Empirical Assessment of Government Policies and Flattening of the COVID-19 Curve

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Abstract

The objective of the study is two-fold. First, it estimates the COVID19 flattening curve using Panel Random Coefficient Model. This allows each country to have its trajectory while allowing for random error effects to transfer across countries. Second, it calculates the expected number of days to reach the flattening point of COVID19 curve and estimate the empirical effectiveness of government policies around the world using Poisson regression. This study avails global COVID19 incidence data for 190 countries between January 22nd 2020 and May 11th 2020. In the absence of a vaccine or of more appropriate treatment options, non-pharmaceutical approaches must be used to control the spread of the 2019 new coronavirus disease (COVID19). This study proposed that the contact tracing, stay at home restrictions and international movement restrictions are most effective in controlling the spread and flattening the COIVD19 curve. At the same time, habits that hurt the immune system like smoking have a negative effect on the flattening of the curve. The government should integrate these policies in their lockdown plan to make it smart lockdown.

Keywords: Coronavirus; social distancing; contact tracing; work from home;

1. Introduction

Coronavirus SARS CoV-2 (COVID19) was detected on January 21st when the first of the Chinese health workers were infected in Wuhan (Nature, 2020; Sharif et al.,2020). While it was spreading in China, the developed county's health systems were of the perception that like previous scourges, i.e. yellow fever, cholera, HIV/AIDS and Ebola, their systems will prevail against the COVID19. Practically past experiences were of little use, especially for the case of the US Health System (Chokshi & Katz, 2020). This was the story for the developed economy; on the other hand, there are more than 63000 cases in 53 countries of Africa. Their fragile system was not able to cope with the needs of the population (Divala et al., 2020). Furthermore, the fallout in terms of economic recession after COVID19 is predicted to overshadow the financial crises of the late 2010s. This is because this crisis is not only affecting the developed; rather, it is also changing developing economies. It will create not only supply short but also the demand shock leading to an estimated fall of GDP by 6% (Wren-Lewis, 2020). One study projected Indonesia's poverty to rise from 9.2% to 12.4% (Suryahadi, Al Izzati & Suryadarma, 2020). Kilbbin and Fernando (2020) provided several scenarios in which COVID19 could decrease GDP. According to estimates, the GDP loss could be up to -9.9% for Japan, -8.7% for Germany, and -8.4% for the rest of the Euro area. This shock had reduced the market capitalization by 30% at the global level (Siddiquei & Khan, 2020).

Each country handled the COVID19 differently, leading to different consequential forms of the pandemic. Countries like USA, Italy and the UK delayed government intervention in the expectation of achieving community-based immunization. In contrast, countries like India and New Zealand locked down international borders and restricted domestic movements. Lastly, there were countries which used the hybrid approach of allowing businesses to continue with special operating procedures (SOPs), social distancing and smart tracking of the COVID19 incidence. Figure 1 shows the exponential increase in the confirmed cases while the log series show slight flattening after 100 days from the first case of COVID19 in their country. Several studies have proposed the theory to handle the COVID19. One of the most popular is the flattening of the

COIVD19 incidence curve. Figure 2 shows the quadratic fit of log COVID19 incidence against the count of days since the first case was reported. It is observed here that there is a flattening pattern emerging globally.

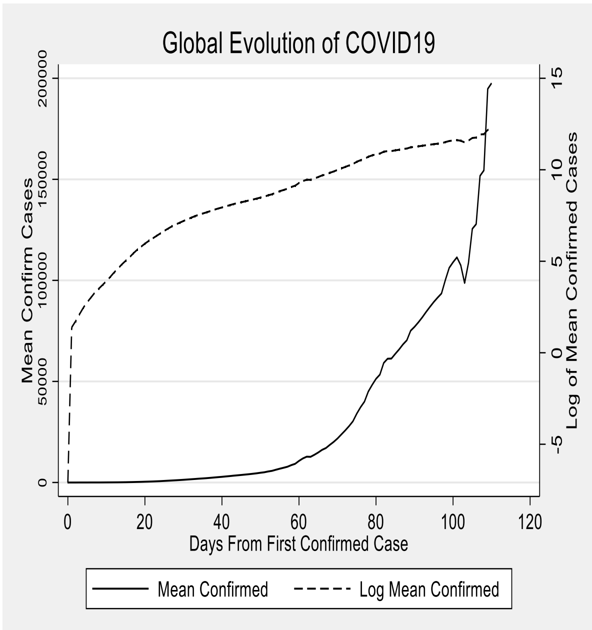

Figure 1 – Average Incidence of COVID-19

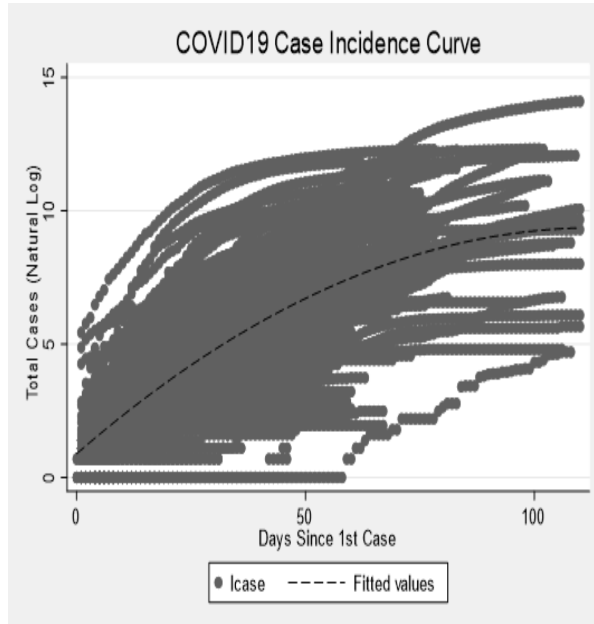

Figure 2 – Flattening of COVID19 – Quadratic Fit

Studies claim that COVID19 will eventually expose every one as it is invisible, and it tends to communicate via social interaction. The young ones who are not experiencing its symptoms will be the one spreading it to the masses. The social and medical way to evade this spread is discussed under the measures to flatten the curve. This approach may not eradicate the COVID19, but it will reduce the strain on the health systems and pressure on the development of cure (Anderson et al., 2020; Giesecke, 2020; World Health Organization, 2020). The policies to manage the spread included lockdowns across the world (Koh, 2020) which are useful to contain the spread (Sharma, Talan & Jain, 2020).

In the literature, various studies find various factors which contribute to flattening the COVID19 curve. For example, Rotondi et al. (2020) find that in Italy, comovement restriction and social distancing contribute in flattening COVID19 curve. Block et al. (2020) also find that social distancing strategy significantly affects on COVID19 curve and make it flatten. Breitenbach et al. (2020) used DAE method by considering mostly effected 31 countries. The used first 100 days data of COVID19 and consider various factors which help in flattening COVID19 curve a such number of doctors, speed and nature of lockdown, health expenditure. They find mixed results, for example, 12 of the 31 countries in our sample were efficient, and 19 were inefficient in the use of resources to manage the flattening of their COVID19 contagion curves. Furthermore, they find that lockdown strategy is highly effective in for the flattening of COVID19 curve. Careful literature review on flattening COVID19 curve suggests social distancing and comovement restriction main factor of flattening COVID19 curve. However, previous studies on flattening of COVID19 curve ignored many other essential factors; therefore, it is dire need to extend the literature by incorporating additional variables also.

The objective of the study is two-fold. First, it estimates the COVID19 flattening curve using Panel Random Coefficient Model. This allows each country to have its trajectory while allowing for random error effects to transfer across countries because of passenger and goods movement. Second, it calculates the expected number of days to reach the flattening point of COVID19 curve and estimate the empirical effectiveness of government policies around the world using Poisson regression. This study contributes to the literature in various ways. First, we include other important variables such size of the economy, smoking prevalence, population density, cancelling of events, stay at home restrictions, internal movement restrictions, contact tracing, information campaigns, international movement restrictions, workplace closure and school closure. The inclusion of these variables in the model provides a better understanding of the factors that affect COVID19 curve. Second, this study uses a large data set that has data from 190 countries, including developed and developing, a large data set proved more detailed outcomes. Third, this study estimates the Panel Random Coefficient Model (RCM); this model allows country-specific slope coefficients while constituting homogenous residuals. This specification helps in the determination of country-specific COVID19 curve with random spillover effects[2]. Several other competitive models exist which can estimate this data set like panel data models (fixed and random effect) which does not allow the slope coefficients to vary across cross-sections. Fourth, this study provides various policies based on empirical findings.

The rest of the paper is structured, as section 2 discusses the theory of the COVID19 curve. Section 3 discusses the review of the literature. Section 4 consist of data and methodology. Section 5 discusses the outcomes and discussions. Finally, section 6 discuss conclusions and policy implications.

2. Theory of COVID19 Curve Flattening

While discussing the curve, this paper will present the positive and negative forces for both regions (figure 3). For the case of an increase in the cases, the virus spread rate, increase in the number of testing and the size of the economy and social activity are the positive forces of increase in cases. While population density, awareness of the people and knowledge about the mechanism of virus spread are possible opposing forces of increase in the cases. For the case of a decrease in cases region, the rigidity to slow down the economic and social activity and immunodeficiency prevalence of the population are the opposing forces that resist in decreasing the cases. While the stringency of government policies, development of medical treatment and immunization in the community are the forces promoting the decrease in the cases. The incidence of these positive and negative forces explain the days taken / to be taken by each country in reaching the flattening stage (Routley, 2020; World Health Organization, 2020).

[2] This is necessitated because of the fact that countries are allowing their residents to come home with restricted flights where few of them are positive for COVID19.

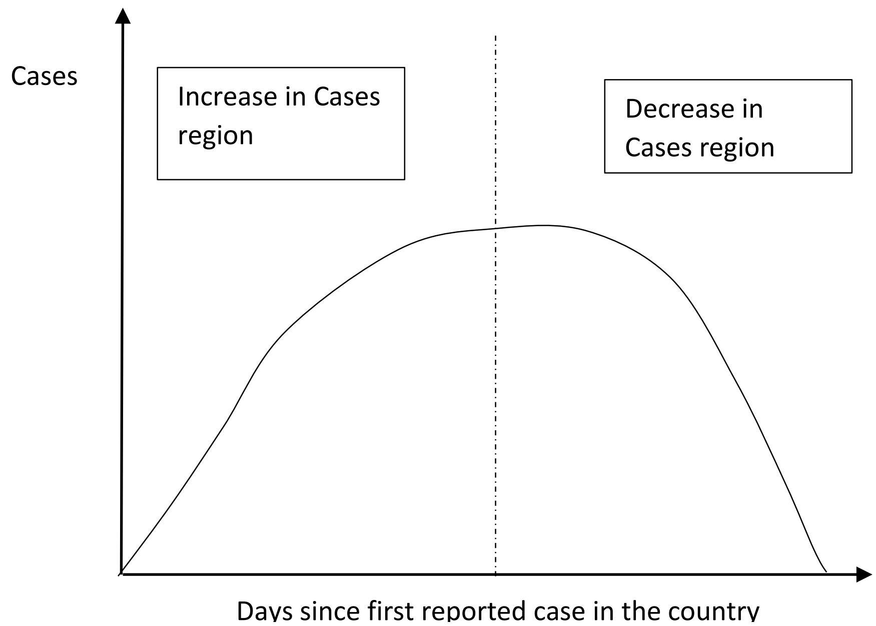

Figure 3 – Flattening of COVID19 Curve

This study proposes that each country have different positive and negative factors of increase and decrease in COVID19 cases. This study developed the Panel RCM model to estimate the country-specific COVID19 curve and country-specific days to reach the flattening stage. Further, this study will explore the effectiveness of each government policy instrument in reducing the number of days to flatten the COVID19 incidence curve. This assessment will be instrumental in the strategizing the smart lockdown approach whereby appropriation combination of restrictions are applied to limit the spread of the virus. A study by (Saez et al., 2020) theoretically assessed the potency of different measures to flatten the epidemic curve as this situation is crucial for the case of weak economies who are facing a dilemma of saving the economy vs saving the lives.

3. Literature Review

The spread of SARS CoV-2 has not even spared the people in prisons. Last few decades have seen a high number of incarcerations in the USA, adding to 2.2 million people in prisons and jails. Akiyama, Spaulding and Rich (2020) asserted the importance of flattening the curve within prisons and within the community. Fineberg (2020) discussed that China was able to flatten the COVID19 curve successfully. They did it using clear command and control, aggressive testing, protecting medical personnel and forming cluster-based policy. African countries are looking for a lockdown, but there had been no studies evaluating the cost and benefits of government intervention for these countries (Divala et al., 2020). Park, Choi and Ko (2020) discussed the success of advanced tracking in tackling the COVID -19 for the case of South Korea. In this strategy, multiple data sources were utilized like mobile services, immigration services, policy, credit card companies, public transit companies, government agencies and lastly health insurance agencies. All of them integrate their data to disclose ware bouts of population publically. Giordano et al. (2020) provided their model to categorize the cases of SARS-CoV-2. However, according to them, successful implementation requires social distancing and contract tracing. The case of Bangladesh also showed that increased testing would not help if there is not contact tracing mechanisms in place (Khan & Howalder, 2020).

Within a month of the first positive case, and aggressive intervention approach by New Zealand seen a decrease in the number of cases. It happened because of their completely locking up of borders. They are now experiencing falling in COVID19 cases (Cousins, 2020). India was the first to lock down its international borders after their first case completely. However, it led to the severity of socio-economic conditions within a 1.3 billion population. Now they are moving towards testing and tracing contacts and isolating patients (Lancet, 2020). Similarly, the misinformation must also be dealt with at Government level, so that correct information regarding COVID19 can be disseminated among the masses (Donovan, 2020). Further, since the youth are the major carriers of COVID19, the closure of the schools are the first and foremost strategy to limit the movement of virus (Couzin-Frankel, 2020). Cowling and Aiello (2020) proposed that to mitigate the pandemic, there is a need for temporary close schools, workplaces and discourage gatherings. The more people accept to stay at homes; the more chances are that it will flatten the curve.

Poland (2020) stated that the positive COVID19 cases are doubling in every 3-4 days across the world. To handle this, there should be a collective and appropriate suspension of social interaction which provide impetus to SARS-CoV-2 transmission. The comorbidities of the society, like smoking, obesity and immunocompromised people have led to magnified death rates in several countries. The availability of large data sets helps the researchers in terms of making decisions to combat the spread of this pandemic (Callaghan, 2020). Research in the domain of social sciences can help in managing the perceived risk of individuals and behavioural response to the epidemic until medical treatment or vaccination is developed (Betsch, 2020). Bastos and Cajueiro (2020) use the data of Brazil to model the incidence of COVID19 and Atkeson (2020) did for the US. In South Asia, several strategies were adapted to counter the spread, which included contact tracing, travel restrictions, stay at home restrictions and awareness sessions (Sharma et al., 2020). Guidotti and Ardia (2020) developed an integrated portal which reports the data of COVID19, relevant economic indicators and all social restrictions indicators which governments have opted to abate the spread.

4. Data and Methods

To fulfil the research objectives, the data and methods required are discussion in this section.

4.1. Data Source

This study has availed the COVID19 data repository in R 3.6.3 developed by (Guidotti & Ardia, 2020). This data constitutes the indicators of confirmed, recovered and dead cases of COVID19, qualitative indicators of government intervention and quantitative indicators of the economy. This daily data constitutes of 190 countries ranging between, January 22nd 2020 to May 11th 2020. Following is the functional form of the model and description of the symbols used in the functional form for the selected variables is given in table 1:

$$\mathrm{dflat} = f(\mathrm{lGDP}, \mathrm{lGDP2}, \mathrm{SMOK}, \mathrm{lPD}, \mathrm{CEVE}, \mathrm{SHRES}, \mathrm{LMRES}, \mathrm{CTRAC}, \mathrm{INFG}, \mathrm{IMRES}, \mathrm{WSCLOS}, \mathrm{SCLOS})$$

Table 1 Variables and Construction

Variable name	Symbol	Definition
Confirmed COVID19 Cases	lCase (Natural Log)	No of COVID19 positive cases, cumulative.
Days since 1st COVID19 positive case	Days	No of days since 1st COVID19 positive case
Size of the economy	lGDP (Natural Log)	Final market value of goods and services produced in the country in a year.
Smoking Prevalence	SMOK	Prevalence of Smoking as percentage of adults in the country
Population Density	lPD (Natural Log)	Population per unit area
Cancelling of Events	CEVE	0 No Measures Taken 2 Required Cancelling
Stay at Home Restrictions	SHRES	0 No Measures 3 Require not leaving house with minimal exceptions
Internal Movement Restrictions	LMRES	0 No Measures 2 Require Closing
Contact Tracing	CTRAC	0 No Contract Tracing 2 Comprehensive Contact Tracing for All Cases
Information Campaigns	INFG	0 No COVID19 Public Information Campaign 2 Coordinated Public Information Campaign
International Movement Restrictions	IMRES	0 No Measures 4 Total Border Closure
Work Place Closure	WSCLOS	0 No Measures 3 Require Closing (or Work From Home) all-but-essential workplaces
School Closure	SCLOS	0 No Measures 3 Require Closing All Levels

4.2. Methods

This study estimates the Panel Random Coefficient Model (RCM Model by, Swamy, 1970) with the natural log of confirmed cases and quadratic function of the number of days since the first case as an independent variable. RCM model will allow country-specific slope coefficients while constituting homogenous residuals. This specification helps in the determination of country-specific COVID19 curve with random spillover effects[3]. Several other competitive models exist which can estimate this data set like Panel data models which do not allow the slope coefficients to vary across cross-sections. Equation 1 is used to estimate the days to flatten COVID19 curve. It is expected that the COVID19 incidence curve will follow the law of diminishing returns, whereby $\alpha_{2i} > 0$ and $\alpha_{3i} < 0$. While equating first derivative equal to zero, this study will estimate the country-wise value of an estimated number of days by which their COVID19 incidence curve will flatten. Several studies like (Zahid et al., 2020; Arshed et al., 2019; Hanif, Arshed & Aziz, 2019;

[3] This is necessitated because of the fact that countries are allowing their residents to come home with restricted flights where few of them are positive for COVID19.

Iqbal, Kalim & Arshed, 2019) have used this method to estimate the minima or maxima of the curve.

$$\mathrm{lCase}_{it} = \alpha_{1i} + \alpha_{2i}\mathrm{Days}_{it} - \alpha_{3i}\mathrm{Days}_{it}^{2} + e_{it} \quad (1)$$

$$\frac{\partial \mathrm{lCase}_{it}}{\partial \mathrm{Days}_{it}} = \alpha_{2i} - \alpha_{3i}2 * \mathrm{Days}_{it} = 0$$

$$\mathrm{Days}_{it}^{*} = \frac{\alpha_{2i}}{2\alpha_{3i}}$$

This discrete data of the number of days to flatten is then used as a cross-sectional data, and the effectiveness of policy intervention are used as independent variables while controlling for the size of the economy, social and demographic indicators. Poisson regression is used in this case. Studies like Arshed (2020), Anwar, Arshed and Anwar (2016) and Arshed, Kalim and Anwar (2019) have used this Poisson regression model for the case of the discrete dependent variable. Equation 2 provides the stochastic form of estimation equation where the variables used are discussed in Table 1.

$$\mathrm{dflat}_i = \beta_1 + \beta_2\mathrm{lGDP}_i + \beta_3\mathrm{lGDP}_i^2 + \beta_4\mathrm{SMOK}_i + \beta_5\mathrm{lPD}_i + \beta_6\mathrm{CEVE}_i + \beta_7\mathrm{SHRES}_i + \beta_8\mathrm{LMRES}_i + \beta_9\mathrm{CTRAC}_i + \beta_{10}\mathrm{INFG}_i + \beta_{11}\mathrm{IMRES}_i + \beta_{12}\mathrm{WSCLOS}_i + \beta_{13}\mathrm{SCLOS}_i + e_i \quad (2)$$

In this equation 2, the quadratic specification of log of GDP accounts for the inertia effect because of the size of the economy which resists or takes time to slow down or lock down. The log of population density (PD) accounts for the difficulty to maintain social distancing among the people. Smoking prevalence (SMOK) accounts for the non-healthy habits which may deteriorate the immunity against viruses. While all other variables are types of restrictions imposed the government to control the spread of COVID19.

5. Results and Discussions

Table 2 shows the descriptive statistics of the variables which are used in the study. Here it can be seen that almost all of the variables have the mean value higher than the standard deviation. This confirms that all the variables are under dispersed. While other than GDP and SMOK, all the variables are statistically non-normal. This study avails the central limit theorem to assume variables to be asymptotically normal.

Table 2 Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	JB Test Prob.
Dflat	181	71.28	55.18	0.00***
lGDP	167	24.50	2.09	0.34
SMOK	167	0.21	0.09	0.12
lPD	138	4.42	1.43	0.02**
CEVE	141	0.82	0.48	0.00***
SHRES	181	0.61	0.47	0.00***
LMRES	181	0.61	0.42	0.00***
CTRAC	181	0.63	0.55	0.01***
INFG	181	1.10	0.67	0.00***
IMRES	181	1.67	1.05	0.00***
WSCLOS	181	0.85	0.611	0.00***
SCLOS	181	1.20	0.71	0.00***

***, ** indicates significant level at 1&5% respectively

Before estimating the Panel Random Coefficient Model, this study tested the lCase variable for its stationarity. ADF and PP Fisher panel unit root tests confirmed that the variable lCase is stationary at level. Hence simple panel data models may suffice. Table 3 provides the estimates. These estimates are based on 12,803 country – day observations based on 190 countries. The significant value of the Wald test confirms that the overall model is fit. In contrast, the significant value of parameter constancy test confirms that the COVID19 incidence curve is heterogeneous for all countries. Here it can be seen that on the average, increase in one day after the first case, lead to an increase in total cases by 0.198%. This is because of several factors like its spread and increase in testing. However, the effect of days is not linear. Here for every increase in days, the marginal impact of days diminish by 0.001%. This is because of factors like increase in people recovered, an increase in the immunity levels and an increase in awareness and precautionary measures related to COVID19.

Table 3 Panel RCM Estimates

Panel Random Coefficient Estimates (Dep. Var. lCase)		
Variable	Coef.	Prob.
Days	0.198	0.000***
$Days^2$	-0.001	0.000***
Constant	0.502	0.000***
	Regression Statistics	
Observations	12803	
Countries	190	
Wald	960.08	0.000***
Parameter Constancy Test	500000	0.000***

Note: *** indicates a level of significance at 1%.

Figure 4 provides the distribution of the days to flatten the COVID19 curve. Here the majority of the countries are laying between 40 to 70 days mark while the distribution has a long right tail. Figure 5 plots the new indicator of log-transformed days to flatten on the map. Here it can be seen that region like Mexico and South Sudan is showing shorter time to flatten. They are followed by regions like Greenland, Spain, Morocco and Sweden.

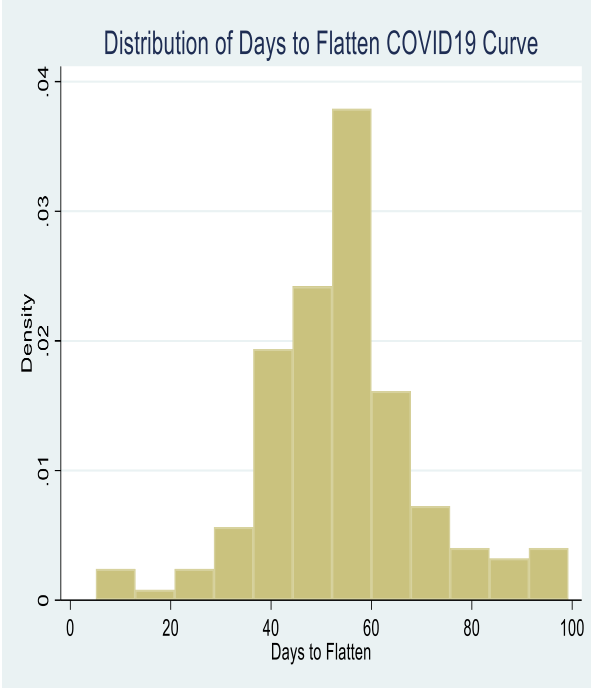

Figure 4 – Histogram of Days to Flatten COVID19 Curve

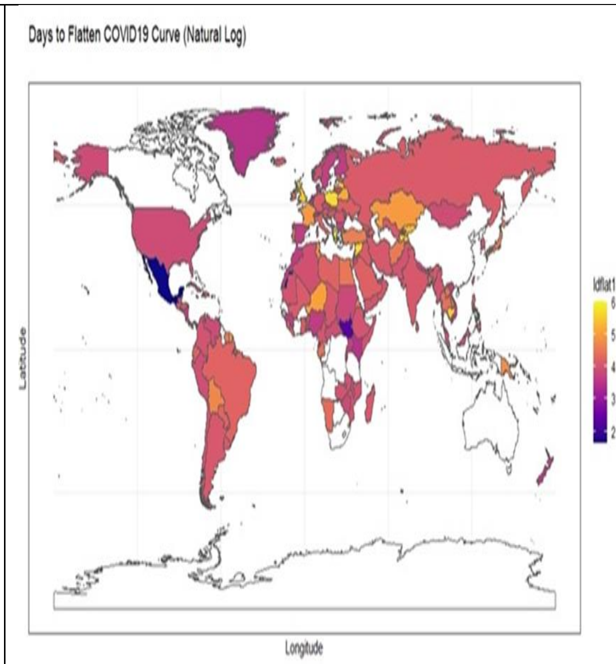

Figure 5– Spatial Incidence of Days to Flatten COVID19 Curve

In table 4, the days to flatten are estimated using equation 2. The estimation was done using 110 valid samples. The significant value of LR Chi^2 shows that the overall model is fit, and the proposed independent variables explain 18.6% variation in the days to flatten. For the case of controlling factors, a 1% increase in the smoking prevalence, leads to a 1.6% increase in days to flatten the curve. This shows that people who smoke first are addicted, they have to visit shops often to buy cigarettes which increases chances of becoming affected by the virus. Secondly, they tend to have a weakened immune system. Hence they take longer time to negate the effects of the virus. This immunodeficiency effect of smoking is well established (El. Taweel et al., 2019; Woskie & Wenham, 2020). A 1% increase in population density leads to a decrease in days to flatten by 0.046% on average. This shows that the urban areas with high density are the main focus of Government facilities, awareness and intervention, which leads to a decrease in the time to flatten. A study for the case of India poised the challenged in ensuring social distancing in a densely populated area (Wasdani & Prasad, 2020).

The effect of the size of the economy is quadratic. A 1% increase in the size of the economy leads to a 0.60% decrease in the days to flatten the COIVD19 curve. But for each percent increase in the size, the decreasing effect of days to flatten reduces by 0.013%. This shows that the smaller economies are better able to manage and slow down the economic and social activities as compared to the larger economies. Big metropolitan cities like, New York took time to slow down which lead to heightened incidence of COVID19 (Rotman, 2020).

Table 4 Poisson Estimates

Poisson Regression (Dep. Var. dflat)		
Variable	Coef.	Prob.
Lgdp	-0.60	0.000***
lGDP^2	0.013	0.000***
SMOK	1.642	0.000***
Lpd	-0.046	0.000***
CEVE	0.209	0.019**
SHRES	-0.171	0.000***
LMRES	0.476	0.000***
CTRAC	-0.262	0.000***
INFG	-0.044	0.238
IMRES	-0.176	0.000***
WSCLOS	-0.070	0.040**
SCLOS	0.137	0.810
Constant	11.438	0.000***
Regression Statistics		
Observations	110	
LR Chi^2	781.64	0.000***
Pseudo R^2	0.1866	

Note: ***, ** indicates the level of significance at 1% and 5% respectively.

Now while comparing the pandemic related government policy options. Empirically cancelling the events and limiting the internal movements has not led to a decrease in the days to flatten. This may indicate that closing the intercity transport and cancelling of events increased the number of free people. It increased panic as the first thing people want to do when they are free is to allocate to a comfortable place.

Empirically the effects of closing schools and information campaigns had no significant effect on the days to flatten, while other indicators had a significant negative effect. Here restricting people to say at home had led to a 0.17% decrease in the days to flatten, as it reduced the social interaction because of which the communicable disease could spread. The difference in differences estimates for USA showed 30.2% decrease in the weekly cases of COVID19 (Fowler et al., 2020). The comprehensiveness of contact tracing had led to a decrease in the days to flatten by 0.26%. This had allowed governments to address the spread of the virus and isolate the confirmed cases. The contact tracing strategy have been proved to reduce the reproduction and rapid flattening. Further it has lower chances of second wave outbreak (Browne et al., 2020). Increase in the international movement restrictions had led to a 0.18% decrease in the days to flatten the curve. Study for the case of Malaysia showed that limiting the movement of people helps in limiting the COVID19 (Amiruzzaman et al., 2020). Lastly closing the workplace and moving to work from home strategy had led to a reduction in the days to flatten by 0.07%. Working from home helps reduces the pressure of the transmitting virus from work to home and in the society (Heinen, 2020). Hence out of all policies, the contact tracing had been the most effective strategy.

6. Conclusion and Policy Implications

Global economies are on the verge of collapse after the hit from pandemic COVID19. Its spread rate across developed and developing economies had surprised the large economies. The higher number of cases are witnessed in the economies where the health infrastructure was successful in handling previous epidemics like yellow fever, cholera, HIV/AIDS and Ebola. World Health Organization (WHO) and different research studies have proposed the countries to envisage flattening of COVID19 curve. Which will ease the pressure on their respective health systems and avail time to develop the vaccination. Under this premise, several strategies were proposed by research studies like social distancing, school and work closure, national and international travel restrictions, cancelling of events and gatherings, information disbursement and contact tracing. But the issue at hand is that countries are not unified on the type of strategies to be used. This study firstly developed an indicator which represented the pace of flattening of COVID19 curve. Figure 5 presented the global distribution of days to flatten. This indicator is then empirically analyzed against different policy strategies indicators.

The recent developments showed that the straight forward lockdown will not be an optimal strategy especially for the poor economies. It will effect more because of poverty and hunger than of COVID19. Hence there was a need to compare and share the most effective strategy to cater the spread of COVID19. The multipronged analysis using Panel RCM and Poisson Regression led to a final assessment of government strategies. Here, the most effective strategy was, contact tracing, international movement restriction, stay at home restrictions, work closure and information campaigns, arrange in decreasing order of effectiveness. This assessment rests all the debates related to the potency of the counter COVID19 strategies. WHO and local government needs to invest in the rigorous implementation of contact tracing mechanisms. This will help in minimizing the spread of possibly lethal viral infection.

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