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Adapted Bass Diffusion Model for the Spread of COVID-19 in the Philippines: Implications to Interventions and Flattening the Curve

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Understanding the spread of the COVID-19 pandemic is one of the most studied phenomena at present. Researchers were using various models to show their characteristics to make solutions. In this study, an adapted bass diffusion model was used to determine the time when the COVID-19 curve flattens in the Philippines. Further, it also determined the possible incidence of the second wave of infection. Also, it forecasted the number of infections per month and calculated the doubling time. Results revealed that the flattening of the curve is still not happening at present in the Philippines. The country is still facing the first wave. With this, sustaining and boosting its strategies in fighting the spread of the virus is a priority.

Key words: *Bass diffusion model, COVID-19, doubling time, flattening the curve, second wave.*

Introduction

The Corona Virus 2019 or the COVID-19 is a prevailing disease that affects the human respiratory system. Over almost three months since its outbreak in China, the virus is now considered a global pandemic, where each country strategises ways and means to lessen the spread in its national territory. The problem is that its transmission spreads exponentially fast in the absence of a cure. The Bass Diffusion Model can predict this infectious spread. This challenging paradigm is considered to forecast the diffusion of technological or product innovations (Massiani & Gohs, 2015). As proposed by this procedure, patterns on dispersion can be modelled through two mechanisms about innovators adopting the new product, and imitators purchasing the new product when exposed to existing users. However, an application of the model can be made to predict curves for infectious diseases. In light of the COVID pandemic, innovators can be considered as the spontaneous rate of infection from people who are exposed to infection due to ignorance. In contrast, the imitators can be treated as the rate of infection from people who are already aware of the danger of the transmission from infected people. Respectively, these will be referred to as p and q.

Various models and techniques were used by researchers to study the behaviour of the pandemic. Azarafza et al. (2020) employed a clustering algorithm and the geographical information system (GIS) to determine the virus spread. Very recently, Batista (2020) estimated the final size of coronavirus pandemic by the SIR model, while Chen et al. (2020) proposed a time-dependent SIR model for COVID-19 for undetectable infected persons. Buhat et al. (2020) developed a mathematical model of transmission of COVID-19 between health care providers and the general public. Gupta (2020) utilised an adapted bass model to project the spread of coronavirus in India.

Galvez, the Chief Implementer of the National Covid-19 Task Force, stated that the Philippines is winning the war against the virus (Newman, 2020). Wong, an epidemiologist from the Ateneo School of Medicine and Public Health, said that on May 5th, the coronavirus curve in the Philippines has started to flatten (Cepeda, 2020). The Department of Health supported the claim of Wong and warned the public about the possibility of a second wave. However, the equivalent terms contradict their mathematical definition. On the one hand, Duque, the Secretary of Health, was criticised when he stated that the Philippines is already on the second wave of infection (Cepeda, 2020). The Malacañang officials contradicted Duque with its firm stand that the country is still on the first wave. Roque, the Presidential Spokesman, supported this with a graph (Ranada, 2020). This contradiction added to the confusion brought about by the current pandemic situation.

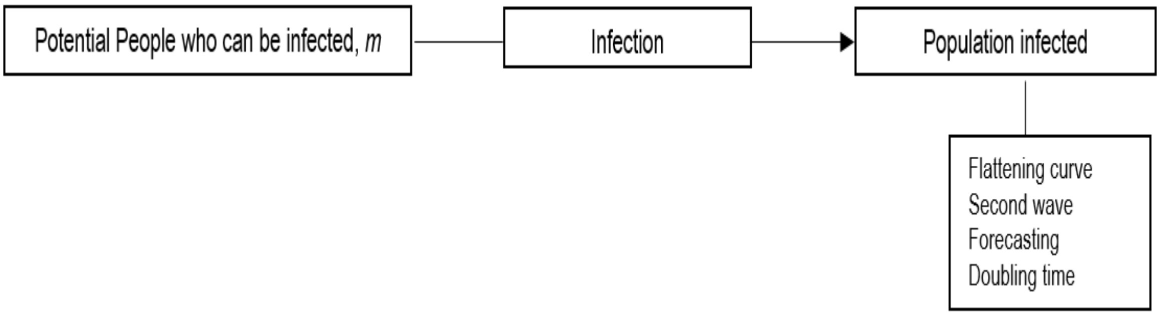
Flattening the curve, second wave, and doubling time were predominantly used to describe the infection. By definition, the pandemic curve refers to the projected number of cases over some time. Flattening the curve is the plateau of the cumulative distribution function of the number of new cases over a long period. Additionally, the doubling time refers to the time it takes for newly reported cases to increase two-fold. When rates of new infections appear to be shrinking, there is a possible end to the first wave of the pandemic. The second wave persists when infection rates begin to climb again. The longer the phenomenon continues, the more waves are likely to occur. It is, therefore, the objective of this study to determine the time the curve flattens and the possible incidence of the second wave infection in the Philippines. This paper will also forecast the number of monthly infections, saturation points, and doubling time. Furthermore, this will provide implications on intervention and flattening the curve.

Conceptual Framework

This study's main anchorage is on the Bass Model or the Bass Diffusion Model. It has been widely used in forecasting, especially new products' sales forecasting and technology forecasting, but this paper attempts to utilise the model in forecasting COVID-19 spread in the Philippines. Its significant contribution is the assumption that the probability of additional first-time adoptions of a new product in the future time is the function of the number of consumers who have adopted the product. Thus, this model treats this new product diffusion to be viral, essentially stating that diffusion occurs identical to the spread of a viral disease in a community such as Coronavirus disease (Boehner & Gold, 2012).

Coronavirus disease (COVID-19) is an infectious viral illness caused by a newly discovered coronavirus. It can infect a potential population, *m* in the country. The growth in the number of the infected community is a function of how the rate of infection diffused in an area, as shown in figure 1, similar to the novel Bass model described. The said model generates a curve that identifies the period cumulative infected population where plateaus will be determined, vital for the analysis of flattening curves and waves. It also forecasts the number of infections per month and calculates doubling time at the saturation point.

Figure 1. The Framework of the Study



The Model

The coronavirus-19 (COVID-19) disease is highly transmittable. Each one of us can be a potential victim for Covid-19 infection. We assume that there is a fixed number of a potential victims, say size m. At the first strike of the transmission, all m people are exposed to susceptibility. However, as more people are infected, then fewer people are left who would be a potential victim. To model the spread of COVID-19 disease, we use the Bass Model.

Let F(t) be the fraction of the population who have caught COVID-19 up to and including the t^{th} day, also known as the cumulative fraction of infections. Thus, the function F(t) is a function of time for which the unit of time is identified in a day. The parameter p is the spontaneous rate of infection. On the onset of the spread of the virus, some people are exposed to the disease due to ignorance and will catch the infection on their own without being aware of the other infected. Nonetheless, there is a new set of the populace who are already conscious of the danger of social interactions with the infected. Still, they choose to indulge in reckless and careless behaviour and allow themselves to be exposed to COVID-19 infection. Such susceptible individuals are called idiot-susceptible, and the rate of being infected is q in a symbol.

The basic Bass model is given by

$$\frac{dF(t)}{dt} = (p + qF(t))(1 - F(t)) \qquad (1)$$

The rate of infection on a given day $\frac{dF(t)}{dt}$ is just the rate of the infections $p + qF(t)$ times the rate of the potential victim$(1 - F(t))$ who are not yet infected. Rewriting (1), we have

$$f(t) = (p + qF(t))(1 - F(t)) \qquad (2)$$

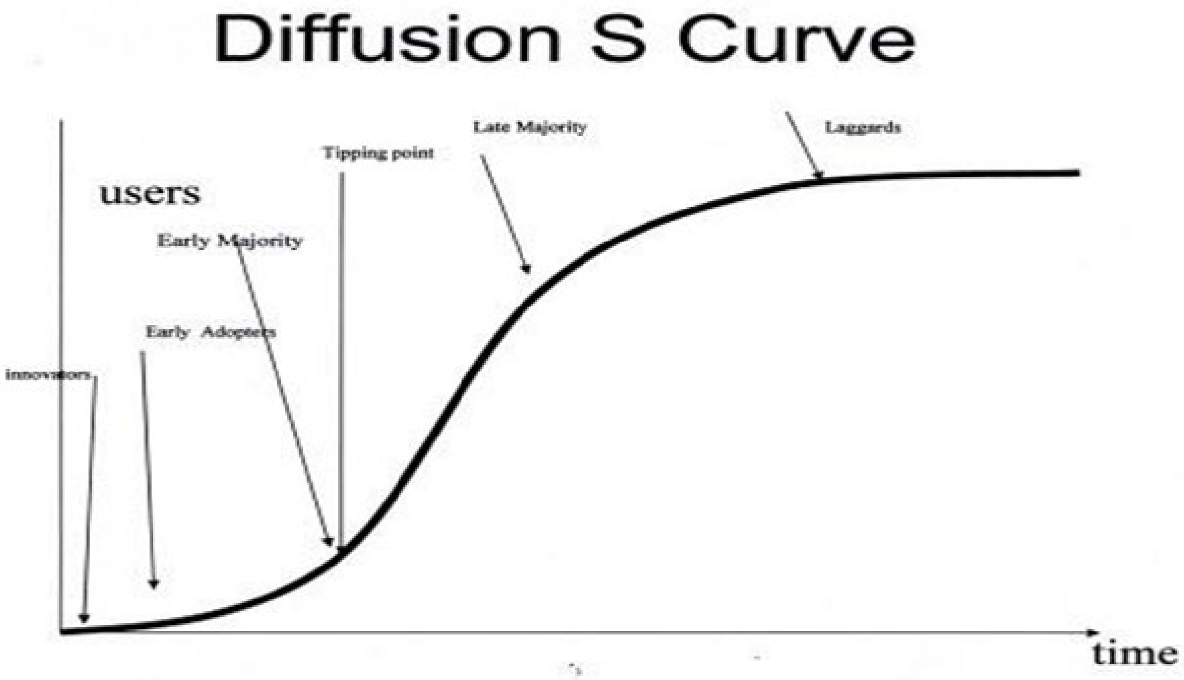
and $$S(t) = m \cdot f(t) \qquad (3)$$

Where S(t) is the number of infections on day t, and m is a total potential victim. Equation (3) can also be rewritten to

$$S(t) = m \cdot (p + qF(t))(1 - F(t)) \qquad (4)$$

For which $Y(t) = m \cdot F(t)$ is the cumulative infections on day t. At the start, what matters is the value of p. If p>0, this means that there is an acceleration in infections. Once the disease is transmitted, there will be a sudden increase in spread. Hence, the epidemic takes off. However, as Y(t) approaches m, then we have reached the saturation point, and the epidemic curve has flattened, as shown in figure 2.

Figure 2. S-shape Curve



The basic Bass model assumes only that the spread of infection is contagion. In the case of the escalation of COVID-19 infections, the individuals who have caught the disease will eventually reach the outcome, either they will recover or succumb to death. We will add another component to the Bass model, which is the outcome. Gupta (2020) modified the Bass model by integrating the outcome component, either recovered or died.

Adapted Bass Model: Gupta (2020)

Let O(t) be the fraction of persons who have caught COVID-19 and reached an outcome, either recovered or death, up to and including the t^{th} day. O(t) is a function of cumulative infection rate F(t), i.e., $O(t) = c.F(t)$, c is the outcome rate. Then we have

$$\frac{dF(t)}{dt} = \left(p + q(F(t) - O(t))\right)(1 - F(t))$$

$$\frac{dF(t)}{dt} = \left(p + q(F(t) - cF(t))\right)(1 - F(t)) \quad (4)$$

$$\frac{dF(t)}{dt} = (p + q(1 - c)F(t))(1 - F(t)) \quad (5)$$

Integrating (5) gives us,

$$F(t) = \frac{\left(1 - e^{-(p+q(1-c))t}\right)}{1 + \frac{q(1-c)}{p} e^{-(p+q(1-c))t}} \quad (6)$$

If c=0,

$$F(t)=\frac{\left(1-e^{-(p+q)t}\right)}{1+\frac{q}{p}e^{-(p+q)t}} \qquad (7)$$

Estimating the Parameters

The Adapted Bass Model now has four unknown parameters, namely, m, p, q, and c. To estimate the unknown parameters, we will make use of the real data, i.e. COVID-19 cases from January 30 to June 1, 2020. There are four known methods of estimating the parameters of the Bass Model. This study utilised the nonlinear least square method (NLS). To obtain the estimates of the parameters using the NLS, the expression for the number of infections on the time interval (t_{i-1}, t_i) is by definition,

$$S(t_i)=m\left(F(t_i)-F(t_{i-1})\right)+u_i$$

$$S(t_i)=m\left(\frac{\left(1-e^{-(p+q(1-c))t_i}\right)}{1+\frac{q(1-c)}{p}e^{-(p+q(1-c))t_i}}-\frac{\left(1-e^{-(p+q(1-c))t_{i-1}}\right)}{1+\frac{q(1-c)}{p}e^{-(p+q(1-c))t_{i-1}}}\right)+u_i, \qquad (10)$$

for $i=1,2,\ldots,n$

Where u_i is the additive term with variance σ^2.

Saturation Point

The saturation point is the time t, t>0 at which the curve of the function F(t) after its rapid increase started to flatten or decline in negative acceleration until, at zero growth rate, the population stabilises. The flattening of the curve occurs when $\frac{dF(t)}{dt}=0$. The saturation point, denoted by $(t^*, f(t^*))$, is given

$t^*=\frac{lnq(1-c)-lnp}{p+q}$, t is the time of peak infection and

$f(t^*)=m\left(\frac{q(1-c)}{4}+\frac{p}{2}+\frac{p^2}{4q(1-c)}\right)$.

The times of inflection points t^{**} are given by $t^{**}=\frac{lnq(1-c)-lnp\pm lnln\left(2+\sqrt{3}\right)}{p+q(1-c)}$ or $t^{**}=t^*\pm\frac{lnln\left(2+\sqrt{3}\right)}{p+q(1-c)}$

Results and Discussion

The Empirical Data

The data utilised in this study is dependent on the daily COVID-19 update of the Department of Health (DOH) in the Philippines. Based on the record, the first confirmed case is enlisted on January 30, 2020. As of June 1, 2020, the total confirmed case in the country is now at 18,638, with total recoveries of 3,979 and 960 total deaths. Data from January 30 up to June 1, 2020, were used as the basis for estimation of parameters of the Adapted Bass Model and for forecasting the number of COVID-19 cases, deaths, and recoveries until the day it reaches its saturation point. Table 4 shows the empirical data. Figure 3 reflects the time series plot of these data.

Figure 3. COVID-19 Confirmed, Death, Recovered Cases in the Philippines

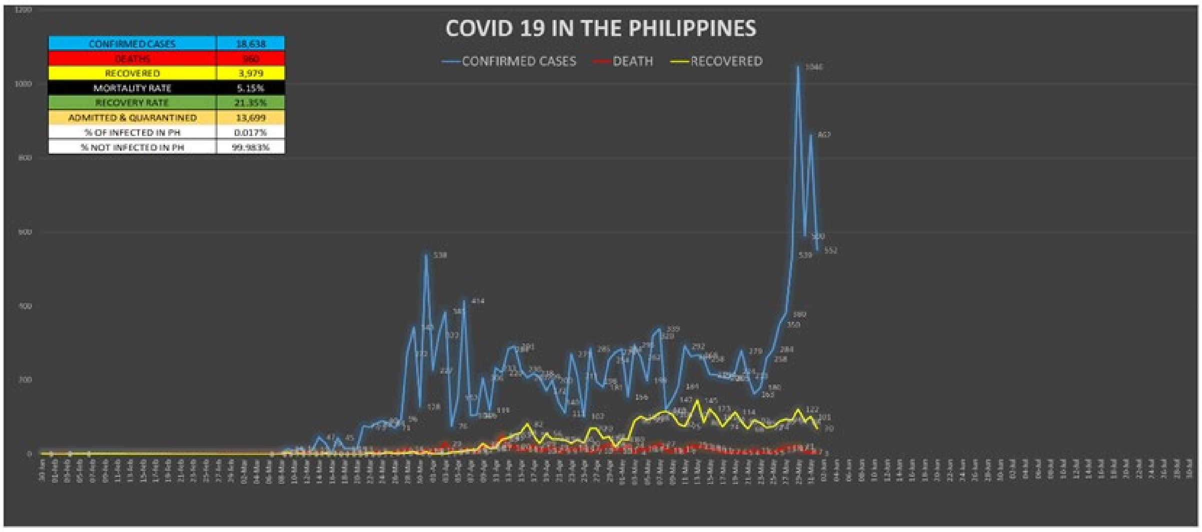


Table 4: Raw Data of Confirmed, death and recovered cases

Date	Confirmed Cases	Death	Recovered	Date	Confirmed Cases	Death	Recovered
30-Jan	1	0	1	21-Apr	140	9	41
2-Feb	2	1	0	22-Apr	111	9	39
5-Feb	2	0	1	23-Apr	271	16	29
5-Mar	0	1	0	24-Apr	211	15	40
7-Mar	1	1	0	25-Apr	102	17	30
8-Mar	4	1	0	26-Apr	285	7	70
9-Mar	14	1	6	27-Apr	198	10	70
10-Mar	9	1	0	28-Apr	181	19	43
11-Mar	16	4	2	29-Apr	254	28	48

12-Mar	3	3	0	30-Apr	276	10	20
13-Mar	12	2	1	1-May	284	11	41
14-Mar	47	2	0	2-May	156	24	40
15-Mar	29	3	2	3-May	295	4	90
16-Mar	2	0	0	4-May	262	16	101
17-Mar	45	1	0	5-May	199	14	93
18-Mar	15	1	0	6-May	320	21	98
19-Mar	15	1	0	7-May	339	27	112
20-Mar	13	1	0	8-May	120	11	116
21-Mar	77	1	0	9-May	147	8	108
22-Mar	73	0	4	10-May	184	15	82
23-Mar	82	8	1	11-May	292	7	75
24-Mar	90	2	2	12-May	264	25	107
25-Mar	84	3	6	13-May	268	21	145
26-Mar	71	7	2	14-May	258	18	86
27-Mar	96	9	3	15-May	215	16	123
28-Mar	272	14	4	16-May	214	11	101
29-Mar	343	3	7	17-May	208	7	74
30-Mar	128	7	0	18-May	205	7	94
31-Mar	538	10	7	19-May	224	6	114
1-Apr	227	8	1	20-May	279	5	89
2-Apr	322	11	1	21-May	213	4	68
3-Apr	385	29	1	22-May	163	11	92
4-Apr	76	8	5	23-May	180	6	85
5-Apr	152	8	7	24-	258	5	72

				May			
6-Apr	414	11	9	25-May	284	5	74
7-Apr	104	14	11	26-May	350	13	89
8-Apr	106	5	12	27-May	380	18	94
9-Apr	206	21	28	28-May	539	17	92
10-Apr	119	18	16	29-May	1046	21	122
11-Apr	233	26	17	30-May	590	8	88
12-Apr	220	50	40	31-May	862	7	101
13-Apr	284	18	45	01-Jun	552	3	70
14-Apr	291	20	53				
15-Apr	230	14	58				
16-Apr	207	13	82				
17-Apr	218	25	52				
18-Apr	209	10	29				
19-Apr	172	12	56				
20-Apr	200	19	41				

Based on the data, there is an increase in cumulative infection in the country. As noted by WHO as of March 8, 2020, transmission classification in the Philippines clusters the cases with evidence of community transmission in highly urbanised areas of NCR, Cebu, and Davao. Population Action International (2011) mentioned that population density and urbanisation are two factors affecting disease spread in contributing to the current number of confirmed cases. As May ended, the fight against the coronavirus continues. However, there is increased capacity in testing that led to the escalation of figures. It is noticeable that after this, the graph made a slow continuous descending fluctuation. The government's multi-sectoral response made a huge impact on the decrease in number through the Interagency Task Force. This response includes the upgrade of health care systems needing management on cases of isolation, quarantine, hospitalisation, and social amelioration programs.

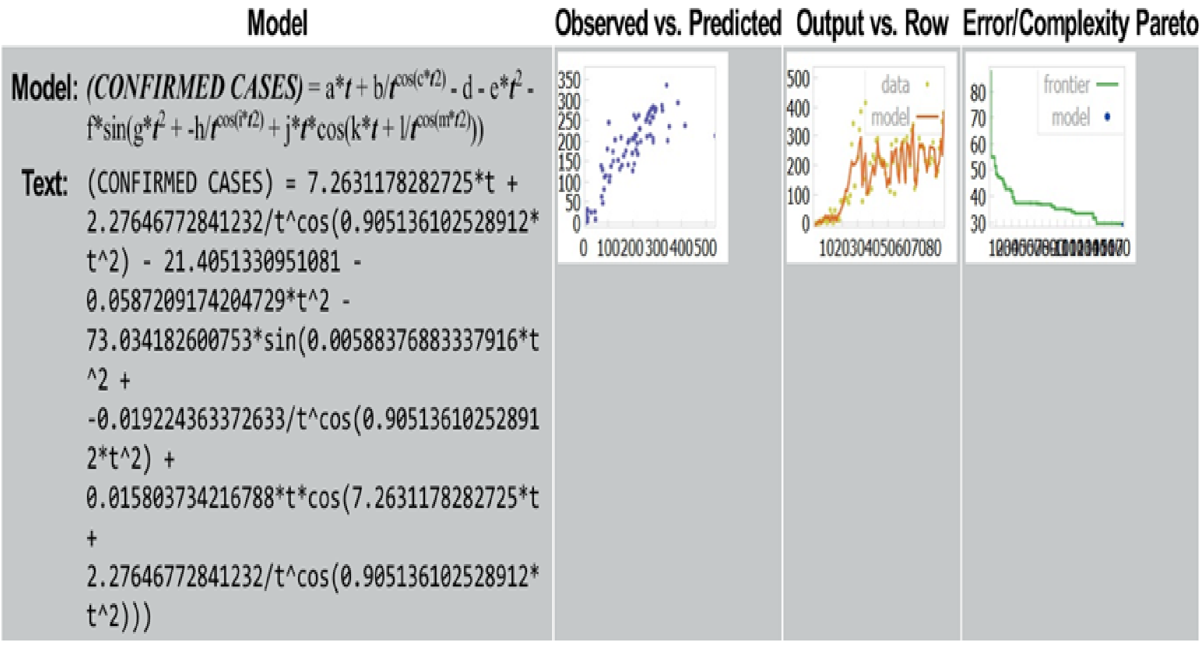
Recovery by the numbers similarly started to fluctuate continuously at a recovery rate of 21.35%. The government gave paramount efforts on controlling the number of deaths, improving hygiene and sanitation through proper and frequent information dissemination, and improving health care systems (PwC, 2020). On the authority of DOH, training was provided to public and private hospital workers on how to monitor COVID-19 patients with the provision of first-rate health facilities.

From another view, data on death fluctuates over time ranging from 0 to 50. The country's mortality rate is 5.15%, lower than the global average, which is 6.4 percent. The Philippines also contributes to 0.28 percent of global deaths, and most of the fatality victims are recorded within the age range of 50 years old and above (Santos, 2020). It was also reported that there were 32.6% deaths (N=696) in 60 to 69-year-old and 36.6% in 70 years old and up (World Health Organization, 2020). Data also showed that 71.8% of the death toll was reported from NCR, followed by CALABARZON (12.3%) and Central Luzon (4.1%). Overall, there is 0.017% of the population infected in the country, and 99.983% COVID-19-free, implying that government efforts and control strategies aided to contain the disease.

Figure 3 is a representation of the number of confirmed cases (blue) along with the daily count of deaths (red) and recoveries (yellow). The graph shows irregularities as data fluctuates over time. Peaks are noted to arise on May 29 with 1046 confirmed cases, May 13 with 145 recoveries, and April 12, 2020 with 50 deaths recorded. According to DOH, the 1,046 number of cases reported on May 29 came from 46 "fresh cases" and 1000 "late cases." Fresh cases were test results released to the patient within the last three days, while "late cases" were test results released more than four days ago.

The time series model for the COVID-19 infections found in figure 4 showed that there is a function of an exponential, power function, cosine, and sine functions. The irregularities of the curve indicate that the spread of the coronavirus is very intricate. Various factors play an amount of influence on the cause of the virus complexity (Azarafza et al., 2020; Gupta, 2020). Also, studies say that the disease is similar to the butterfly hypothesis, where the virus transmission can have a dynamo effect on other systems. These systems evolve, diffuse, and are very sensitive to the initial conditions which are themselves subjected to persistent shifting. Another note that causes the rapid spread of the disease is the presence of asymptomatic infected populations who can be carriers of the disease unnoticeably.

Figure 4. Time Series Model for the Covid-19 Infections



Model

Model: $(CONFIRMED\ CASES) = a*t + b/t^{\cos(c*t2)} - d - e*t^2 - f*\sin(g*t^2 + -h/t^{\cos(i*t2)} + j*t*\cos(k*t + l/t^{\cos(m*t2)}))$

Text:

```
(CONFIRMED CASES) = 7.2631178282725*t +
2.27646772841232/t^cos(0.905136102528912*
t^2) - 21.4051330951081 -
0.0587209174204729*t^2 -
73.034182600753*sin(0.00588376883337916*t
^2 +
-0.019224363372633/t^cos(0.90513610252891
2*t^2) +
0.015803734216788*t*cos(7.2631178282725*t
+
2.27646772841232/t^cos(0.905136102528912*
t^2)))
```

$$confirmed\ cases = 7.26t + \frac{2.28}{t^{\cos(0.91t^2)}} - 21.41 - 0.06t^2 - 73.03\sin(0.01t^2 + \frac{-0.02}{t^{\cos(0.91t^2)}} + 0.02t\cos(7.26t + \frac{2.28}{t^{\cos(0.91t^2)}}))$$

Estimation of Parameters, Saturation Point and Times of Inflection

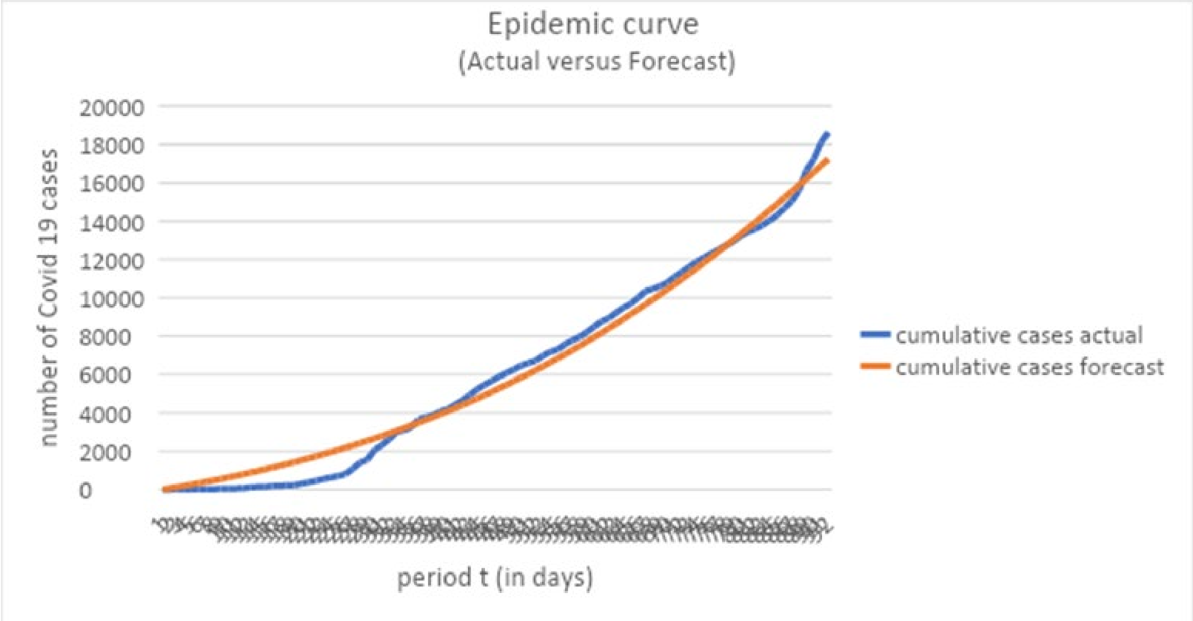
Parameters m, p, q, and c used the empirical data to obtain the estimates. In the Philippines, the pandemic started to take off in the first week of March and breached 15,000 at the end of May within three months. We let *m* be the potential victim of infection with the assumption that this number will approximately triple in the next few months this year, say m=50,000. To estimate p and q, we use statistical software that fits the Bass model to past data using nonlinear least squares. The estimates are obtained where $\hat{p} = 0.00124$ and $\hat{q} = 0.02740$. Now we estimate the value of c, the daily outcome rate. Outcome refers to either recovery or death. When the number of deaths and recoveries are combined, the daily outcome c is 0.0029, and the total outcome rate is 0.26, where 0.21 is the recovery rate, and 0.05 is the death rate. Table 1 summarised the estimates of the parameters.

Table 1: Estimates of parameters

Parameter	Estimate
The potential victim, m	50,000
Spontaneous rate of infection, p	0.00124
Rate of infection, q	0.02740
Daily outcome rate, c	0.0029

Using the estimates, we can find the saturation point of the COVID-19 infection as well as its times of inflection. The saturation point is at 108.21, 22,277.08. The epidemic curve model, shown in figure 5, will start to plateau in the period of $t = 109$. That is, the peak of the epidemic curve will be approximately the third week to the fourth week of June. In Tables 2 and 3, the number of COVID-19 cases increases before these periods and started to decrease after these periods. When the enhanced community quarantine took effect last April, IATF said that the epidemic curve had flattened because the doubling time had increased. However, there is no presence yet of a plateau in our cumulative distribution for both the model and the actual data, as revealed in figure 5. This indicates that flattening of the curve is about to come if we continue to observe proper hygiene, social distancing, and other preventive measures to contain the corona virus.

Figure 5. Epidemic Curve of the Actual and Predicted Cumulative Number of Cases



Further, the inflection times of the model were computed. The inflection point is the point that the epidemic curve changes its concavity, i.e., the moment when a rapid increase in the number of cases is replaced by a slower increase or vice versa. If the rate of accumulation changes from increasing to decreasing, then this could be when the decline starts to take place. The first inflection time occurs when $t = 62.10$. Looking at tables 2 and 3, the rate of change of the number of COVID-19 cases whose period closer to 62 days is high and changes from slower increase to higher increase. The second inflection point will occur when $t = 154.32$ days. At this period or closer to this period, the curvature of the curve changes again, which indicates the time when two incubation period ends after the saturation point at t=109 days. If the epidemic curve climbs up for another time, then there would be a possibility of 2nd wave of the pandemic. If the spread of infection will slowly decline until it stabilises, hence, the virus is successfully contained. Two months (February and March) from the start of spread in the Philippines approximately, the COVID-19 cases are slowly rising and suddenly change exponentially in April. However, in the third or 4th week of June, the curve may start to flatten and will continue until the second inflection time, sometime in August. Considerably, the turning point of the pandemic can be foreseen around that time, whether the second wave of the pandemic will transpire if not contained or the outbreak will finally end.

Doubling Time

Epidemic doubling times characterise the sequence of intervals, number of days, at which the number of cases doubles or the cumulative number of COVID-19 cases doubles. For the doubling time of the number of cases for March is 3 days, for April is 5 days and for June is 6 days. Further, the doubling times of the cumulative number of cases for March, April, and May were computed. From March 5 to March 31, there were 8 number of intervals that the cumulative cases are doubled. The average doubling time is three days. For April, from April 1-31, the doubling time occurs on April 10 and April 30. On average, the doubling time is 15 days. In May, the number of cases from April 30 doubled on the last day of May, May 30, with a doubling time of 30 days. Using tables 2 and 3, the next doubling time will occur in the last week of July. These tables show longer doubling time which indicates that the pandemic is slowing down. However, this does not indicate that the epidemic curve is flattened. In the unavailability of mass testing, we should not be complacent. A relaxation of preventive measures such as physical distancing and wearing of masks might bring another spike in the number of COVID-19 cases. As a consequence, doubling time may be shortened.

Forecasting

Forecasting plays an imperative role in the public health system, especially during a pandemic. Using the estimates in table 1, we can forecast the number of cases, the number of recoveries and deaths. Table 2 shows the actual and the predicted value of the number of infections, the cumulative number of infections, number of outcomes, number of deaths, and number of recoveries with an error estimate of 136.53 using Root Mean Squared Error for the number of cases, 26.60 for number of recovery and 8.36 for the number of deaths.

Table 2: Actual Cases versus Cumulative Cases

Time t (days)	No. of cases Actual	No. of cases (Estimates)	Cumulative Cases (Actual)	Cumulative Cases (Estimates)	No. of Outcome (Actual)	No. of Outcome (Estimates)	Cum. Outcome (Actual)	Cum Outcome (Estimates)	No. of death Actual	No. of death (Estimates)	No. of recovered actual	No. of recovered (Estimates)
0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	64	1	64	1	17	1	17	0	3	1	13
2	2	65	3	129	1	17	2	34	1	4	0	14
3	2	67	5	196	1	18	3	52	0	4	1	14
4	0	69	5	265	1	18	4	70	1	4	0	14
5	1	71	6	336	1	19	5	89	1	4	0	15
...	...	...	...	...	...	...	...	...	...	...	...	...
61	**156**	**236**	**8928**	**8412**	**64**	**63**	**1727**	**2229**	**24**	**13**	**40**	**50**
62	**295**	**240**	**9223**	**8651**	**94**	**64**	**1821**	**2293**	**4**	**13**	**90**	**50**
63	**262**	**244**	**9485**	**8895**	**117**	**65**	**1938**	**2357**	**16**	**13**	**101**	**51**
64	**199**	**248**	**9684**	**9143**	**107**	**66**	**2045**	**2423**	**14**	**14**	**93**	**52**
65	**320**	**252**	**10004**	**9394**	**119**	**67**	**2164**	**2489**	**21**	**14**	**98**	**53**
66	**339**	**255**	**10343**	**9650**	**139**	**68**	**2303**	**2557**	**27**	**14**	**112**	**54**
67	**120**	**259**	**10463**	**9909**	**127**	**69**	**2430**	**2626**	**11**	**14**	**116**	**55**
68	**147**	**263**	**10610**	**10172**	**116**	**70**	**2546**	**2696**	**8**	**14**	**108**	**55**
69	**184**	**267**	**10794**	**10439**	**97**	**71**	**2643**	**2766**	**15**	**15**	**82**	**56**
70	**292**	**271**	**11086**	**10710**	**82**	**72**	**2725**	**2838**	**7**	**15**	**75**	**57**
71	264	275	11350	10985	132	73	2857	2911	25	15	107	58
72	268	279	11618	11264	166	74	3023	2985	21	15	145	59
73	258	282	11876	11546	104	75	3127	3060	18	15	86	59
74	215	286	12091	11833	139	76	3266	3136	16	16	123	60
75	214	290	12305	12123	112	77	3378	3212	11	16	101	61
76	208	294	12513	12416	81	78	3459	3290	7	16	74	62
77	205	297	12718	12714	101	79	3560	3369	7	16	94	63
78	224	301	12942	13015	120	80	3680	3449	6	17	114	63
79	279	305	13221	13319	94	81	3774	3530	5	17	89	64
80	213	308	13434	13628	72	82	3846	3611	4	17	68	65
81	163	312	13597	13939	103	83	3949	3694	11	17	92	65
82	180	315	13777	14254	91	83	4040	3777	6	17	85	66
83	258	318	14035	14573	77	84	4117	3862	5	17	72	67
84	284	322	14319	14894	79	85	4196	3947	5	18	74	68
85	350	325	14669	15219	102	86	4298	4033	13	18	89	68
86	380	328	15049	15547	112	87	4410	4120	18	18	94	69
87	539	331	15588	15878	109	88	4519	4208	17	18	92	70
88	1046	334	16634	16212	143	89	4662	4296	21	18	122	70
89	590	337	17224	16549	96	89	4758	4386	8	18	88	71
90	862	340	18086	16889	108	90	4866	4476	7	19	101	71
91	552	343	18638	17232	73	91	4939	4566	3	19	70	72

From day 1-5, the actual cases are quite far from the forecasted cases. But from day 30-91, the actual cumulative cases and the cumulative cases forecast are roughly similar. Initially, there is a comprehensive deviation between the estimates and the actual cases, but as it increases, the estimate is closer to the actual value.

The time series plot of the actual number of COVID-19 cases and the predicted cases is shown in figure 6. As observed, the graph of the actual number of cases per day is sinusoidal, while the graph of the predicted number of cases, is a rising straight line. Table 3 is the forecast for the amount of COVID-19 infections, the cumulative number of infections, and the number of outcomes (death and recoveries) from day 92 to day 169.

Figure 6. Time Series Plot of Actual Cases versus Forecast Cases

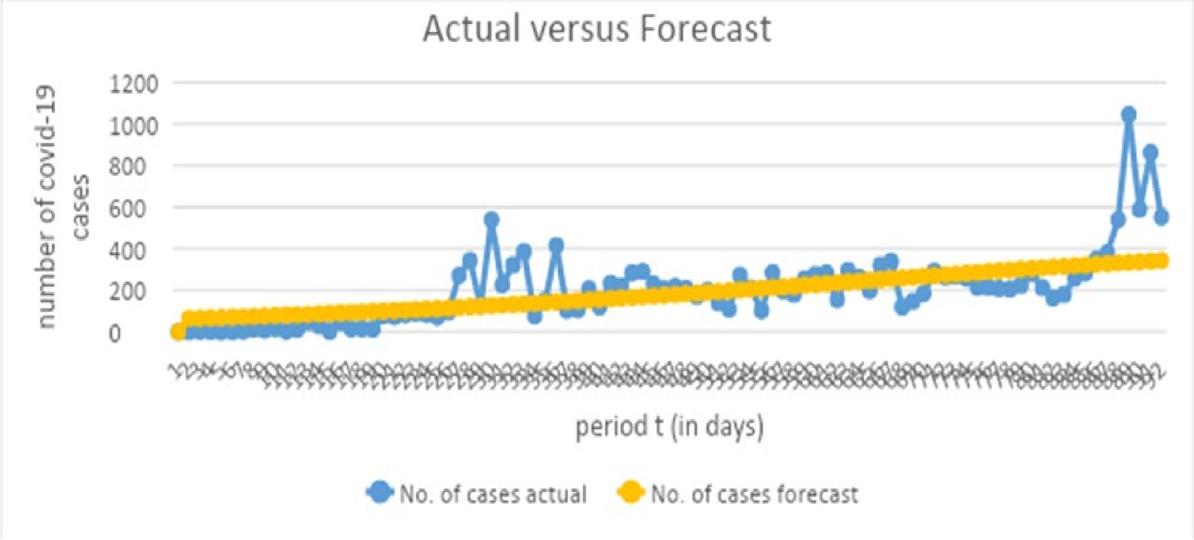


Table 3: Forecasting Day 92-169

time t (days)	No. of cases (forecast)	cumulative cases (forecast)	no. of outcome (forecast)	no. of death (forecast)	no of recovered (forecast)	time t (days)	No. of cases (forecast)	cumulative cases (estimates) (forecast)	no. of outcome (forecast)	no. of death (forecast)	no of recovered (forecast)
92	345	17577	91	18	74	131	351	31800	93	19	74
93	348	17925	92	18	74	132	348	32149	92	19	73
94	350	18275	93	18	75	133	346	32495	92	19	73
95	352	18627	93	18	75	134	343	32838	91	19	72
96	355	18982	94	18	76	135	341	33179	90	19	72
97	357	19339	95	18	76	136	338	33517	90	19	71
98	359	19697	95	18	77	137	335	33852	89	18	70
99	361	20058	96	18	77	138	332	34184	88	18	70
100	362	20420	96	18	78	139	329	34513	87	18	69
101	364	20784	96	19	78	140	326	34839	86	18	68
102	365	21150	97	19	78	141	323	35161	86	18	68

103	367	21517	97	20	77	142	319	35481	85	18	67
104	368	21885	98	20	77	143	316	35797	84	17	66
105	369	22254	98	20	78	144	313	36109	83	17	66
106	370	22624	98	20	78	145	309	36418	82	17	65
107	371	22995	98	20	78	146	306	36724	81	17	64
108	372	23367	99	20	78	147	302	37026	80	17	63
109	372	23739	99	20	78	148	298	37324	79	16	63
110	373	24112	99	20	78	149	295	37619	78	16	62
111	373	24485	99	20	78	150	291	37910	77	16	61
112	373	24858	99	20	78	151	287	38197	76	16	60
113	373	25232	99	20	78	152	284	38481	75	16	60
114	373	25605	99	20	78	153	280	38761	74	15	59
115	373	25978	99	20	78	154	276	39037	73	15	58
116	373	26350	99	20	78	155	272	39309	72	15	57
117	372	26722	99	20	78	156	268	39577	71	15	56
118	371	27094	98	20	78	157	264	39841	70	14	56
119	371	27464	98	20	78	158	260	40101	69	14	55
120	370	27834	98	20	78	159	256	40358	68	14	54
121	369	28202	98	20	77	160	252	40610	67	14	53
122	367	28569	97	20	77	161	249	40859	66	14	52
123	366	28935	97	20	77	162	245	41103	65	13	51
124	365	29300	97	20	77	163	241	41344	64	13	51
125	363	29663	96	20	76	164	237	41581	63	13	50
126	361	30024	96	20	76	165	233	41814	62	13	49
127	359	30383	95	20	76	166	229	42043	61	13	48
128	357	30741	95	20	75	167	225	42268	60	12	47
129	355	31096	94	19	75	168	221	42489	59	12	46
130	353	31449	94	19	75	169	217	42706	58	12	46

Implications to Interventions and Flattening the Curve

Wise decisions will help fight the pandemic spread. Strategies and interventions need to be in place at the right time and the precise place to sustain resources and stay alive. Given that the pandemic curve is still rising at present in the country, government actions and decisions matter. It may make or break all the efforts exerted for the safety of the citizens.

The rising pandemic curve suggests strict compliance to quarantine protocols. However, food resources of many families are scarce due to “no work, no pay” schemes, thus, discontinuing the quarantine measures would allow higher chance of infection. More people will be infected as they socialise with one another, especially not knowing if they are infected or not. It will not be helpful to release the constraints because the rate of infection will be fast.

In addition, not releasing constraints would also lead to hunger, depression, and the like which will also result in adverse consequences. With the prevailing cyclic variations of the pandemic curve, there is a need to take note of the low and high frequency of cases in terms of the period of time to inform government officials when to lift the constraints.

Lifting the constraints needs to be rationalised to avoid more problems. Knowing when to do it is the key. The shift from Enhanced Community Quarantine (ECQ) to General Community Quarantine (GCQ) and Modified General Community Quarantine (MGCQ) has to be decided at the correct geographical location and period of time. Currently, the pandemic curve has not reached its saturation point. This information will lead government officials to strictly impose the protocols. Having the saturation point as the only reference in lifting constraints; citizens' health may be safeguarded but the economy will eventually die together with its people. With this, the diminishing rate of change in the number of cases over time may be considered as the basis.

Sustained safety precautionary measures have to be exercised to have a flattening pandemic curve and further lead to zero number of infected cases. Rapid and robust preparedness and response strategies make a substantial difference in infection rates of countries (Sung & Kaplan, 2020). This is like in Vietnam, a combination of early lockdown, fast spread of health information, regulation for wearing a mask in public, and the country's unity to cope with COVID-19 (Huynh, 2020). Vietnam and Singapore have learned their lessons from the 2003 SARS outbreak that paved the way for them to enhance the way they deal with COVID-19. They used the information to promote government-citizen and intragovernmental cooperation. A measure implemented in these countries is a systematic tracing of pathogen carries and the early imposition of travel bans as with countries like South Korea and the United Arab Emirates. Access to online health information platforms allows citizens to remain vigilant and participate in government initiatives like contact tracing. However, in Japan, there is no lockdown. The Japanese government has been aggressive in identifying clusters and containing the spread. South Korea and Taiwan are also among the few countries to have demonstrated robust and consistent standard operating procedures.

Conclusion

The spread of COVID-19 infection is an intricate process. Different models may have different results and interpretations. In the present study, with an adapted bass diffusion model, the flattening of the curve is still not happening at present. The country is facing the first wave at present. With this, the country still needs to sustain and boost its strategies in fighting the spread of the virus. At present, the country is using a combination of containment and mitigation activities. Community quarantine is at disposition, and massive actions from the inter-agencies were very transparent. As individuals, let us do our share. Keeping ourselves healthy, eating the right food, and maintaining proper hygiene could be a big help to the efforts of the government.

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