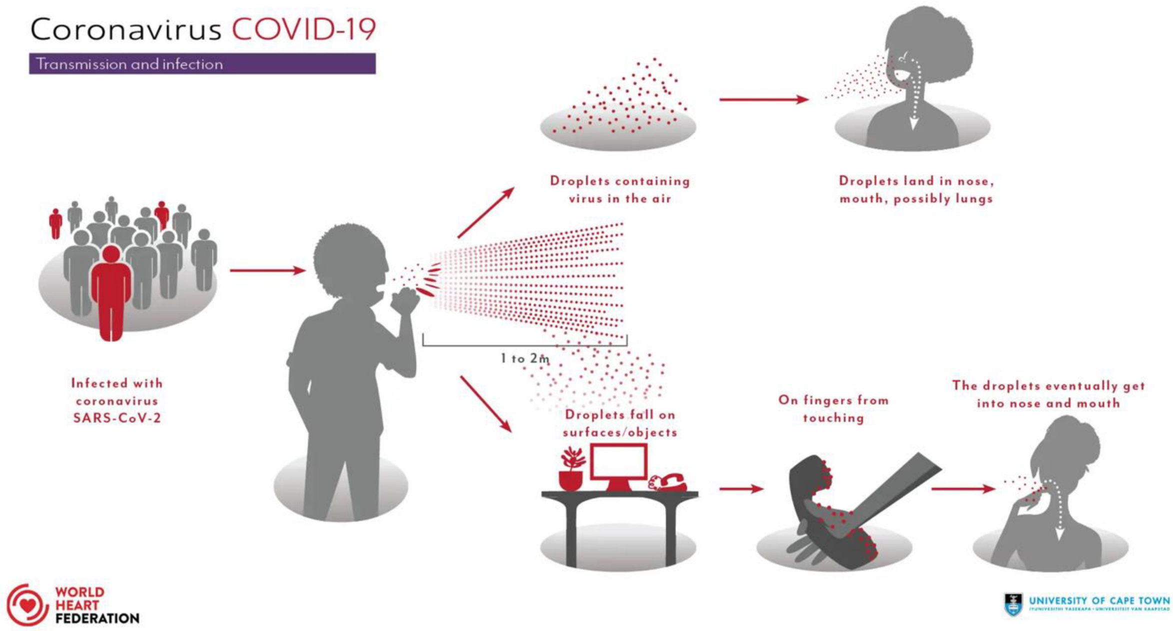
3.1.1 Virus transmission

Current evidence indicates that the virus is primarily transmitted through airborne and droplet routes. For instance, when speaking, breathing, sneezing or coughing, small splashes and drops of saliva and nasal mucus that contain diseases are released from the mouth or nose. Another individual, during close contact, up to 2 meters away, will become infected with the virus when the infectious particles that pass through the air are inhaled or directly enter contact with the eyes, nose, or mouth.

At times, the progression of the disease may be asymptomatic, yet even in such cases, individuals can remain infectious, enabling the virus to spread to others. The peak of infectivity typically occurs during the early stages of the disease and at the onset of initial symptoms. In severe cases, the infectious period may extend for a longer duration (Lotfi et al., 2020).

The virus demonstrates a propensity for spreading in environments with limited ventilation, particularly where a substantial number of people congregate for extended periods, such as classrooms or offices (Wong, Li, 2020). This is attributed to the ability of viruses to remain suspended in the air or travel distances beyond those associated with normal conversation. Additionally, infection can occur through contact with surfaces or objects that have been contaminated, followed by touching the eyes, nose, or mouth (Dockery et al., 2020).

In the early days of the SARS-CoV-2 outbreak, the transmission mechanism was initially unclear. However, subsequent to the initial wave, preventive measures were proposed to curb the transmission of COVID-19. The virus primarily spreads through expelled fluids and particles, with the concentration being highest in proximity to the infected individual. The likelihood of transmission is consequently most elevated in that immediate area (Wong, Li, 2020).



Picture 2 Covid - 19 transmission

Source: https://world-heart-federation.org/resource/covid-19-transmission/

Transmission commonly occurs through actions like coughing, wherein airborne particles play a central role. Direct contact with infected individuals or their bodily excretions, as well as procedures generating aerosols, are also significant modes of transmission. Infected individuals emit droplets and particles during exhalation, ranging in size from microscopic to visible. Inhaling air containing these particles from an infected person poses a transmission risk, allowing them to disperse throughout enclosed spaces. The likelihood of transmission exceeds 20 percent within a two-meter radius of the infection source (Jayaweera, 2020).

While less common, alternative modes of transmission include direct contact with contaminated surfaces, followed by unwittingly touching these surfaces and subsequently the face.

Maintaining awareness of these varied transmission routes is crucial in implementing effective preventive measures and reducing the overall risk of COVID-19 transmission

(Jayaweera, 2020). Such awareness among the public is very important to understand the importance of compliance with these measures.

3.1.2 Seasonality in the spread of COVID-19

The seasonality of COVID-19 is evident, showcasing an increase in cases during the winter months, aligning with patterns observed in other coronavirus infections and seasonal influenza. Research has unveiled a notable correlation between the transmission frequency of COVID-19 and seasonal variations, with higher latitudes experiencing heightened transmission rates(Sajadi, 2020).

In colder climates, studies have shown a rise in both the infectivity and mortality associated with SARS-CoV-2, contributing to an overall increase in the total number of infections during the cold season. Conversely, the warmer seasons in various countries have been linked to a reduction in the overall number of infections (Liu, 2021).

However, it's imperative to acknowledge that the mere increase in humidity and temperature during spring and summer is insufficient in itself to cause a decrease in the volume of cases. Mitigating the spread of COVID-19 demands a multifaceted approach that goes beyond seasonal variations. While warmer weather might play a role in reducing transmission, it must be complemented by robust preventive measures and public health initiatives (Liu, 2021).

This emphasizes the importance of sustained efforts in vaccination campaigns, promoting good hygiene practices, encouraging mask-wearing, and adhering to social distancing guidelines, regardless of the season.

3.2 Coronavirus Prevention

The World Health Organization has issued general guidance that can be used to reduce the probability of being infected with SARS-CoV-2:

- regularly lave your hands with soap or utilize an alcohol-based hand sanitizer;
- When coughing or sneezing, cover your mouth and nose with a bent elbow or a disposable tissue;
- try to avoid touching your nose, mouth, and eyes as much as possible;
- maintain a 1 meter distance from other people in public areas.

Picture 3 Coronavirus prevention methods

Source: https://elch.org/patients-visitors/covid-19-patient-visitor-information/

During a pandemic the most effective strategy for stemming the spread of infection involves a multifaceted approach aimed at controlling the sources of the disease. This involve the isolation, early diagnosis, and communication to the population about the nature and preventive measures associated with the disease(Adhikari et al., 2020).

Numerous countries have adopted and implemented social distancing strategies as part of their comprehensive response to the pandemic. These strategies include travel bans, the temporary closure of schools and colleges, encouraging telecommuting, isolating and quarantining sick individuals, and canceling events. All these measures afford to slowing of the infection's progression(Matrajt, Leung, 2020).

Research based on disease spread modeling emphasizes the pivotal role of quarantine in reducing the spread of disease and reducing mortality rates. However, the most significant impact is achieved through the coactiong implementation of various preventative measures alongside quarantine practices. This integrated approach, which may include widespread testing, contact tracing, and vaccination efforts, maximizes the effectiveness of containment strategies (Adhikari, et al. 2020).

3.3 Incubation period

Guided by the premise that the incubation period for COVID-19 spans from 1 to 14 days, the World Health Organization advocates a 14-day isolation period for close contacts. Different variants of the virus have their own characteristics: the Omicron variant develops symptoms within two to three days, while the alpha and beta variants develop over a five-day incubation period(Jansen et al., 2021). The Delta variant follows suit with an incubation period of 4.3 days, and notably, the Omicron variant boasts the swiftest manifestation, taking only 3-4 days post-infection (Lauer et al., 2020).

During this incubation phase, as symptoms first make their appearance, it is advisable to undergo retesting, as this period may impact the accuracy of test results. Some tests could be positive for COVID-19 even during the incubation period. The highest level of contagion is observed within the 48 hours preceding symptom onset, steadily escalating over the subsequent five days after symptoms emerge (Backer, Klinkenberg, Wallinga 2020).

3.4 Severity of illness

Covid-19, caused by the SARS-CoV-2 virus, can manifest in varying levels of severity, from mild symptoms to severe and critical conditions. These levels are often classified into three categories: mild, moderate and severe (Verity et al., 2020).

3.4.1 Light form

People with mild COVID-19 often experience mild symptoms, which may include:

- Headache
- Fatigue
- Mild muscle pain
- Loss of smell or taste
- Slight sore throat.
- Slight increase in temperature.

Most people with mild illness recover at home without the need for hospitalization. However, even if the condition is light, it is important to stay in touch with medical services, especially if the condition worsens (Henry et al., 2020), (Verity et al., 2020).

3.4.2 Moderate form

Moderate severity includes more severe symptoms and possibly longer duration of illness. This may include:

- Breathing difficulties
- High temperature
- Constant chest pain
- Violation of the sense of reality
- Severe weakness and fatigue

People with moderate disease sometimes require hospitalization for medical observation and treatment.

3.4.3 Severe form

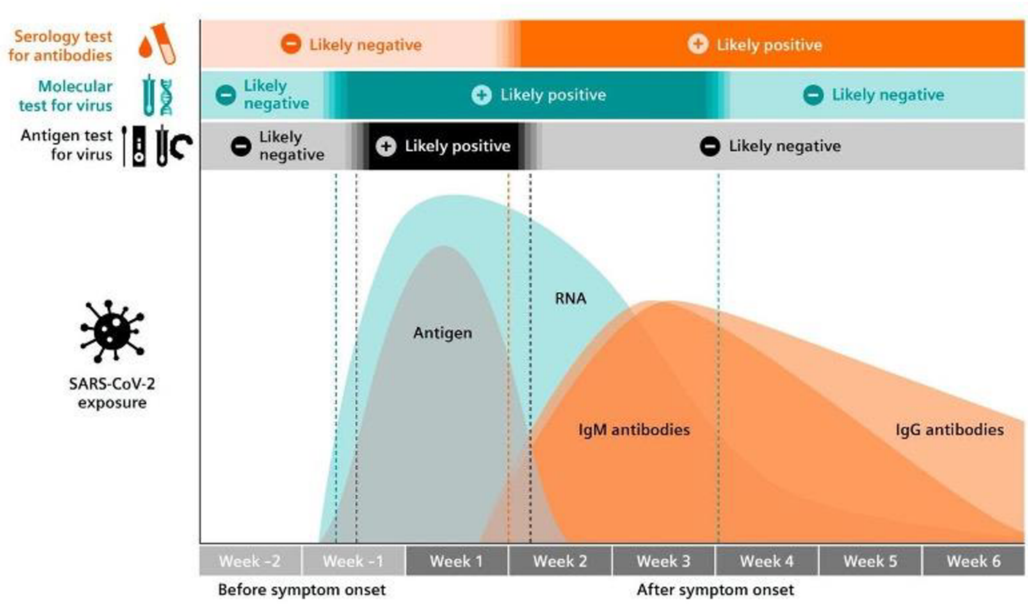
Severe COVID-19 can lead to serious breathing problems and organ problems. Symptoms may include:

- Severe breathing difficulties
- Constant pain or pressure in the chest
- Blue tints to the skin or lips
- Inability to awaken or remain awakened

People with severe forms often require intensive care and the use of medical devices to support breathing (Henry et al., 2020).

3.5 COVID-19 testing

Testing for COVID-19 is an important aspect of managing the spread of the virus. Effective testing is key to controlling the spread of COVID-19, and different methods can tailor the approach to the situation and provide accurate and rapid results to effectively manage the pandemic. There are several testing methods, each of which has its own characteristics.



Picture 4 Different types of COVID-19 testing

Source: https://www.siemens-healthineers.com/cz/laboratory-diagnostics/assays-by-diseases-conditions/infectious-disease-assays/serology-testing-for-covid-19

3.5.1 Polymerase chain reaction

PCR (polymerase chain reaction) testing is a highly accurate and widely used method for diagnosing genetic material, including viruses, bacteria and other pathogens. In the second case of COVID-19, PCR testing became registered to detect the national SARS-CoV-2 virus. PCR testing is an effective tool for early diagnosis of COVID-19, which allows measures to be taken to control the spread of the virus (Ai et al., 2020).

In the case of testing for COVID-19, the genetic material of the virus is examined. Typically, PCR testing uses a sample of the mucous membrane of the upper respiratory tract, such as a nasal or throat swab (Ai et al., 2020). Correct sample collection and the quality of the reagents used play a key role in achieving accurate results. A positive result indicates the presence of the virus in the body. A negative result does not exclude the possibility of infection, especially if the sample is taken early in the incubation period (Corman et al., 2020).

PCR tests are used for screening, diagnosing infection, monitoring the epidemiological situation, and confirming recovery from the disease.

Picture 5 PCR test method

Source: https://www.freepik.com/premium-vector/nasal-swab-test-concept_8510640.htm

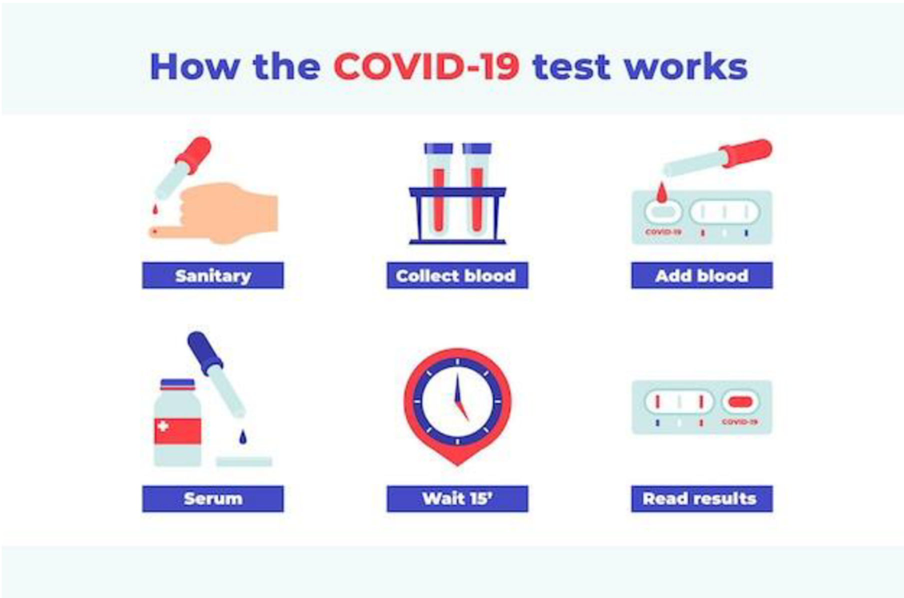
3.5.2 Antibody Test

This is an analysis that detects antibodies to Covid-19. Such testing shows high results in terms of accuracy, but there is an important nuance. In humans, IgM antibodies are first produced in response to infection, and only later – IgG (Hou et al., 2020).

Antibody testing is an important aspect of diagnosing COVID-19. The immune system produces antibodies in response to antigens such as pathogenic viruses and bacteria. The presence of IgG and IgM antibodies in body fluids, including blood and extrinsic secretions, indicates an underlying infection (Hou et al., 2020).

IgM antibodies are detected first, usually within the first week after infection, while IgG antibodies are detected 7–10 days after infection. Serological tests are used to detect and monitor antibodies in infected patients and assess the severity of patients' symptoms (Xiang et al., 2020).

The accuracy of serological tests can be improved by combining the detection of IgM and IgG antibodies. However, such tests can give both false positive results due to other strains of the virus, and negative results that do not rule out infection (Xiang et al., 2020).



Picture 6 Antibody test method

Source: https://www.freepik.com/free-vector/how-covid-19-tests-work-with-steps_8015357.htm#query=covid%20Antibody%20Test&position=0&from_view=search&track=ais&uuid=94c24e9a-bed1-46ef-a68f-e84efdd6e760

3.5.2.1 Immunoglobulin M

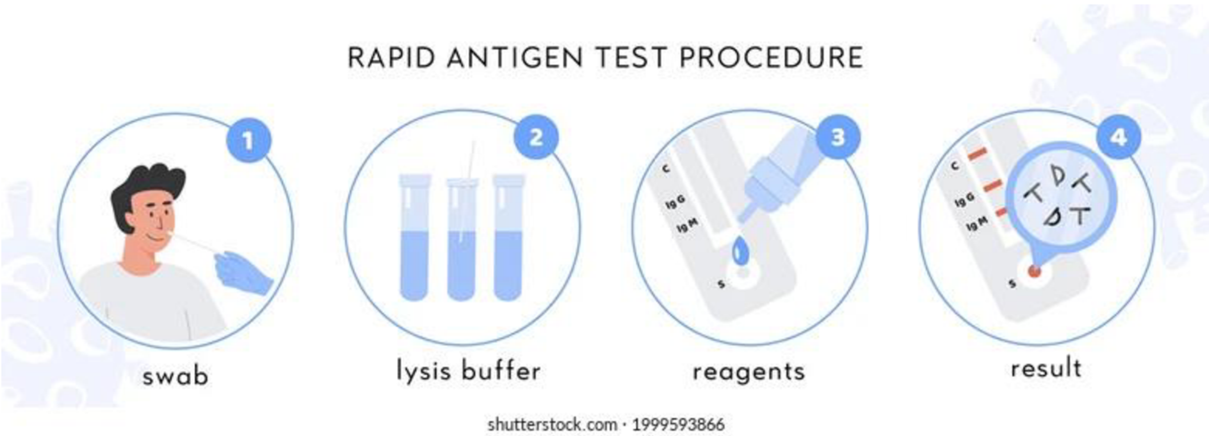
IgM is present in the body with severe symptoms of the disease (usually 5-7 days after the first symptoms), and then the concentration of these antibodies drops. In fact, IgM testing may be an alternative to PCR during the active stage of the disease (Xu et al., 2020).

3.5.2.2 Immunoglobulin G

The IgG test shows the presence of immunity to Covid-19. It is advisable to do it already 2-3 weeks after the first symptoms, or even later. The reason for taking an IgG test is often a person's desire to understand whether he has had a coronavirus infection or not, whether the body has developed immunity to infection (Xu et al., 2020).

3.5.3 Antigen tests

Antigen tests are a method for quickly diagnosing infections, including COVID-19. These tests aim to detect the presence of certain proteins in the body that are characteristic of the SARS-CoV-2 virus. Antigen tests provide speed and convenience in screening and responding to potential infections, playing an important role in the fight against the pandemic (Mak et al., 2020).



Picture 7 Antigen test instruction

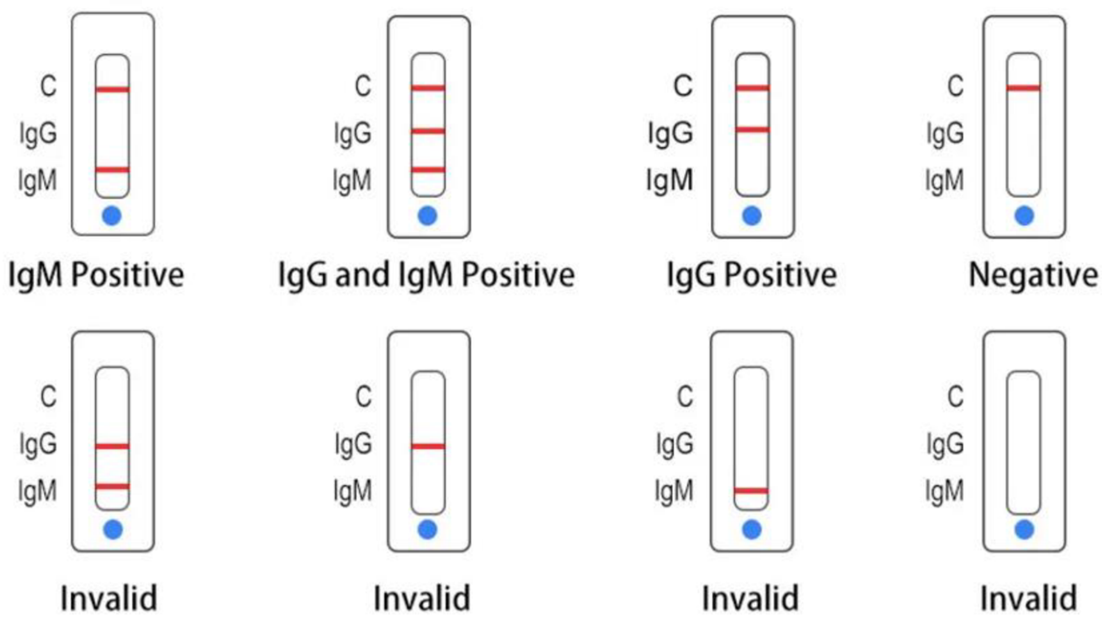
Source: https://stock.adobe.com/dk/images/covid-19-rapid-antigen-test-procedure-infographic-a-doctor-takes-nasal-swab-from-male-patient-coronavirus-swap-sample-in-lysis-buffer-strip-with-reagents-and-result-with-antigen-molecules-vector/442462068

Antigen tests use antibodies that are specific to virus antigens. If a virus is present in the sample, the antibodies react with the antigens, causing a visible reaction. A swab from the upper respiratory tract, such as the nose or throat, is usually used (Mak et al., 2020).
One of the key advantages of antigen tests is their speed. Results are usually available in 15-30 minutes. Compared to PCR tests, antigen tests may have slightly lower sensitivity and specificity, especially in early stages of the disease or in people without symptoms.

The widespread use of antigen tests has become an important element of strategies to control the spread of COVID-19, especially in situations that require rapid and accessible results (Mak et al., 2020).

The results may be positive, negative or invalid (Picture 9).

- Positive result: If a test line appears, this may indicate the presence of antigen in the sample.
- Negative result: If the test line is missing, this may indicate that there is no antigen in the sample.
- Invalid result: In some cases, the test may not be sensitive or specific enough, resulting in an indeterminate result. In such cases, it is recommended to repeat the test.



Picture 8 COVID - 19 test results interpretation

Source: https://www.antibodies.com/de/covid-19-rapid-test-kit-igg-igm-colloidal-gold-a122152

3.6 Czech Republic

3.6.1 Beginning of the pandemic at spring 2020

First cases and reaction:

- The first cases of COVID-19 in the Czech Republic were recorded in March 2020.
- The government has introduced measures including school closures, traffic restrictions and restrictions on businesses.

Quarantine and movement restrictions:

- A strict quarantine was introduced, restricting the movement of citizens and closing many public places.

Medical measures:

- Testing and contact tracing have been significantly enhanced.
- Scaling medical capacity to combat the outbreak.

3.6.2 Summer-autumn 2020

Easing restrictions:

- Since the summer of 2020, with the number of cases decreasing, the Czech Republic began to ease restrictions.
- Opening of restaurants, shops and other businesses with safety measures in place.

Re-burst control:

- A second wave at the end of 2020 led to new restrictions and temporary closures of public places.

3.6.3 Winter-spring 2020-2021

Vaccination and continuation of measures:

- Vaccination began at the beginning of 2021. Priority was given to health workers and the most vulnerable groups.
- Continued measures in response to the third wave of the pandemic.

3.6.4 End of 2021 – 2022

Continued vaccination and adaptation of measures:

- Vaccinations were expanding to include wider age groups.
- The authorities adapted measures depending on the epidemiological situation.

Restrictions on events and movement:

- Restrictions have been introduced on public events and travel, depending on the level of infection.

Adaptive measures for the summer:

- In the summer months of 2021, as the situation improved, many restrictions were eased again.

Additional surges and measures:

- Some regions have seen new surges, leading to local restrictions.

3.7 Germany

3.7.1 Beginning of the pandemic spring 2020

Quarantine and movement restrictions:

- In March 2020, Germany introduced a partial lockdown, closing schools, shops and restaurants.
- Citizens were advised to stay at home, and travel was allowed only for urgent cases.

Ban on mass events:

- Large gatherings and events such as festivals and concerts have been cancelled.

Work from home:

- Many companies have moved to remote work for employees to reduce exposure and the risk of transmission of the virus in the workplace.

Medical measures:

- Testing measures have been stepped up and extensive contact tracing has been introduced.
- Hospitals were expanding units to treat COVID-19 patients.

3.7.2 Summer-autumn 2020

Gradual lifting of restrictions:

- After the summer of 2020, depending on the epidemiological situation, the government gradually relaxed restrictions.
- Restaurants, shops, and other businesses opened, but with strict safety measures in place.

Economic support:

- The state provided financial support to companies, entrepreneurs and the population affected by the pandemic.

Vaccination:

- Vaccination began at the end of 2020. At first, priority was given to health workers and the most vulnerable groups.
- The vaccination program has rapidly scaled up, with vaccines becoming available to a wider audience in 2021.

3.7.3 End of 2021 – 2022

Continuation of vaccination:

- Vaccination efforts continued with a focus on increasing population coverage.

Adaptation of measures depending on the situation:

- The authorities regularly updated measures in response to the dynamics of the incidence and epidemiological situation.

3.8 Netherlands

3.8.1 Beginning of the pandemic spring 2020

First cases and reaction:

- The first cases of COVID-19 in the Netherlands were reported in February-March 2020.

- Government authorities have begun introducing measures to prevent the spread of the virus.

Quarantine and movement restrictions:

- In March 2020, a smart lockdown was introduced with the closure of restaurants, bars, and educational institutions.
- Citizens were advised to work from home and travel was limited.

Contact testing and tracing:

- Testing measures for COVID-19 have been strengthened and a contact tracing system has been introduced to quickly identify and isolate infected people.

3.8.2 Summer-autumn 2020

Easing restrictions:

- After the summer of 2020, a decline in the number of cases allowed the Netherlands to gradually ease restrictions.
- Restaurants, shops, and other businesses opened.

Increase in cases and new measures:

- In the fall of 2020, as the number of cases increased, new measures were introduced, such as restrictions on opening hours and maximum number of visitors.

3.8.3 Winter-spring 2020-2021

Second wave and tightening of measures:

- The second wave at the end of 2020 led to stricter measures, including the closure of some types of businesses and the introduction of a “smart” lockdown.

Vaccination:

- Vaccination began at the beginning of 2021. Priority was given to health workers and the most vulnerable groups.

3.8.4 End of 2021 – 2022

Continued vaccination and adaptation of measures:

- The vaccination process has been scaled up to include wider age groups.
- Authorities continued to adapt measures in response to the epidemiological situation.

Third wave and additional measures:

- In the spring of 2021, a third wave prompted new restrictions, including the temporary closure of some public places.

Restrictions on events and movement:

- Restrictions have been introduced on public events and travel, depending on the situation in different regions.

Adaptive measures for the summer:

- In the summer months of 2021, as the situation improved, many restrictions were eased again.

4 Practical Part

The practical section of the thesis has several stages aimed at performing analysis. These steps cover the processes of collecting data from open data source, cleaning and preparing it for subsequent analysis, and generating the graphs needed to conduct linear analysis and regression. Particular attention is paid to the methodology of data collection, data cleaning and pre-processing. These stages represent key steps in preparing data for analysis.

4.1 Open data

Open data is a concept that reflects the idea that certain data should be freely available for machine-readable use and further republication without restrictions of copyright, patents and other control mechanisms (Kitchin, 2014).

4.2 Regression

Regression is a statistical technique used to study the relationship between a dependent variable and one or more independent variables. The main purpose of regression is to understand how changes in one variable are related to changes in another (Draper, Smith, 1998).

There are several types of regression, but one of the most common is linear regression, where a linear relationship is assumed between variables. A linear regression equation looks for the line that best fits the data and can be used to predict the values of a dependent variable based on the values of the independent variables.

Significance of regression coefficient is an assessment of the statistical significance or insignificance of the coefficients obtained in regression analysis. When a regression model is built to predict a dependent variable from one or more independent variables, each coefficient on the independent variable has its own statistical significance (Sen, 1968).

Correlation Coefficient Value (r)	Direction and Strength of Correlation
-1	Perfectly negative
-0.8	Strongly negative
-0.5	Moderately negative
-0.2	Weakly negative
0	No association
0.2	Weakly positive
0.5	Moderately positive
0.8	Strongly positive
1	Perfectly positive

Picture 9 Meaning of correlation coefficient value (r)

Source: https://www.researchgate.net/figure/Meaning-of -correlation-coefficient-value-r_tbl1_299402589

4.3 Data preparation

We will use publicly available data by downloading two files: "epidemiology.csv" and "oxford-government-response.csv". After this, we will select the information we are interested in from these files and combine it into one, thereby creating a consolidated data set. This approach will provide convenience for subsequent analysis, allowing us to work with a single and structured data set.

In this work will be used the following libraries: pandas, matplotlib, seaborn, scikit-learn (via LinearRegression), and the requests and StringIO modules are also used.

The pandas library provides powerful tools for working with data in tabular form, making it easy to load, process, and present data. Matplotlib and seaborn are used for data visualization. Matplotlib produces a variety of plots, while seaborn provides a high-level interface for creating statistical plots, making it easy to visualize data distributions and other statistical aspects.

Scikit-learn provides an implementation of a linear regression model, which is used to approximate a linear relationship between variables. This model is useful for analyzing the influence of variables on the dependent variable.

The requests and StringIO modules are used to provide the ability to load data from external sources via HTTP requests and process data in CSV format, respectively. Thus, the joint use of these libraries and modules provides a full cycle of working with data, from loading and processing to visualization and building models for further analysis (McKinney et al., 2011).

4.3.1 Downloading data

Our analysis requires key indicators: country code('location_key'), new COVID-19 cases('new_confirmed'), observation dates('date') and level of severity of restrictions ('stringency_index'). We will extract this data from open sources and combine it for subsequent analysis.

Sets the URL where the CSV file with COVID-19 incidence data is stored.
requests.get(url) sends a request to the specified URL and the response is stored in response_epd.

```
url = 'https://storage.googleapis.com/covid19-open-data/v3/epidemiology.csv'

response_epd = requests.get(url)
```

If the request is successful, the data is read from the CSV file into a DataFrame object using the pandas library.

```
df = pd.read_csv(StringIO(response_epd.text))
```

Then only those rows are selected where the 'location_key' column value matches one of the selected names (countries).

```
selected_names = ['CZ', 'DE', 'NL']

df_filtered = df[df['location_key'].isin(selected_names)]
```

Only the required columns are retained: 'date', 'location_key' (country code) and 'new_confirmed'.

```
selected_columns = ['date', 'location_key', 'new_confirmed']

df_selected = df_filtered[selected_columns]
```

Then the final data is saved to a CSV file named 'chosen country.csv' without indexes.

```
chosen_country_path = 'chosen country.csv'

df_selected.to_csv(chosen_country_path, index=False, encoding='utf-8')
```

In the same way we download the second file "oxford-government-response.csv", also filtering the necessary data by selecting columns: 'date', 'location_key', 'stringency_index'. Then we save the received data into file "stringency.csv" for subsequent work.

4.3.2 Data merging

Read the data for subsequent merging from two CSV files ('chosen country.csv' and 'stringency.csv') into two separate DataFrames - countries and stringency.

```
countries = pd.read_csv('chosen country.csv')

stringency = pd.read_csv('stringency.csv')
```

Specified the common columns by which the data will be merged: 'date' and 'location_key'.

```
common_columns = ['date', 'location_key']
```

Two DataFrames are merged using common columns defined in common_columns. The result is stored in a new DataFrame merged_df.

```
merged_df = pd.merge(countries, stringency, on=common_columns)
```

The combined data is saved to a new CSV file named 'combined data.csv' and no indexes are retained.

```
merged_df.to_csv('combined data.csv', index=False)
```

Now the resulting file with complete information can be used for subsequent analysis.

4.4 Preparing data for analysis

In the same way as before, we load data from the CSV file "combined data.csv" into the DataFrame using the "read" function.

Define variables to use in the code, such as column names for date (date), number of new cases (cases), country code (countries), and selected countries (selected_countries).

```
date = 'date'

cases = 'new_confirmed'

countries = 'location_key'

selected_countries = ['CZ', 'DE', 'NL']
```

The date column is converted to datetime objects and set as an index into the DataFrame for working with time series.

```
df[date] = pd.to_datetime(df[date])

df.set_index(date, inplace=True)
```

Created a new graphics window and then line graphs are plotted for each selected country. To improve visualization, the data is resampled by week and the number of new cases is divided by 1 million.

```
plt.figure(figsize=(10, 6))

for country in selected_countries:

new_cases = df[df[countries] == country].resample('W-Mon')[cases].sum()

new_cases = new_cases / 1000000

plt.plot(new_cases.index, new_cases, label=country)
```

Adding axis labels, graph title, and country legend.

```
plt.xlabel(f'Date')

plt.ylabel(f'New confirmed cases per million')

plt.title(f'New cases in Czech Republic(CZ), Germany(DE) and the Netherlands(NL)')

plt.legend()

plt.show()
```

4.4.1 Linear graph

Next, we will create a graph of 'new_confirmed' and the 'stringency_index' in just one country to better define the time periods for analysis.
Selecting data only for a specific country (in this case, the Czech Republic).

```
selected_country = 'CZ'

filtered_data = df[df['location_key'] == selected_country]
```

The date column is converted to datetime objects for more convenient work with time series.

```
filtered_data['date'] = pd.to_datetime(filtered_data['date'])
```

Create a figure fig and an axis ax1 for the first subplot.

```
fig, ax1 = plt.subplots(figsize=(10, 6))
```

Creating plot for new cases (new_confirmed) using the left axis ax1.

```
ax1.plot(filtered_data['date'],                filtered_data['new_confirmed'],
label='new_confirmed', color='blue')

ax1.set_xlabel('Дата')

ax1.set_ylabel('new_confirmed', color='blue')

ax1.tick_params('y', colors='blue')
```

A second subplot ax2 created with a common x-axis.

```
ax2 = ax1.twinx()
```

A graph is plotted for the stringency level (stringency_index) using the right axis ax2 and adding the graph.

```
ax2.plot(filtered_data['date'], filtered_data['stringency_index'], label='stringency_index', color='green')

ax2.set_ylabel('stringency_index', color='green')

ax2.tick_params('y', colors='green')

plt.title(' {}'.format(selected_country))

plt.show()
```

4.4.2 Linear correlation and regression plot

This code analyzes the relationship between two variables for a specific firm and over a specified time range.

Data is loaded from a CSV file into a DataFrame df.

Data is selected only for a specific country (target) and in a specified time range (start_date and end_date), which is considered in this case to analyze the relationship between new cases and the stringency index.

```
target = 'DE'

start_date = '2021-10-01'
```

```
end_date = '2022-03-31'

filtered_data = df[(df['location_key'] == target) & (df['date'] >=
start_date) & (df['date'] <= end_date)]
```

Building a scatter plot for the variables 'new_confirmed' and 'stringency_index', as well as a linear regression line predicting 'stringency_index' based on 'new_confirmed'.

```
plt.figure(figsize=(10, 6))

sns.scatterplot(data=filtered_data, x='new_confirmed',
y='stringency_index', marker='o')


correlation =
filtered_data['new_confirmed'].corr(filtered_data['stringency_index'])


X = filtered_data[['new_confirmed']]

y = filtered_data['stringency_index']

regressor = LinearRegression()

regressor.fit(X, y)

y_pred = regressor.predict(X)

plt.plot(X, y_pred, color='red', linewidth=2)
```

Add an annotation with the correlation coefficient on the graph, adding graph title and axes.

```
plt.text(filtered_data['new_confirmed'].min(),
filtered_data['stringency_index'].max(),
```

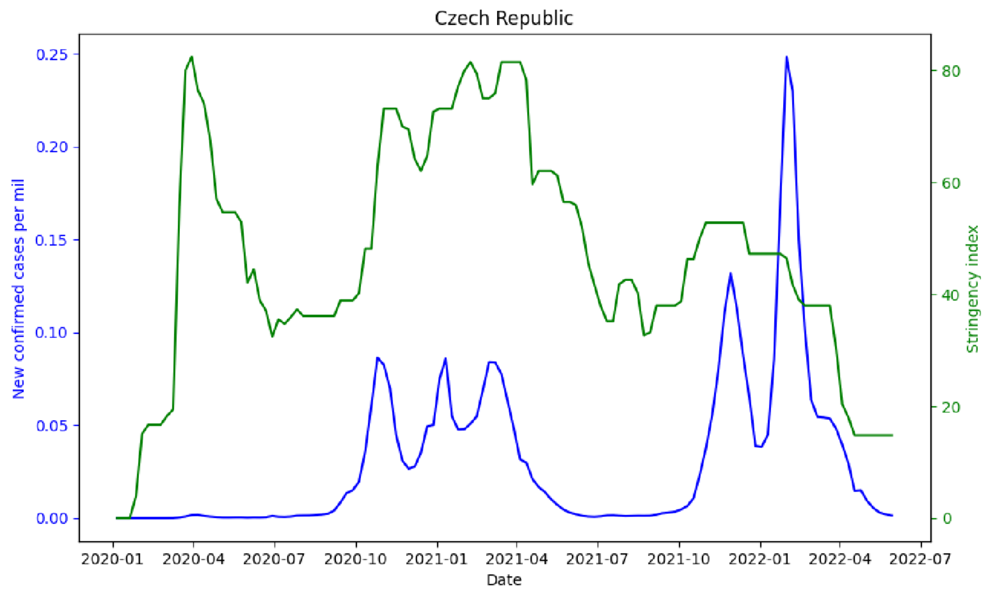
```
    f'Correlation: {correlation:.2f}', verticalalignment='top',
horizontalalignment='left',
    color='red', fontsize=12, bbox=dict(facecolor='white', alpha=0.7))
plt.title(f'Scatter plot for Germany')
plt.xlabel('New confirmed')
plt.ylabel('Stringency index')
plt.grid(True)
plt.show()
```

4.5 Data analysis

4.5.1 Czech Republic

At different periods of time, restrictions were introduced in the Czech Republic, such as quarantine measures, restrictions on movement, and the closure of enterprises and educational institutions. The introduction and lifting of restrictions often depended on the current epidemiological situation.

The Czech Republic actively participated in the vaccination program and provided access to various vaccines for its citizens. Vaccination is a key tool for controlling the spread of the virus and mitigating the severity of the disease.

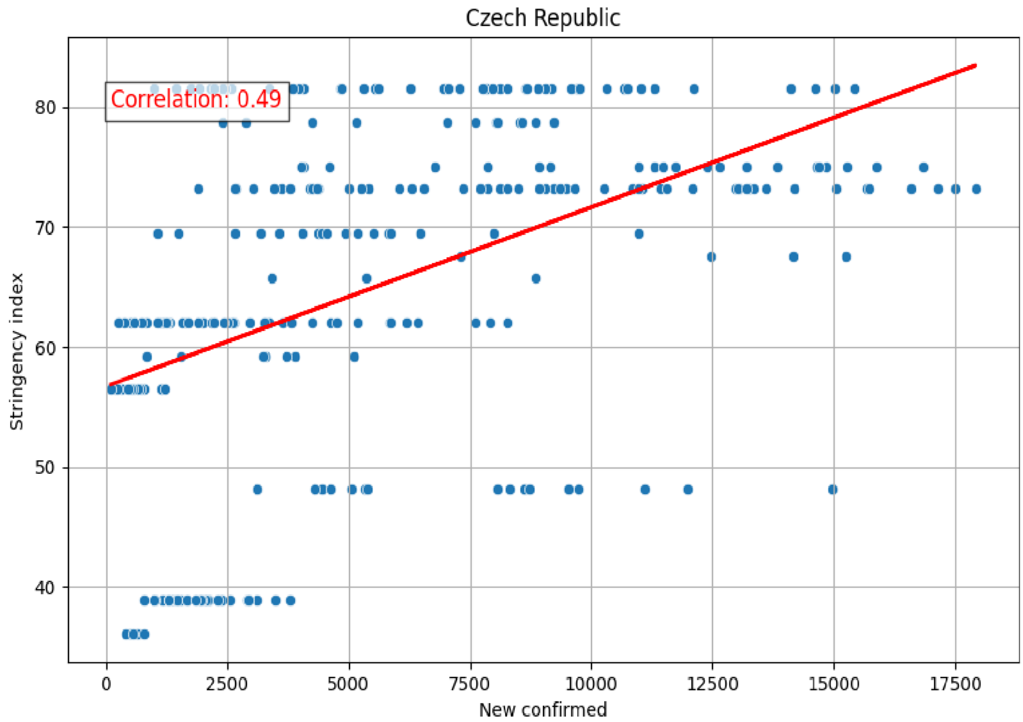


Graph 1 Czech Republic Linear graph for new confirmed cases and stringency index

Source: own processing

On the graph that we received in the previous part of the work, we can configure the two largest waves, new cases increasing in the autumn periods and decreasing in the spring periods (graph 1).

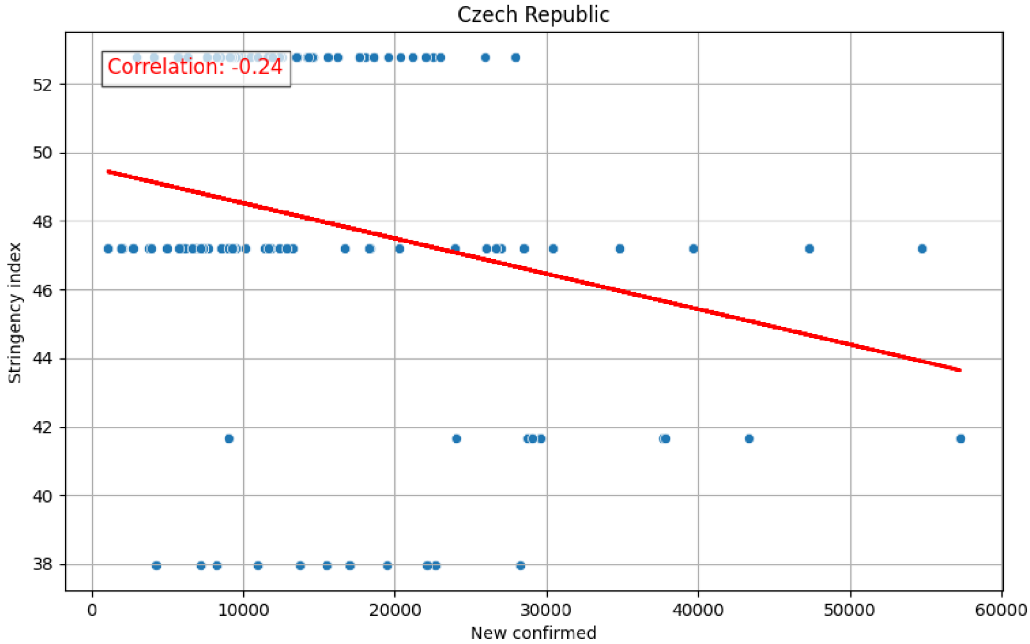
The graph shows the two main largest waves of increase in incidence. For selected time periods of a large jump in the disease, we will conduct a correlation analysis and find its R-value.



Graph 2 First big wave in the Czech Republic

Source: own processing

During the first large wave of Covid disease in the Czech Republic, the government introduced restrictive measures as a "response" to the increase in new cases. On the graph we can see the increase and decrease of the stringency index. When the rate of new cases increased, the government increased the severity of restrictions, but when the increase in new cases decreased, the restrictions were eased over time. Therefore, on the correlation graph we observe an average positive correlation of 0.49 (graph 2).



Graph 3 Second big wave in the Czech Republic

Source: own processing

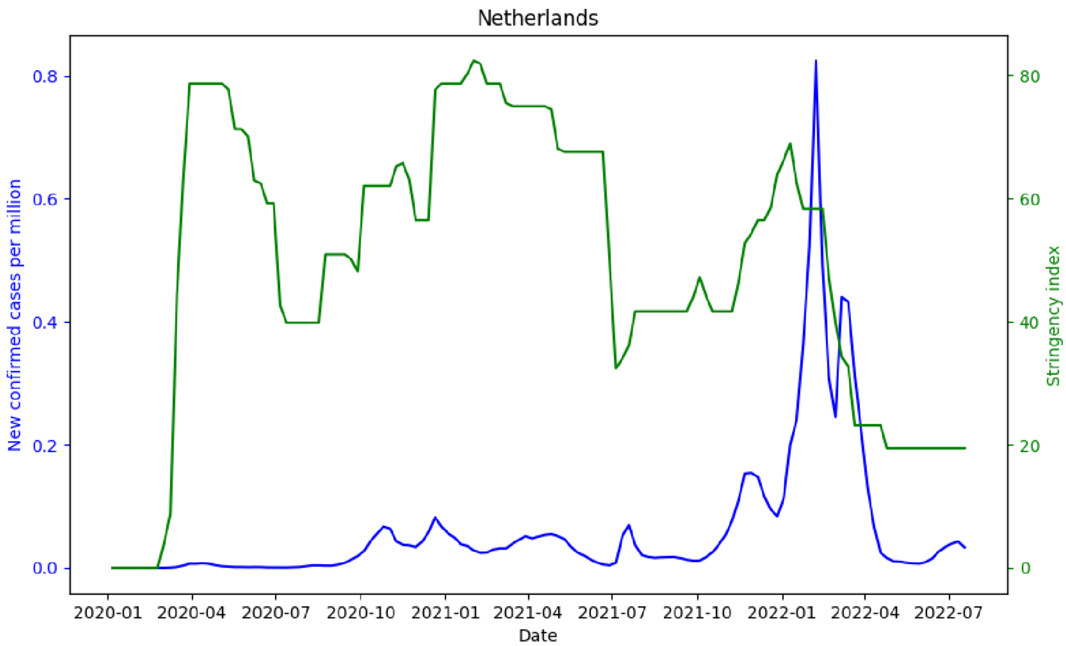
The next major outbreak of the disease was from autumn 2021 to spring 2022. However, due to the fact that at this time the population of the Czech Republic was actively vaccinated, a milder strain of the Omicron virus was active, the disease was more easily tolerated by people, and therefore the burden on the healthcare system was less. Despite the growing number of new cases of the disease, the government continued to ease restrictions.

Thus, here we can observe a rather small negative correlation valued -0.24 (graph 3), which can be explained by a sharp jump in new cases of the disease. Despite this, this surge subsided very quickly, and the number of new cases began to decline, as did the strength of the restrictions.

4.5.2 Netherlands

The Netherlands, like many other countries, has faced various stages of the COVID-19 epidemic. The country has introduced social distancing measures, limits on gatherings, and other restrictions to curb the spread of the virus.

The Netherlands has also been involved in large-scale vaccination programs to protect the population from the virus. Vaccination is a key element of the strategy to combat the pandemic and mitigate its impact.

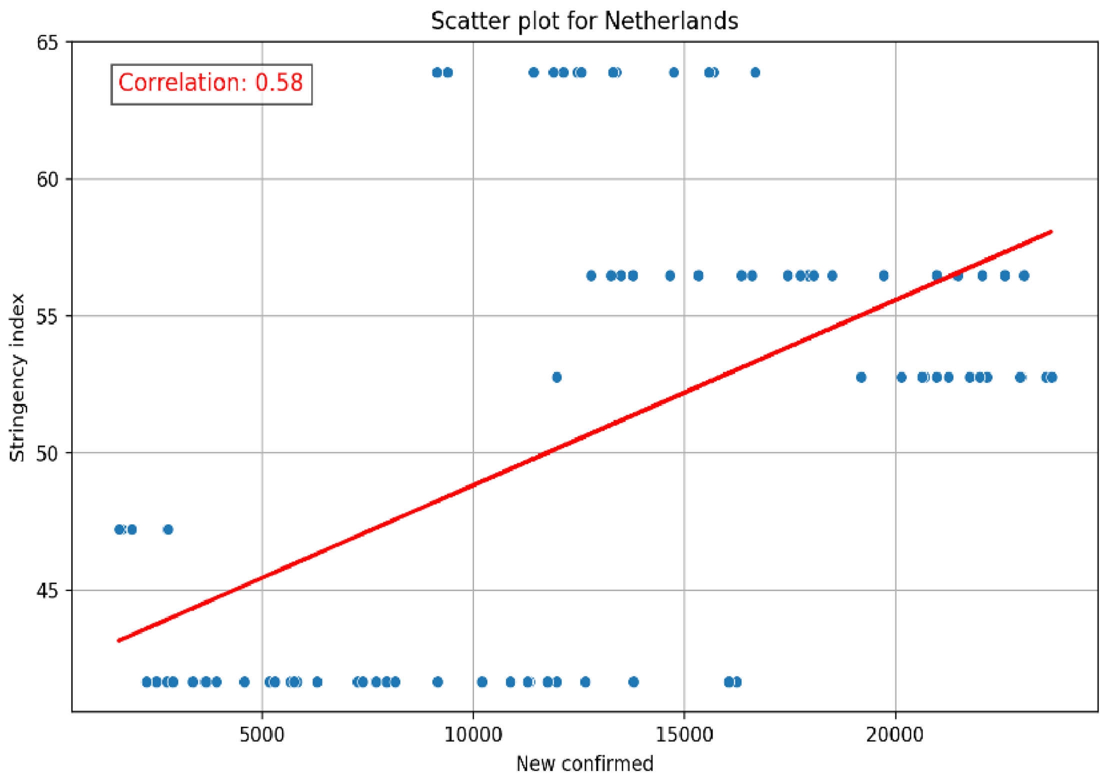


Graph 4 Netherlands linear graph for new confirmed cases and stringency index

Source: own processing

Additionally, the graph demonstrates a significant increase in illnesses in July of 2021, this is because about two weeks prior after “openingsplan”, the majority of the country experienced a large increase in cases. At this point, the Covid restrictions already had a weaker reputation, we can therefore observe the effect this had on the disease's spread. As a result, on July 10th, 2021, a decision was made to shut down bars and restaurants between midnight and 6 a.m.

Having examined the mortality rate graph for the Netherlands, we will also highlight the main disease surges for analysis. The greatest surges in the disease, as in other countries, were seasonal in the autumn-spring period (graph 4).



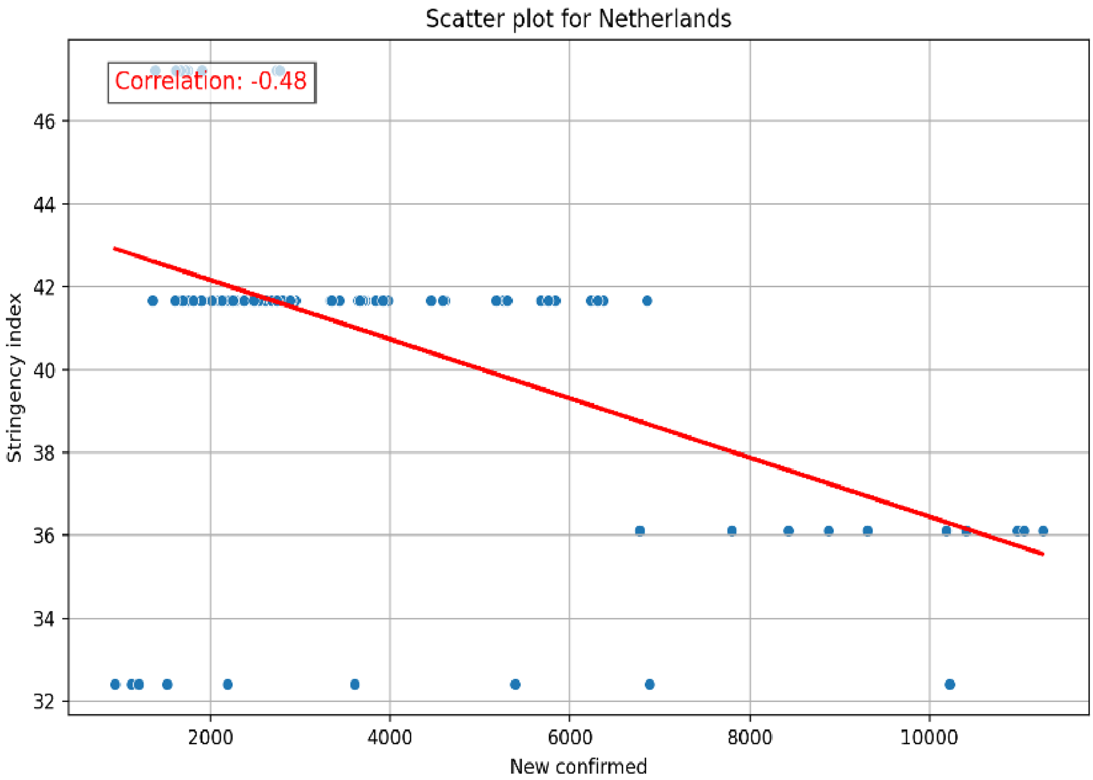
Graph 5 First big wave in the Netherlands

Source: own processing

The first large wave of the disease was not so large-scale compared to other countries; at that time there were quite strong restrictions in the Netherlands.
Restrictions in the Netherlands were more stable and did not make such leaps as in the Czech Republic. The correlation level for the first wave of the disease was 0.58 (graph 5).

By the second wave of growth of the disease, thanks to the availability of vaccination and a milder version of the virus, the Netherlands also began to reduce the level of restrictions.

After the easing of restrictions, the growth of the disease was longer and greater than in the Czech Republic, so we can observe a stronger negative correlation valued -0.48 (graph 6).



Graph 6 Second big wave in the Netherlands

Source: own processing

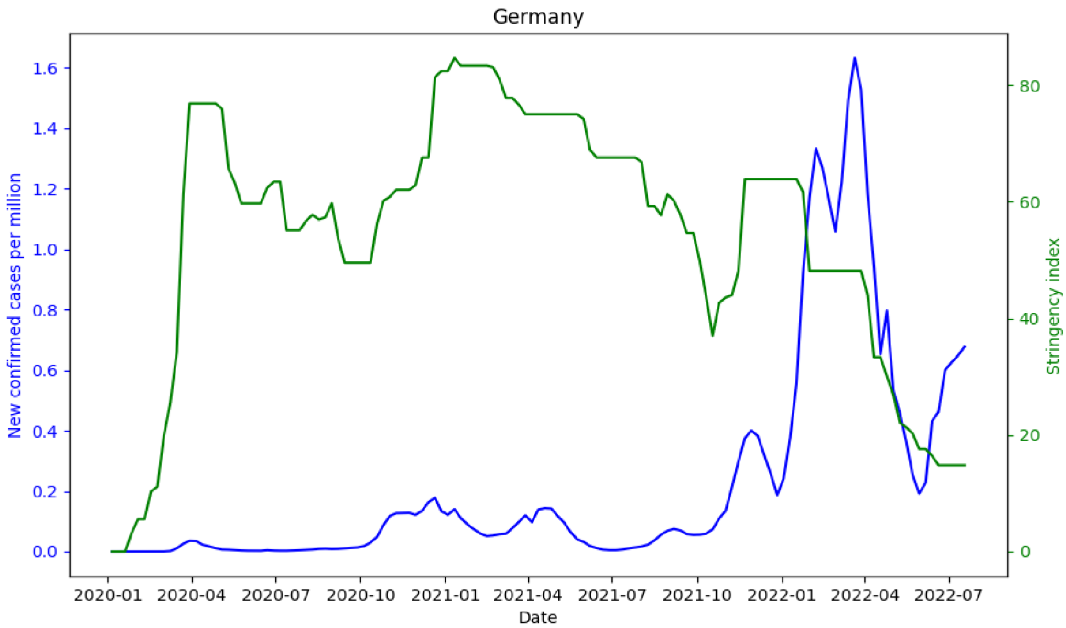
4.5.3 Germany

In Germany, similar restrictions were introduced, as in the Czech Republic and the Netherlands, such as restrictions on gatherings of people, the use of masks, lockdowns and distancing. Germany has also been actively involved in the vaccination program.

In Germany, as in the similar countries under consideration, the main periods of strong growth in the incidence of COVID-19 occurred in the spring-autumn time interval (graph 7).

As we can see in the graph, the first wave of incidence in Germany was not so large and sharp, as well as in the Netherlands, in contrast to the Czech Republic.

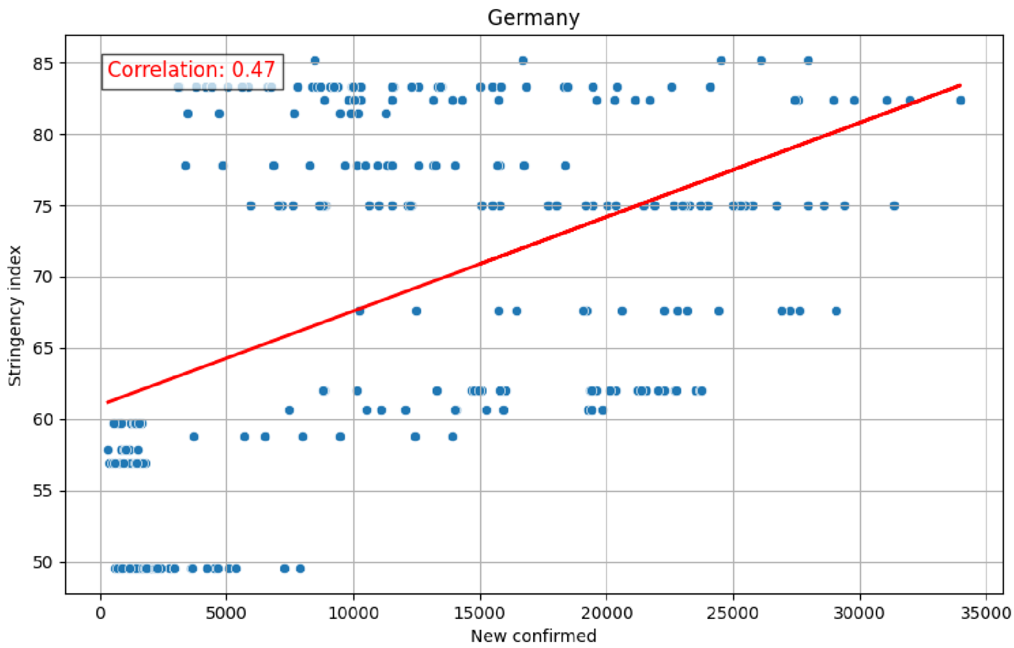
It is worth noting that in Germany, unlike the other selected countries, during the summer period the restrictions were not so strong, but remained quite strong even for the “non-seasonal” time of the disease.



Graph 7 Germany linear graph for new confirmed cases and stringency index

Source: own processing

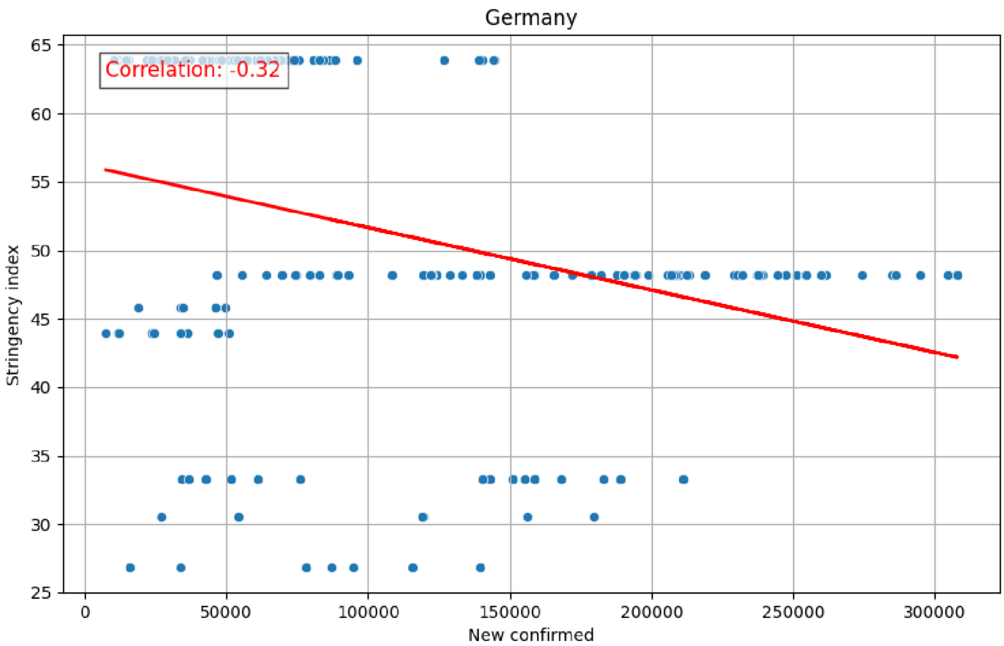
On the correlation graph we see the average strength of the relationship between the variables, equal to 0.47 (graph 8).



Graph 8 First big wave in the Germany

Source: own processing

During the second wave of the disease, like other countries, Germany relaxed the force of restrictions. After reducing the strength of restrictions, there was an increase in disease, which explains the weak negative correlation of -0.32 (graph 9). The surge in the disease lasted longer than in the Czech Republic and the Netherlands, but then it also began to decline.



Graph 9 Second big wave in the Germany

Source: own processing

5 Results and Discussion

The COVID-19 pandemic has certainly had a global impact, posing a serious threat to health, social stability and economic well-being. Since the outbreak of the virus in late 2019 and its subsequent recognition as a pandemic by the World Health Organization in March 2020, the world has faced great changes. The scale of the pandemic was unprecedented in recent decades. Millions of people around the world have become infected with the virus, and hundreds of thousands have lost their lives. This global storm has affected almost every aspect of our daily lives.

Confronting the pandemic required urgent and innovative measures on the part of governments, health authorities and society as a whole. The introduction of quarantines, social distancing, mass testing and border closures have become key strategies to contain the spread of the virus. These measures have proven incredibly difficult for society, causing serious economic consequences, social unrest and changes in daily life. Working from home, distance learning, travel restrictions and the use of personal protective equipment have become commonplace.

The public reaction to the measures introduced was mixed. Most people have shown understanding and discipline in following guidelines and rules to keep themselves and others safe. However, despite the need for restrictions, there were also those who expressed dissatisfaction.

The purpose of this study was to examine in detail the impact of anti-Covid restrictions on the spread of the COVID-19 disease. The analysis was carried out to find out how effective the measures taken were in slowing the spread of the virus in the selected countries. The main focus of the study was to determine the relationship between the level of compliance with restrictions and the dynamics of the incidence, which allowed for a deeper understanding of how successful and effective the measures taken were in containing the pandemic.

During the work were used methods of visual data analysis and statistical correlation analysis to identify trends and relationships. The analysis considered various types of restrictions, such as social distancing, quarantine measures, restrictions on movement and others. The study also took into account factors that could influence the results, such as the pace of vaccinations, testing patterns and public reaction to restrictions. As part of the analysis of correlation graphs and visual assessment of data related to the strength of applied restrictions in the context of the spread of COVID-19, a positive effect of such measures on slowing the spread of the disease was identified. This assessment has become an important element in understanding the effectiveness of measures taken and forming strategies to combat the pandemic.

Visual data analysis plays a key role in understanding the dynamics of the pandemic. The graphs visualize changes in the number of cases of the disease and the dynamics of the introduction of various restrictive measures in the countries under consideration. This approach allows us to see the relationship between the level of strength of restrictions and the rate of spread of the virus.

Analysis of line graphs in this study clearly revealed the relationship between the strength of anti-Covid restrictions and the dynamics of the spread of the COVID-19 disease in the countries under consideration - the Czech Republic, the Netherlands and Germany. The results reflect the dynamics of the disease depending on changes in the level of severity of the restrictions introduced. An important conclusion from the analysis was that when the severity of restrictions decreases, there is an increase in new cases of the disease, while an increase in the strength of restrictions is accompanied by a decrease in the number of new cases. The line graphs clear show trends: during periods when restrictions became less stringent, the curve of new cases soared, highlighting the faster spread of the virus. While during periods of increased severity of restrictions, the graph showed a decrease in the number of new cases, indicating the effectiveness of the measures introduced in containing the spread.

These observations are also confirmed by correlation values, which strengthens the belief that there is a direct connection between the level of compliance with restrictions and the dynamics of morbidity. Positive correlation coefficients highlight the strong link between stricter measures and a decline in the number of cases, while negative correlation coefficients correlate with a more lenient restriction strategy and an increase in the number of new cases.

The Czech Republic experienced more frequent changes in the severity of restrictions compared to the Netherlands and Germany. Unlike the Netherlands and Germany, where restrictions during the main season of the disease (autumn-winter) were kept at consistently high levels and gradually decreased, the Czech Republic, perhaps due to less stable restrictions, had the highest rates of cases per million people and the sharpest jumps diseases in autumn 2020 to spring 2021 among the countries under consideration.

In the case of the Netherlands, the graph clearly shows a significant jump in new COVID-19 cases in the summer of 2021 after a sharp easing of restrictive measures. Even though summer is not the main "season" for the spread of the virus, this does not mean that the likelihood of illness is absent. This once again emphasizes the importance of restrictions in the warm season, when the spread of the virus decreases. As a result, the number of new infections was close to the autumn-winter incidence rates.

However, it is worth noting that despite the positive results, there are factors that could also influence the dynamics of the incidence. These may include, for example, differences in testing strategies, vaccination rates, socioeconomic factors and geographic features.
The reaction of society to the introduction of restrictions also plays an important role. If the population actively supports and follows the recommendations, the effect of the measures can be enhanced. However, it is not always possible to achieve agreement in society, which can affect the final results.

Thus, the results of this analysis show confirmation that the chosen strategy in the countries under consideration had a positive effect in the context of containing the spread of COVID-19.

6 Conclusion

In a study analysing covid restrictions in the Czech Republic, Germany and the Netherlands, a trend was discovered related to the impact of restrictive measures on the dynamics of morbidity. Based on the analysis of line graphs, it was found that when restrictions were tightened, there was a decrease in the rate of spread of the disease, while their easing led to an increase in incidence.

Visual presentation of data on graphs clearly demonstrated the dynamics of the impact of restrictions on the epidemiological situation. At the same time, the correlation analysis supplemented the visual conclusions with a quantitative assessment. The correlation found, although not too strong, did confirm the trend: tightening restrictions was correlated with a decrease in new cases of the disease, while their easing was associated with an increase in incidence.

Thus, it can be noted that the measures taken to slow the spread of the SARS-CoV-2 virus, which causes the disease COVID-19, have proven to be effective and have yielded positive results in reducing the number of cases. During the fight against the pandemic, various standard restrictions were implemented, which played a key role in achieving this positive impact.

Key measures include mandatory wearing of masks, which has helped reduce the risk of transmission of the virus through airborne droplets. Physical distancing measures were also introduced, which helped reduce the spread of the virus through contact. Lockdowns and quarantine measures have also played an important role in preventing mass infections by limiting the movement of people and reducing social contacts.

In addition, sanitary and hygiene standards have been introduced, such as regular hand washing and disinfection of public places and surfaces. All these measures together helped contain the spread of the virus, which led to an improvement in the epidemiological situation and a decrease in the number of cases of the disease.

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8 List of graphs

9 List of pictures

10 Appendix

The following are supplementary data to this thesis:

https://storage.googleapis.com/covid19-open-data/v3/epidemiology.csv

https://storage.googleapis.com/covid19-open-data/v3/oxford-government-response.csv