Modelling Global policies associated with COVID-19 Pandemic using Probabilistic Graphical Models

Aishwarya Jayagopal e0674492@u.nus.edu
Binitha Radhakrishna Shetty e0674470@u.nus.edu
Krishna Kumar Hariprasannan e0677862@u.nus.edu
Srinivasan Kolumam Nandakumar e0674494@u.nus.edu
Tan Kuan Wei Benjamin e0174836@u.nus.edu

1 Motivation

The COVID-19 pandemic has majorly influenced human life across the world in its different dimensions. Governments at all levels are operating in a context of exhaustive uncertainty, faced with difficult trade-offs given the economic, health and social challenges that comes with it. The emergence of new variants over time is further increasing the uncertainty. Many governments have reacted quickly, introducing policies majorly designed around fighting the pandemic. But these policies vary across different regions. For example, while some countries enforce strict mask mandates and lockdowns, others prefer to adopt a more passive response and target a quick herd immunity. Be it government handouts, vaccination drives, strengthening health systems, public investment or digitisation, understanding the factors leading up to these policies along with their effectiveness will help policy makers to construct better future policies.
Thus, in our project we aim to model the various global policies associated with the Covid-19 pandemic using Bayesian Networks and Markov random fields to derive useful insights that can help with policy creation.

2 Problem Formulation

In this project, we aim to model the uncertainties surrounding the COVID-19 pandemic, and thereby analyze the following:

2.1 Policy Effectiveness

The effectiveness of a policy can be analyzed based on the number of confirmed cases and confirmed deaths. Given the policy implemented(like closure of schools, cancellation of public events, travel restrictions), the number of cases can be estimated and used as a measure of policy effectiveness. The degree to which each of these measures is implemented also can be used to understand the overall effectiveness.

2.2 Economic policies and COVID-19

The pandemic has caused a great deal of unemployment, thus increasing the burden on households to repay loans, ensuring availability of daily essentials like water etc. The government in many countries stepped in to address this by providing income support and temporary freezing of loan repayment. An interesting association that could be explored is to see if increased financial support to households is a way to restrict internal travel and movement.

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2.3 Foreign policies in the wake of COVID-19

Vaccine diplomacy versus vaccine nationalism has been a topic that has garnered much attention during the pandemic, since over time it has been observed that what once was supposed to be a diplomatic tool resulted in fewer vaccines left to administer to the citizens of the country. Offering international aid can be a potential indicator that the domestic case load is under control and that potentially fewer containment protocols are in place. The dataset can also quantify the effectiveness of vaccine diplomacy as a diplomatic tool.

2.4 Role of vaccination in containment measures

The percentage of vaccinated population can lead to a less stringent public policy. An indicator of the percentage of vaccinated population is by determining which age groups are yet to be vaccinated. In general, children have been vaccinated last in most countries. The impact of vaccination in containing the pandemic can be analyzed from this dataset. This may also translate into reduced containment measures.

2.5 Variations in policies across time

Since the pandemic has been around since the end of 2019, there is now sufficient data to see how countries have changed their policy over time. The dataset allows us to explore if under the same conditions like season, the policy on containment has changed from 2020 to 2021.

2.6 Identification of influential countries

The policies implemented by certain countries can have an impact on the policies that other countries put in place. Case studies[4] have been conducted to see if policies implemented in one country that successfully contained the spread can work in another country. For example, if country A bans international travel, does that mean that almost all other countries also impose a travel ban?

2.7 Impact of geography on policy making

Countries that are neighbors can influence each other's policy. For example, an increased number of cases in country A may prompt its neighboring country B to impose an international travel ban.

3 Dataset Description

Our World in Data [7] is the primary gateway for accessing datasets used in this project. Using this gateway, we retrieved country-wise aggregate data on Covid-19 such as cases, deaths, hospitalisations, vaccinations, testing, etc,. for the period from April, 2020 to February, 2022. These daily data points are collated from multiple sources such as Johns Hopkins University [5] which in turn collates data from multiple other sources such as World Health Organization.

In addition to the aforementioned daily aggregate data, Blavatnik School of Government, University of Oxford [6] provides collated government responses all over the world in the form of thirteen metrics: 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; international travel controls; testing policy; extent of contact tracing; face coverings; and vaccine policy. These metrics take ordinal values that indicate different levels of strictness such as no policy, mandatory policy, etc, and are also available for the same period indicated above.

4 Literature Survey

Literature survey was done to understand different factors that influenced policy making along with their outcomes.These factors included government power structures (Centralised or Federal), healthcare capacity, socio-economic factors, economic status of the country. [1] covers a comparative study of France, Belgium and Canada which have different government structures with respect to

healthcare. Shared decision making between central and state governments may have lead to slower decision making in Belgium while a decentralised system in Canada lead to huge difference in outcomes across provinces. France with its centralised approach enabled wide spread sharing of resources which was lacking in Canada.

Countries adapted either of the two strategies - Covid zero policy where the major focus was on keeping the number of cases at 0 by having prolonged restrictions and lockdowns or a mitigation policy where restrictions were linked to the burden on the healthcare system and vaccination coverage. A study about the UK and the US[2] show that the best policy is a combination of social distancing , home quarantine and closure of universities and schools.Relaxation of restrictions varied based on several factors like test positivity rate, number of ICU admissions which reflected the burden on the healthcare system and economic factors like fiscal deficits of governments.

A prior model using Bayesian networks[3] was analysed to understand data preprocessing and feature engineering. The study removed data that had questionable responses which gave insights into how to eliminate some key variables. Data discretization was done to create probability distributions where all the features were maintained on the same numeric scale. Additionally for better interpretation, features with similar responses were clustered together.

5 Proposed Method

This project aims to solve the problems mentioned in the formulation by using Bayesian networks. Initially a small subset of countries will be considered for analysis. A network will be built with nodes of the form country_{policy} where the 'policy' can be school closures, restriction of gatherings, income and debt support etc. In addition, the network will also have nodes of the form country_{covidstat} where 'covidstat' can be confirmed cases, number of deaths etc. For example, probability of country_restriction_on_public_transport given country_income_support can be queried from the network.

To evaluate the model the data set will be split into 80% training data and 20% testing data. The Bayesian network will be modelled on the training data and the performance will be evaluated on the testing data. The project also aims to evaluate Markov random fields as an alternate method. Comparison between the two models will also be done.

References

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