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The Options for the UK Leaving Lockdown

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Abstract

A computer simulation of the Covid-19 epidemic has been updated with data that became available on 14 May 2020. The model parameters have been adjusted (i) to provide the best match to data from Public Health England on daily new lab-confirmed infections to 30 April 2020 and (ii) to ensure that the model reproduces the Office of National Statistics central estimate of the average number of recently infected people in England in the week before and the week after 3 May 2020. The new information allows outline guidance to be given for the first time on the approximate consequences of each of the four main options for the UK coming out of lockdown in the absence of an effective vaccine. The options may be ranked based on minimising the sum of deaths due to Covid-19 and those due to national impoverishment. The Government's currently declared aim of keeping the basic reproduction number below 1.0 emerges as the worst in terms of life preservation.

Key words: Coronavirus, Covid-19, lockdown, lockdown exit strategy, J-value, multi-cohort epidemic model, economic challenge

1. Introduction

The coronavirus epidemic originated in China in the autumn of 2019 but had spread to other countries by December of that year or January of the next. As cases and deaths mounted, many nations, including the USA and most in Europe, decided to put their populations into lockdown.

The confinement instituted in the UK became effective on the evening of 23 March 2020. The hospitality and entertainment industries were told they needed to close their doors. Schools were instructed to suspend teaching soon after and universities followed suit. Most types of shop shut, although not grocery supermarkets nor pharmacies.

Employees in all industries were expected to work at home if at all possible. People were told to stay in their homes except for work, medical reasons, buying food or taking exercise once a day locally.

Irrespective of whether or not their industry was officially sanctioned to continue, many businesses where home working was not feasible decided to suspend all or most of their activity. Construction was permitted by the Government, but some regional authorities were hostile to the idea and many construction firms closed. Building companies were, in any case, running out of materials as a result of the progressive closure of builders' merchants, who were finding it difficult to source replacement products and materials from manufacturers who were closing down for the duration.

The lockdown, as originally announced, was expected to last 3 weeks, subject to review. But it was extended at the end of the first period for a further three weeks and later for longer still. The position in mid May 2020 is that people in all industries except hospitality and entertainment are being encouraged to return to work, as from 13 May 2020. This date also marks the lifting of restrictions on travel away from the home in England (although not in Wales, Scotland and Northern Ireland). It is intended that schools should begin to open from 1 June 2020 and hospitality in July 2020. The return to work will be attended by industry-specific social distancing measures, such as erecting perspex shields between workers.

The re-opening of schools is resisted strongly by the teaching unions. There is also a reluctance to return to work amongst workers more generally, many of whom are either receiving their normal salary or being "furloughed". Under the furlough scheme, 80% of an employee's income up to £2,500 per month is provided by the Government until 1 August 2020, with a further extension to October 2020 planned during which the employer is expected to foot part of the bill. On the other hand, many in England, furloughed or otherwise, have taken advantage of the newly granted freedom to travel and flocked to beaches to enjoy the exceptionally sunny weather that has characterised most of the lockdown period in the UK.

A feature of the Government's message in lifting the lockdown restrictions has been its insistence that the basic reproduction number, R_0, (which, in a display of terminological inexactitude, it calls 'R') should be kept below 1.0. It has promised to reintroduce restrictions should the number of people infected by the average person with Covid-19 rise above unity. The consequences of such a policy will be assessed.

This paper will explore the four main options for leaving lockdown in the absence of a vaccine, which are

1. Keep the basic reproduction number, R_0, below 1.0;
2. Move out as quickly as possible without overstraining the health services;
3. Move out completely in 2020 while minimising Covid-19 cases; and
4. Move out of lockdown as fast as possible.

Recently documented methods[1,2] will be used to examine each strategy for its associated total loss of life, both from the coronavirus and as a result of national impoverishment if a long and deep recession is caused.

The layout of the paper is as follows. After a first section that sets the problem in context and specifies the leaving options, Section 2 will explain the matching of the two-cohort epidemic model to the empirical data. Section 3 will provide a mathematical characterisation of the exit process. Section 4 will present results for the four options. Section 5 will give comparative results for sensitivity studies based on a slightly different set of parameters that give as good a match to the measured data as the original set. Section 6 consists of a discussion, while conclusions are given in Section 7.

2. Fitting the two-cohort model to the recorded data

The two-cohort model described in Appendix A of a previous paper[2] was used to model the Covid-19 epidemic. Parameter values are as given there unless stated otherwise in the current text.

People in cohort 1 are expected to experience significant symptoms if they contract SARS-CoV-2. It is assumed that anyone in this group falling ill will be tested for the active virus and found positive. Some of these positive cases but not all will be admitted to hospital.

Meanwhile the members of the second cohort will experience less severe symptoms or else be asymptomatic and will never be subjected to a viral test.

The lockdown is taken to have come into force at 00.01 on 24 March 2020 (t_L) after the Government's announcement the previous evening. It is assumed that the general public became gradually more proficient at conforming over the next 30 days. This renders the basic reproduction number, R_{0i}, i = 1, 2, time-varying for each of the two cohorts, decreasing during the lockdown according to the following expression:

$$R_{0i}(t) = \begin{cases} R_{0i}(0) & t < t_L \\ \left(1 - \frac{f_{\Delta R0}}{30}(t - t_L)\right) R_{0i}(0) & t_L \le t < t_L + 30 \quad \text{for } i = 1,2 \\ (1 - f_{\Delta R0}) R_{0i}(0) & t \ge t_L + 30 \end{cases} \qquad (1)$$

where $f_{\Delta R0}$ is the fractional decrease in the two basic reproduction numbers brought about by lockdown.

[1] Thomas, P., 2020, "J-value assessment of how best to combatCOVID-19", *Nanotechnology Perceptions*, Vol.16, pp. 16–40.

[2] Thomas, P., 2020, "The length and severity of the coronavirus recession estimated from the dynamics of relaxing lockdown", *Nanotechnology Perceptions*, IN PRESS.

The model parameters were then adjusted so as to minimise the sum of the squared errors and so find the best match to

(i) daily new lab-confirmed infections[3] to 30 April 2020, and
(ii) to the central estimate[4] of the average number of recently infected people in England in the weeks before and after 3 May 2020.

Adjustments were made to the constants, $R_{01}(0), R_{02}(0), f_{\Delta R0}, \tau_{\inf,1}, \tau_{\inf,2}, \theta_1$ and $n_2(0)$, where $R_{01}(0), R_{02}(0)$ and $f_{\Delta R0}$ have been defined above, $\tau_{\inf,1}$ is the average time between infections in cohort 1, $\tau_{\inf,2}$ is the average time between infections in cohort 2, θ_1 is the fraction of the population who are members of the vulnerable cohort 1 (with the remaining $\theta_2 = 1 - \theta_1$ belonging to cohort 2) and $n_2(0)$ is the number of people with an active infection at the start of the simulation, 30 January 2020.

The optimal set of parameters is given in Table 1. The ONS survey figure for the number of active infections outside hospitals is reproduced to 1 part in 100,000.

Meanwhile the match to daily new infections is given in Figure 1. The root mean squared error (RMSE) is 388 cases, higher than the corresponding figure of 212 reported previously[2] when the end date was taken to be 10 April as opposed to 30 April 2020. The higher RMSE is brought about by greater exposure to the noisier data evident from the beginning of April onwards. This larger temporal variation appears to be a weekend effect: 12 out of 15 data points falling below the fitted line from 28 March 2020 onwards occurred on either a Saturday or a Sunday.

A dog-leg can be seen in the fitted curve at 23 April 2020, corresponding to the point, 30 days after the start of lockdown, where the public's proficiency in social distancing is assumed to have stopped improving, as modelled by equation (1). From now on the daily new cases are predicted to continue falling in an exponential decline as a result of $(1 - f_{\Delta R0}) R_{0i}(t) < 1.0$, $i = 1,2$.

The same feature is not immediately apparent in the data series. This may imply that the public is continuing to improve but it might mean that some other environmental effect is in play, such as the improving weather as winter turns into spring. If it is the latter, then the projections for the effect of lifting lockdown restrictions will be overly pessimistic for the summer period. On the other hand, one would then expect the situation to worsen significantly during the winter period.

[3] GOV.UK, 2020, Coronavirus (COVID-19) in the UK, https://coronavirus.data.gov.uk/ , Accessed 19 May 2020.
[4] Office for National Statistics, 2020, "Coronavirus (COVID-19) Infection Survey pilot: England, 14 May 2020"

3. Modelling the exit from lockdown

The first emergence from lockdown is assumed to take place over a period of 30 days from the date, t_{R1}, when the first relaxation begins. Hence the basic reproduction numbers are given by

$$R_{0i}(t)=\begin{cases}\left(1-f_{\Delta R0}\right)R_{0i}(0) & t<t_{R1}\\ \left(1-f_{\Delta R0}+\left(1-\eta_1\right)\dfrac{f_{\Delta R0}}{30}\left(t-t_{R1}\right)\right)R_{0i}(0) & t_{R1}\le t<t_{R1}+30\\ \left(1-\eta_1 f_{\Delta R0}\right)R_{0i}(0) & t\ge t_{R1}+30\end{cases}\quad \text{for } i=1,2 \qquad (2)$$

where the start date t_{R1} is 13 May 2020. Thus the first phase of exiting lockdown will be complete on 12 June 2020. Meanwhile, η_1 is the easing efficiency of the first stage of emerging from lockdown. An easing efficiency of 1.0 would keep all of the social distancing benefits of lockdown while an easing efficiency of 0.0 would retain none.

While it is possible to have just one stage of emergence, this will not always be the case, and, indeed, the stages may be separated by up to a year or so. Allowance is made for this eventuality by modelling later stages of emergence by step functions. Hence, for the k^{th} stage of emergence:

$$R_{0i}(t)=\begin{cases}\left(1-\eta_{k-1}f_{\Delta R0}\right)R_{0i}(0) & t<t_{Rk}\\ \left(1-\eta_k f_{\Delta R0}\right)R_{0i}(0) & t\ge t_{Rk}\end{cases}\quad \text{for } i=1,2 \qquad (2)$$

where η_k is the easing efficiency of the k^{th} stage of emerging from lockdown.

An overall basic reproduction number, $R_0(t)$, may be calculated as:

$$R_0(t)=\theta_1 R_{01}(t)+\theta_2 R_{02}(t) \qquad (3)$$

The fraction of the population needing to have been infected to give herd immunity, above which the number of infections people will decline, viz. $dn/dt<0$, is then[5]:

$$\frac{n+n_r}{N}=1-\frac{1}{R_0(t)} \qquad (4)$$

[5] Thomas, P., 2020, "J-value assessment of how best to combatCOVID-19", *Nanotechnology Perceptions*, Vol.16, pp. 16–40, equation (A.16)

where n is the number of infectious people, n_r is the number of people who have either recovered or else, unfortunately, have died and N is the total number of people in the population.

Alternatively, $R_0(t_S)$ may be "measured" by recording the computed values of n and n_r just before and just after the time, t_S, when $dn(t_S)/dt = 0$ and then applying equation (4):

$$R_0(t_S) \approx \frac{1}{2}\left(\frac{N}{N-\left(n\left(t_S^-\right)+n_r\left(t_S^-\right)\right)}+\frac{N}{N-\left(n\left(t_S^+\right)+n_r\left(t_S^+\right)\right)}\right)$$

where the following two conditions hold: $t_s^- < t_S < t_s^+$ and $t_s^- \approx t_S \approx t_s^+$, while, moreover, $dn\left(t_S^-\right)/dt > 0$ and $dn\left(t_S^+\right)/dt < 0$. The fraction of the population that needs to be infected to give herd immunity may then be calculated using equation (4).

4. Results

Option 1: Keep the basic reproduction number, *R*₀, below 1.0

There is limited room for relaxation given the effective value, 0.74, of the combined reproduction number at the start of the process of leaving lockdown. $R_0(t)$ is assumed to rise to 0.999 by 12 June 2020 and then remain there, ensuring that near-lockdown conditions persist indefinitely into the future.

The number of new daily cases of Covid-19 will continue to decline. Figure 2 shows the number of new daily cases normalised to the model's first peak of 3937 cases.

Little immunity is built up. 5% of the population will have contracted the virus after several years, so the nation is almost as vulnerable to further epidemics in 2025 as it was in January 2020.

National output drops to 71% of its pre-lockdown value and does not recover. See Figure 3.

While only a relatively small number of lives are lost to Covid-19, life expectancy declines due to serious national impoverishment.

The cost in human lives is 1.9 million plex-2020, where 1 plex-2020 = 42 years, the population-average life expectancy of a UK citizen in 2020. Almost all of these average UK lives are caused by the nation's fall in economic activity as a result of lockdown and continuing near-lockdown conditions. See Table 2.

Option 2: Move out as quickly as possible without overstraining the health services

This entails a slow move out of lockdown taken in steps, chosen to keep the peaks in new daily cases no higher than about twice that seen at the beginning of April 2020.

The effective, combined basic reproduction number is allowed to rise to 1.18 by 12 June 2020, and is held there steady for about a year, when it is increased to 1.6. This value is held for a year, after which all restrictions are abolished, and $R_0(t)$ rises to its unconstrained level of 1.94 in June 2022. See Figure 4.

The health services need to cope with two peaks each of which is twice the size of that seen in early April 2020. See Figure 5. This will, no doubt, require the Nightingale field hospitals to be brought into service.

The epidemic is essentially over by June 22. Half the population has been infected in the end, meaning that the nation has population or "herd" immunity.

Gross domestic product falls by 20.2% in 2020. The economy does not recover until 2023. See Figure 6.

The cost in average human lives is 644,000. Very roughly 10% of this loss of life is caused by Covid-19 and 90% by the nation's fall in economic activity. See Table 3.

Option 3: Move out completely in 2020 while minimising Covid-19 cases.

The effective, combined basic reproduction number is allowed to rise to 1.45 by 12 June 2020. All restrictions are removed on 1st January 2021, when $R_0(t)$ increases to its unconstrained level of 1.94. See Figure 7.

There is a single additional wave, the peak of which occurs in September 2020 and is about 9 times the size of that seen in April 2020. See Figure 8. The health services would struggle to cope, and the death rate is assumed to double as a result. However, 54% of the population would be infected by the end of 2020, so that herd immunity would be developed.

Gross domestic product falls by 16.1% in 2020 but the economy recovers in 2022. See Figure 9.

The number of average lives lost is 118,000, due entirely to Covid-19 under the assumption that few additional lives will be lost to national impoverishment because the recession is relatively short lived. See Table 4.

Option 4: Move out of lockdown as fast as possible

All restrictions are removed by 12 June 2020, when the effective, combined basic reproduction number returns to its unconstrained value of $R_0(t) = R_0(0) = 1.94$.

There is a single additional spike of infections peaking in late July 2020, 30 times the size of that seen in April 2020. See Figure 10. The health services can be expected to be overwhelmed, and the death rate is assumed to double as a result. 77% of the population are infected by the end of 2020.

Gross domestic product falls by 6.6% in 2020 but the economy recovers fully in 2021. See Figure 11.

The greater overshoot (77%) above the herd immunity level compared with Option 3 (54%) will mean that more people with die from Covid-19. The number of average lives lost is 170,000. All are assumed to be caused by coronavirus as no lives will be lost to national impoverishment because the recession is very short lived. See Table 5.

5. Sensitivity Studies

A feature of the previous research[2] was the large number of possible sets of parameters able to fit the daily case data to 10 April 2020. However the extra data now available has imposed additional constraints through the need to match daily cases up to the later date of 30 April 2020 and to reproduce the survey estimate of the number of people outside the hospital system carrying an active infection. This has narrowed the range of possible parameters.

The Sensitivity Studies feature a set of parameters estimated from a different starting point from that which generated the data-set listed in Table 1 and used in Section 4. The new parameter set was found under the constraint that the average time from infection to passing on the infection was less than 12 days. See Table 6.

Figure 12 shows the match between the daily new cases and the model prediction. The predicted curve has a very similar shape to that displayed in Figure 1, except that the dog-leg is slightly sharper in the later figure.

5.1 Changes between the Sensitivity Studies and the Base Cases under Option 1: Keep the basic reproduction number, R_0, below 1.0

Small changes only. The figure for total average lives lost increases from 1.899 million to 1.948 million plex-2020.

5.2 Changes between the Sensitivity Studies and the Base Cases under Option 2: Move out as quickly as possible without overstraining the health services

Compared with the same option in the Base Cases, the peaks of new daily cases in waves 2 and 3 go up from roughly twice to roughly two and a half times the maximum value observed at the beginning of April 2020 under Option 2 of the Sensitivity Studies. The total for average lives lost from 644,000 to 680,000 plex-2020.

If it is desired to keep the peaks of daily cases in waves 2 and 3 to no more than twice the peak at the beginning of April 2020, then a smaller third wave is incurred. See Figure 13. A recession that is somewhat worse means that the total number of average lives lost rises to 754,000 plex.

5.3 Changes between the Sensitivity Studies and the Base Cases under Option 3: Move out completely in 2020 while minimising Covid-19 cases

The responses are similar in these cases. The Sensitivity Studies under Option 3 calculates a somewhat higher total of average lives lost to the coronavirus: 133,000 compared with 118,000.

5.4 Changes between the Sensitivity Studies and the Base Cases under Option 4: Move out of lockdown as fast as possible

In the Sensitivity Studies, Option 4, the spike in daily new cases reaches a high point of 35 times the peak number found in April 2020, somewhat higher than the factor of 30 found in Option 4 of the Base Cases.

80% rather than 77% of the population becomes infected, and this pushes the loss of life from 170,000 to 204,000 plex-2020.

5.5 Overall comparison

Table 7 compares the loss of life under all 4 options for the Base Cases and the Sensitivity Studies. The toll on life is consistently slightly worse under each option in the Sensitivity Studies, but the ranking of the Base Cases is preserved.

6. Discussion

The range of sets of parameters able to match the measured data on the coronavirus epidemic in the UK has narrowed as more empirical evidence has accumulated. This convergence increases confidence in the two-cohort model as a guide to future dynamic behaviour of the epidemic resulting from the easing of lockdown restrictions.

The possibility of unidentified environmental effects augmenting the reduction in infection transmission during the lockdown period was considered at the end of Section 2. If such effects existed and were seasonal, then benefit would be drawn from their presence in the spring and summer. This would make a fuller exit from lockdown easier. But the beneficial effect would then be reversed in late autumn and winter. In such a case, the model presented here, which takes no account of possible seasonal effects, would represent a middle course.

All options for leaving lockdown, except for Option 1, lead to a second wave of infections.

It is clear from Table 7 that a too rapid emergence from lockdown (Option 4) would precipitate an uncontrolled epidemic but that leaving rapidly (Option 3) would minimise loss of life.

Leaving whilst avoiding overstraining the health services (Option 2) might seem at first glance to be a desirable course of action, but the analysis presented here suggests that the deep and long recession such a slow departure would provoke would lead to great loss of life due to national impoverishment.

The adverse effects of national poverty are illustrated even more clearly in the case of Option 1, where the effective basic reproduction number is kept below 1.0. This policy emerges as the worst in terms of the destruction of human life. The nation would face a huge and unprecedented setback to its economic well-being from which it would have little resource to recover. It is open to question how long Option 1 could be maintained in the face of discontent that might be mounting.

The only way out for a nation embarking wholeheartedly on Option 1 would be the rapid discovery, test, manufacture and extensive deployment of an effective vaccine. Since the consequences of the option are extremely severe, adopting Option 1 would be akin to taking a gamble on such an eventuality.

Option 3 emerges clearly as the best strategy for minimising loss of life.

7. Conclusions

In the absence of a vaccine available in the near future, the exit from lockdown ought to be made rapidly if loss of life is to be minimised.

That exit should be controlled to avoid too great a spike in infections. However, a second wave is an inevitable effect of all leaving strategies except for Option 1.

Option 1, where the effective basic reproduction number is kept below zero, would cause the greatest national impoverishment and the greatest loss of life as a result.

While the model has been matched to UK epidemiological and economic conditions, its general findings are likely to be relevant to other developed countries in addition to the United Kingdom.

	Cohort 1	Cohort 2
Cohort index, i	1	2
Fraction of population in cohort, θ_i	0.116	0.884
Basic reproduction number, R_{0i}	2.53	1.868
Average time between infections, $\tau_{\text{inf},i}$ (days)	8.82	8.25
Number of people with active infections on 30 January 2020, $n_i(0)$	1	167
	Applicable to both cohorts	
Combined basic reproduction number before lockdown, R_0	1.94	
Population or herd immunity fraction	49%	
Fractional decrease in the two basic reproduction numbers after 30 days of lockdown, $f_{\Delta R0}$	0.619	
Combined basic reproduction number after 30 days of lockdown	0.74	
Overall fatality rate after infection	0.0057	
Root mean squared error between daily case numbers to 30 April 2020	388	

Table 1. Parameter set for Base Cases of Section 4.

	Number of average lives lost (plex-2020)
To Covid-19	6,000
To national impoverishment	1,893,000
Total	**1,899,000**

Table 2. Loss of life in plex-2020 under Option 1: Keep the basic reproduction number, R_0, below 1.0

	Number of average lives lost (plex-2020)
To Covid-19	55,000
To national impoverishment	589,000
Total	**644,000**

Table 3. Loss of life in plex-2020 under Option 2: Move out as quickly as possible without overstraining the health services

	Number of average lives lost (plex-2020)
To Covid-19	118,000
To national impoverishment	Not applicable
Total	**118,000**

Table 4. Loss of life in plex-2020 under Option 3: Move out completely in 2020 while minimising Covid-19 cases

	Number of average lives lost (plex-2020)
To Covid-19	170,000
To national impoverishment	Not applicable
Total	**170,000**

Table 5. Loss of life in plex-2020 under Option 4: Move out of lockdown as fast as possible

	Cohort 1	Cohort 2
Cohort index, i	1	2
Fraction of population in cohort, θ_i	0.134	0.866
Basic reproduction number, R_{0i}	2.67	1.940
Average time between infections, $\tau_{\text{inf},i}$ (days)	10.78	9.22
Number of people with active infections on 30 January 2020, $n_i(0)$	1	193
	Applicable to both cohorts	
Combined basic reproduction number before lockdown, R_0	2.04	
Population or herd immunity fraction	51%	
Fractional decrease in the two basic reproduction numbers after 30 days of lockdown, $f_{\Delta R0}$	0.636	
Combined basic reproduction number after 30 days of lockdown	0.74	
Overall fatality rate after infection	0.0066	
Root mean squared error between daily case numbers to 30 April 2020	387	

Table 6. Parameter set for Sensitivity Studies of Section 5.

	Base Cases	Sensitivity Studies
Option 1: Keep the basic reproduction number, R_0, below 1.0	1,899,000	1,948,000
Option 2: Move out as quickly as possible without overstraining the health services	644,000	680,000
Option 3: Move out completely in 2020 while minimising Covid-19 cases	118,000	133,000
Option 4: Move out of lockdown as fast as possible	170,000	204,000

Table 7. Loss of life (plex-2020) under the 4 options in the Base Cases and in the Sensitivity Studies

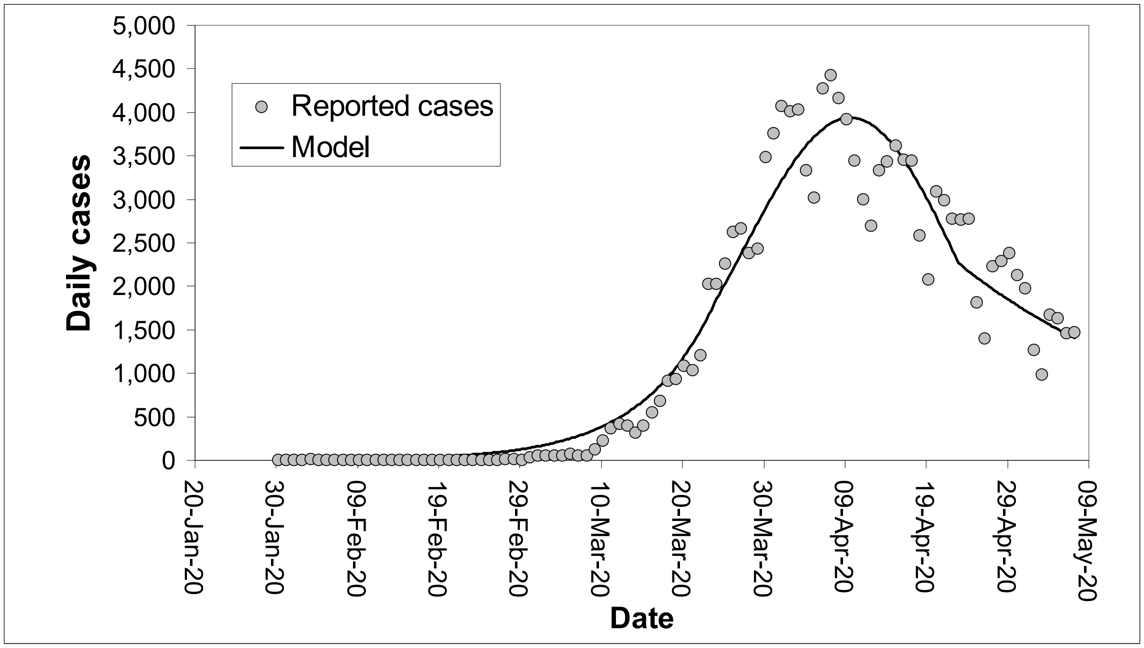

Figure 1. Comparison of model and daily new cases.
The model has been matched to data to 30 April 2020.

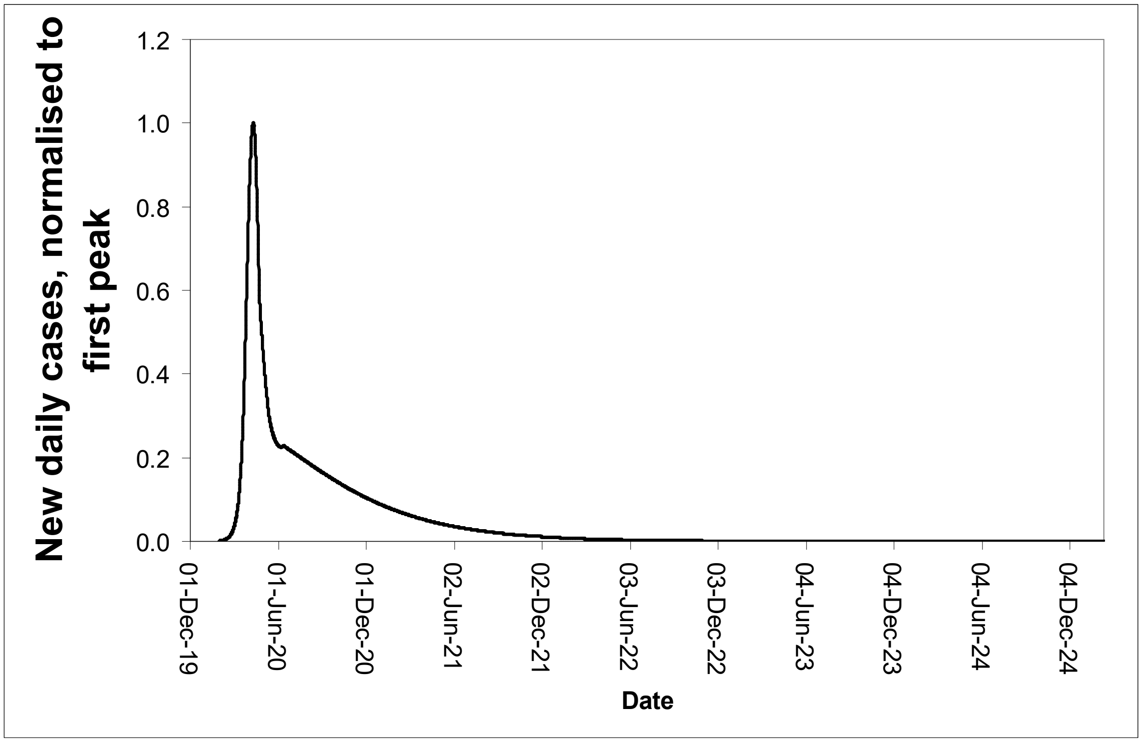

Figure 2. New daily cases normalised to the first peak, under Option 1: Keep the basic reproduction number, R_0, below 1.0

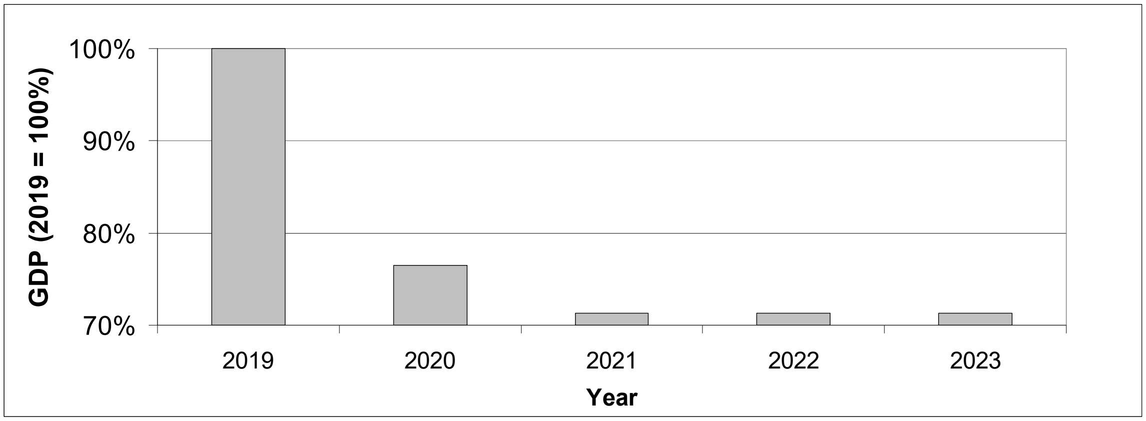

Figure 3. Annual GDP over time under Option 1: Keep the basic reproduction number, R_0, below 1.0

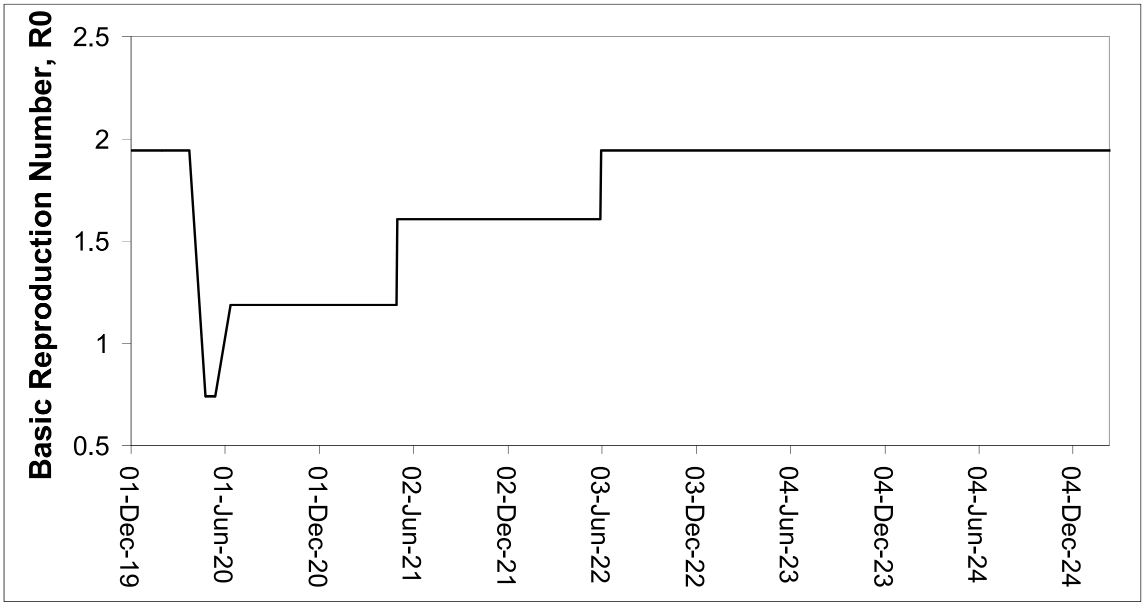

Figure 4. The trajectory of the effective combined reproduction number under Option 2: Move out as quickly as possible without overstraining the health services

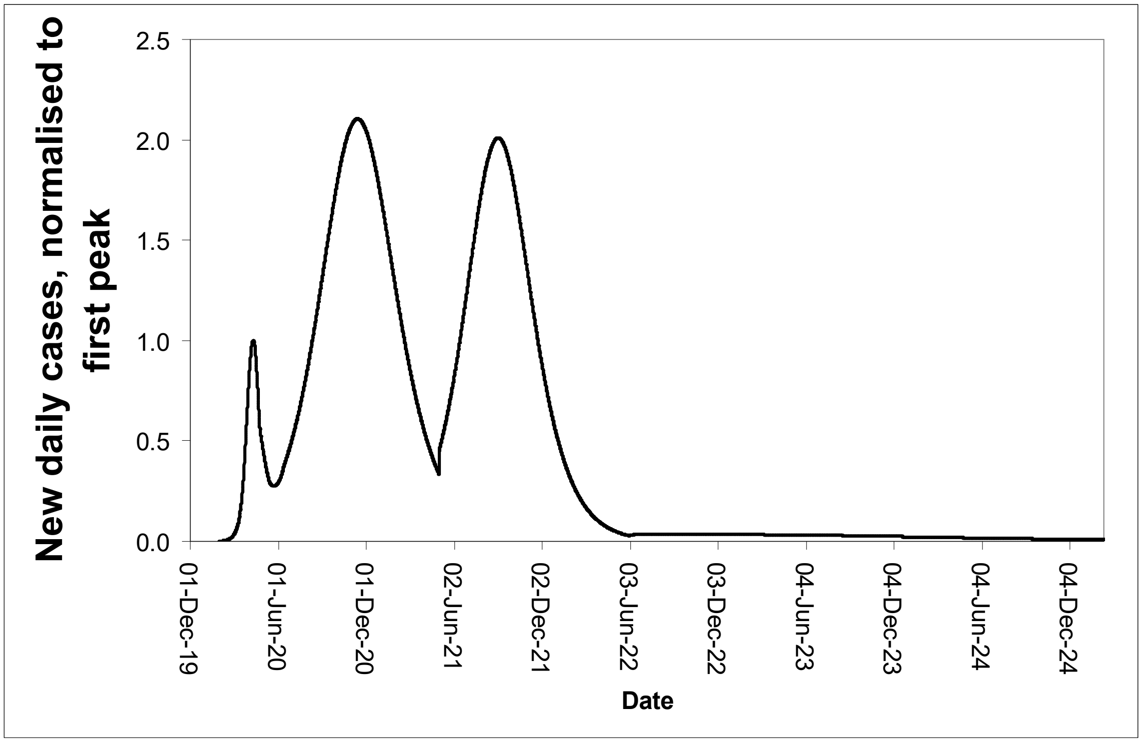

Figure 5. New daily cases under Option 2: Move out as quickly as possible without overstraining the health services

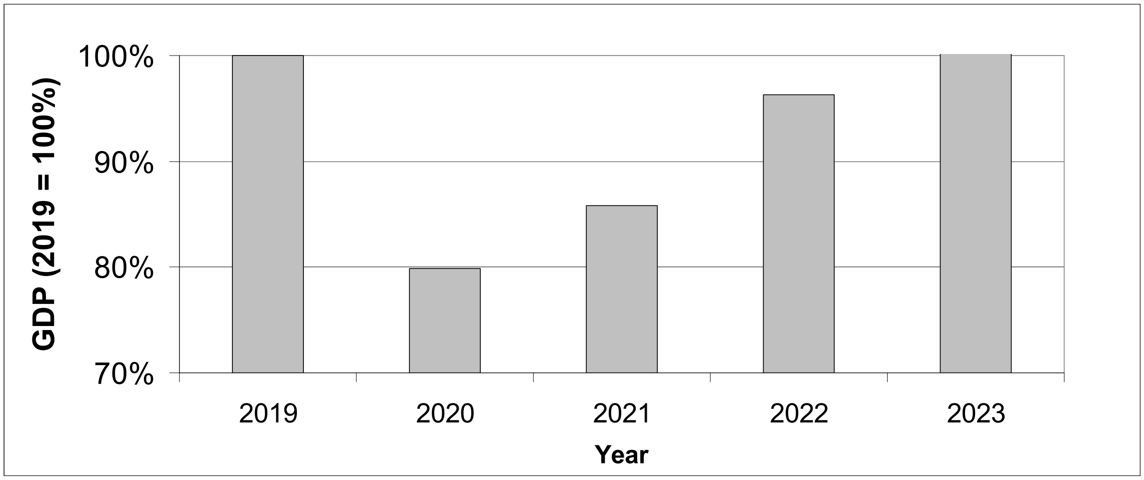

Figure 6. Annual GDP over time under Option 2: Move out as quickly as possible without overstraining the health services

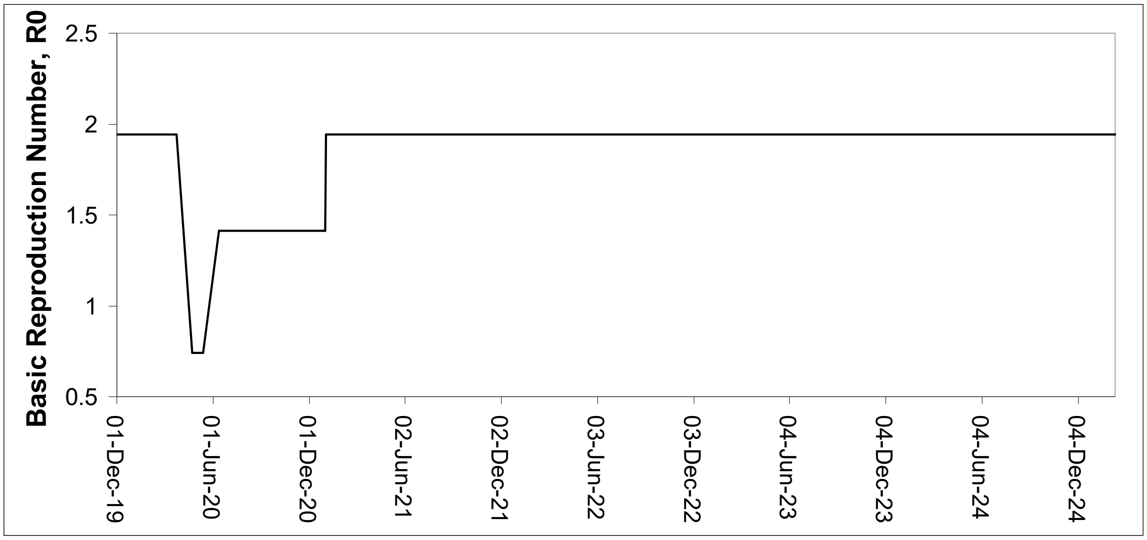

Figure 7. The trajectory of the effective combined reproduction number under Option 3: Move out completely in 2020 while minimising Covid-19 cases

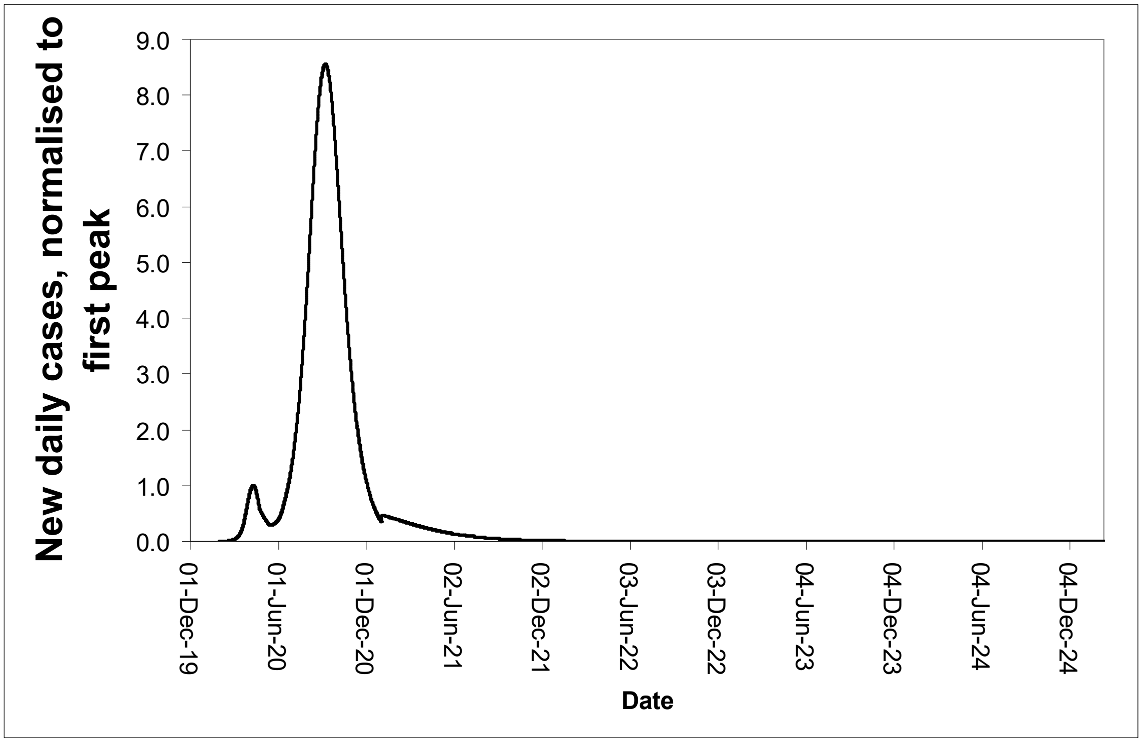

Figure 8. New daily cases under Option 3: Move out completely in 2020 while minimising Covid-19 cases

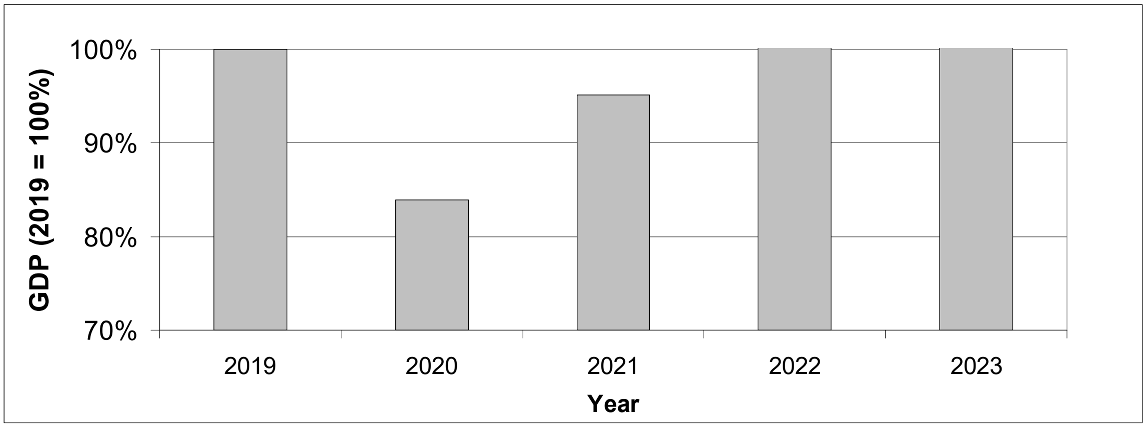

Figure 9. Annual GDP over time under Option 3: Move out completely in 2020 while minimising Covid-19 cases

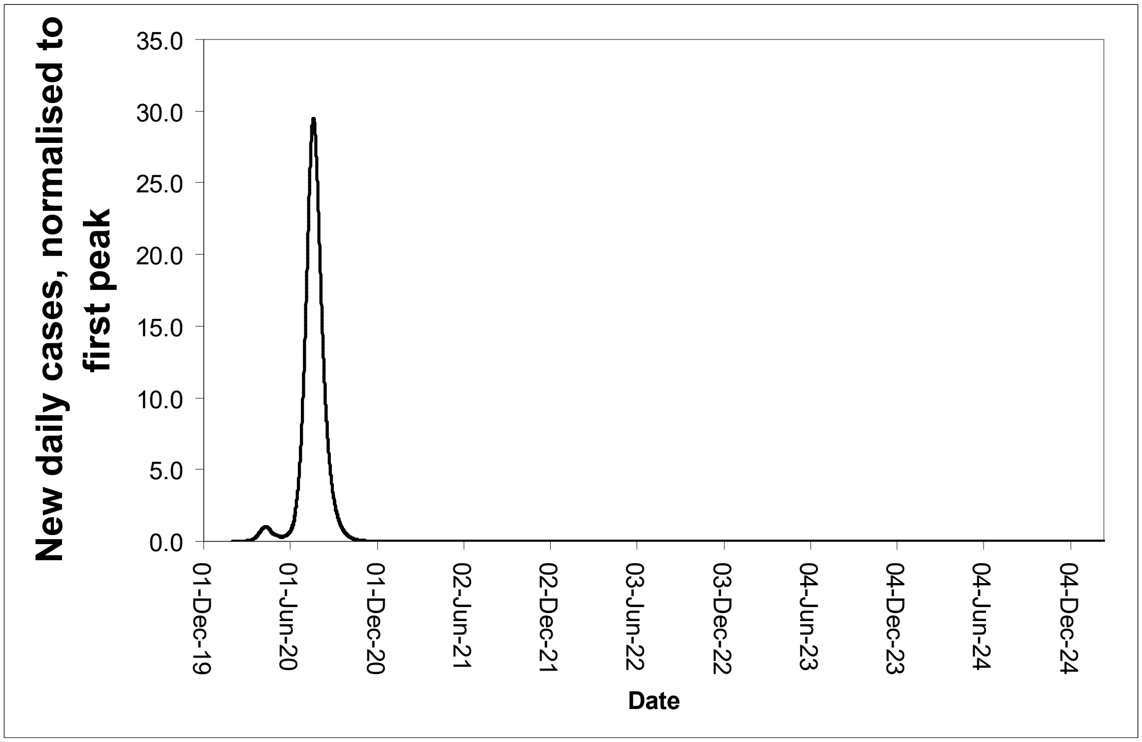

Figure 10. New daily cases under Option 4: Move out of lockdown as fast as possible

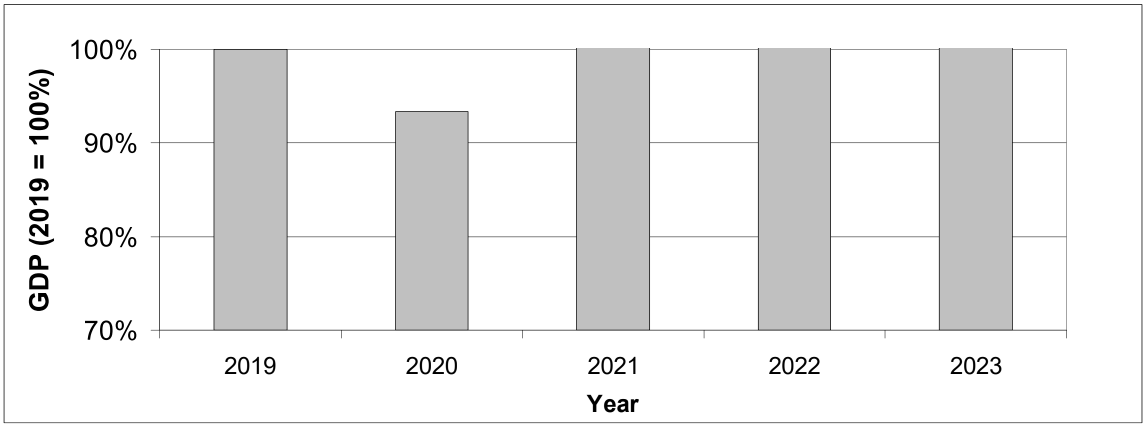

Figure 11. Annual GDP over time under Option 4: Move out of lockdown as fast as possible

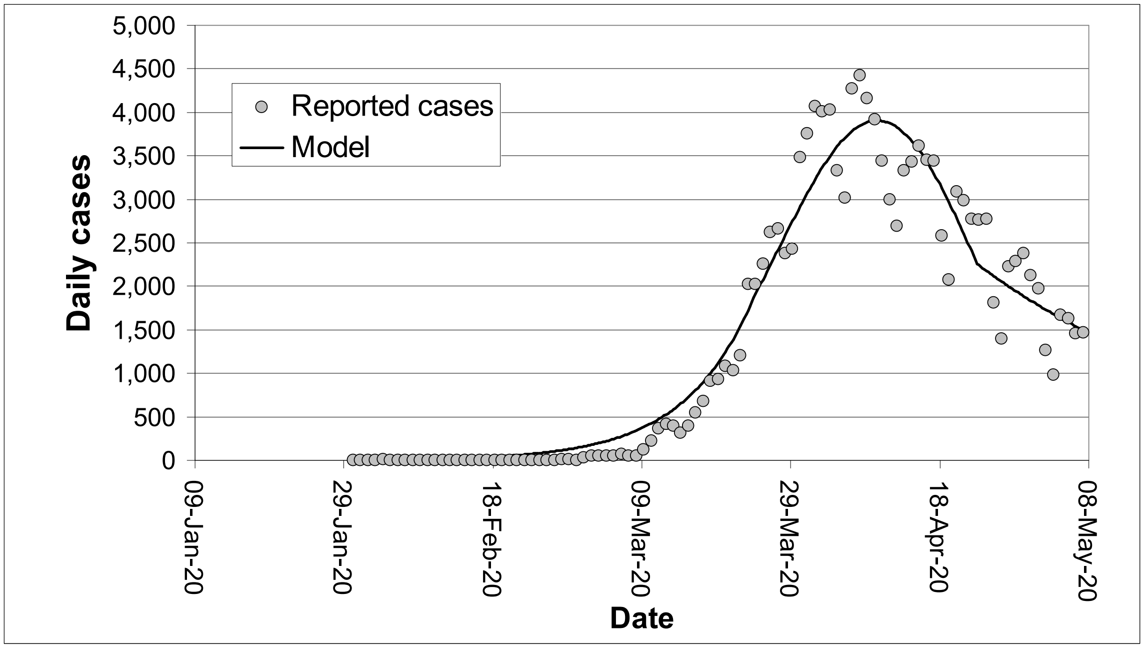

Figure 12. Model and daily new cases using the parameter set of the Sensitivity Studies.

The model has been matched to data to 30 April 2020.

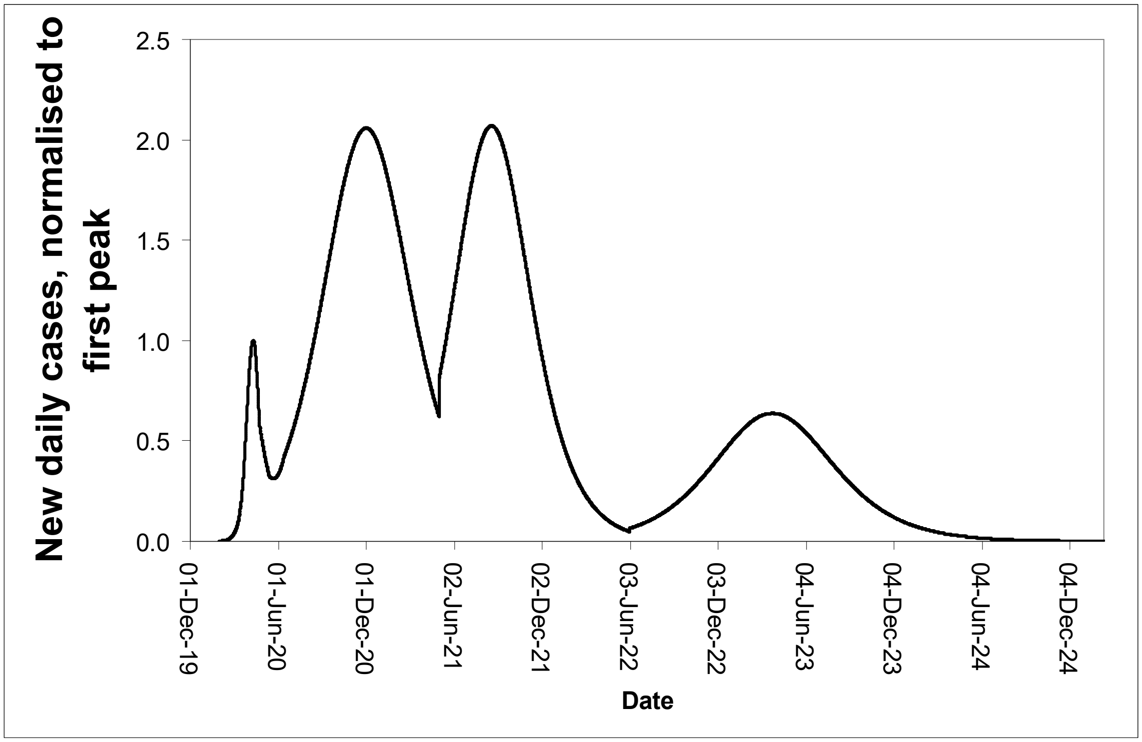

Figure 13. New daily cases under Option 2: Move out as quickly as possible without overstraining the health services; Sensitivity Studies with the constraint that the second and third peaks must be no greater than about twice the first peak