Online Supplemental Material,

Appendix A. Mathematical Models

GEE model for the number of daily new cases

Let \( y_{ij} \) be the number of daily new cases for the \( ith \) locality on the \( jth \) day, which we consider follows a Poisson probability distribution.

We have modelled the average longitudinal evolution over time separately for regions fitting the following GEE-Smooth spline model:

\[
\log \left( E(y_{ij}) \right) = \log(\text{Census}_i) + \gamma \text{Region} + \beta (\text{Region} \times N(\text{Time})_1) + \\
+ \lambda (\text{Region} \times N(\text{Time})_2)
\]

\( i = 1, 2, ..., n; \quad j = 1, 2, ..., T \)

Equation 1

where \( \gamma, \beta \) and \( \lambda \) are the regression coefficients.

“Census” is the offset variable and the terms \( N(\text{Time})_1 \) and \( N(\text{Time})_2 \) denote the basic functions for a natural cubic spline with two degrees of freedom. An internal knot was placed the day the inflexion point of the curve was observed. We considered an interchangeable structure for the correlation matrix, i.e., \( \text{corr}(y_{ij}, y_{ij'}) = \alpha \) and \( \text{corr}(y_{ij}, y_{ij''}) = 0 \).

Hurdle model for the number of daily new cases

For some regions, the count data sets exhibit an excess number of non-detected cases, mainly at the beginning of the follow up. This issue can be addressed using a hurdle model. The hurdle model combines a count data model (that is left-truncated at \( y = 1 \)) and a zero hurdle model (that is right-censored at \( y = 1 \)). In our case, we consider the log link and a truncate negative binomial for the count model and a logit link and a binomial density the zero hurdle model.
Let $y_{ij}$ be the number of daily new cases for the $ith$ locality on the $jth$ day.

- **Count Model:**

$$
\log(E(y_{ij})) = \log(\text{Census}_i) + \gamma_{\text{Region}} + \beta \left( \text{Region} \times N(\text{Time})_1 \right) + \\
\quad + \lambda \left( \text{Region} \times N(\text{Time})_2 \right) \quad \text{if} \quad y_{ij} > 0
$$

$$
i = 1, 2, ..., n; \quad j = 1, 2, ..., T
$$

**Equation 2**

where $\gamma, \beta$ and $\lambda$ are the regression coefficients.

- **Zero hurdle model:**

$$
\log \left( \frac{p_{ij}}{1 - p_{ij}} \right) = \gamma^*_{\text{Region}} + \beta^* \left( \text{Region} \times N(\text{Time})_1 \right) + \\
\quad + \lambda^* \left( \text{Region} \times N(\text{Time})_2 \right) \quad \text{if} \quad y_{ij} = 0
$$

$$
i = 1, 2, ..., n; \quad j = 1, 2, ..., T
$$

**Equation 3**

where $p_{ij} = P(y_{ij} = 1)$ and $\gamma^*, \beta^*$ and $\lambda^*$ are the regression coefficients.

“Census” is the offset variable and the terms $N(\text{Time})_1$ and $N(\text{Time})_2$ denote the basic functions for a natural cubic spline with two degrees of freedom. An internal knot was placed the day the inflexion point of the curve was observed.

**Model M1 and Model M2 for assessing the impact of the phase out measures in several European countries**

M1 and M2 have the same mathematical structure, i.e., if GEE was the most appropriate model for the country A, (Equation 1) then both models are GEE but they differ in the follow up. Model 1 only included information before the impact of the phase out measure, while Model 2 incorporated cases after the impact of the measure.
Model M1

\[
\log \left( E(y_{ij}) \right) = \log(\text{Census}_i) + \gamma \text{Region} + \beta (\text{Region} \times N(\text{Time})_i) + \\
+ \lambda (\text{Region} \times N(\text{Time})_j)
\]

\[i = 1, 2, ..., n; \quad j = 1, 2, ..., ID + 7\]

Equation 4

where ID is the implemented date of the measure

Model M2

\[
\log \left( E(y_{ij}) \right) = \log(\text{Census}_i) + \gamma \text{Region} + \beta (\text{Region} \times N(\text{Time})_i) + \\
+ \lambda (\text{Region} \times N(\text{Time})_j)
\]

\[i = 1, 2, ..., n; \quad j = 1, 2, ..., ID + 14\]

Equation 5

For those countries where hurdle was the optimal model, instead of Equation 1, we considered Equations 2 and 3 for both M1 and M2.
Appendix B. R-based code

# Example of the R-based code for assessing the impact of the phase-out measures.
# In particular the first phase-out measure implemented in Italy on day 10-04-2020

Step Procedure
1. Simulate, for each day and country, random samples that represent the number of inhabitants with event (new positive cases) and the number of inhabitants without event, from a Binomial distribution. The country size and the ratio between daily incidence and country size are the parameters.
2. Repeat step (1) K=30 times. They are representing repeated measures for each day and country.
3. Define the shortest follow up period, T1, starting on day zero, February 20th 2020, and finishing 1 week after the implementation date of the measure.
4. Fit regression model considering only observations of the shortest period, P1. This is the model M1.
5. Predict the daily incidence of new events in a 7 day window using M1.
6. Repeat step (4) for the longest follow up period, T2, starting on day zero, February 20th 2020, and finishing 2 weeks after the implementation date of the measure. This is M2.
7. Use M2 for predicting the daily incidence of new cases in the last week, period T2-T1.
8. Compare predictions obtained on step (7) with the 7-day projections obtained on step (5).
9. Define the number increased (NI) as the difference between the estimated incidence rate obtained using the full model, step (7), and the estimated incidence rate obtained on step (5). Number increased per population, (NIPP), is the number increased per 100,000 inhabitants.
10. Determine the percentage increase, PI, comparing the observed IR(7d) with the NIPP.
11. Repeat steps (1)-(10), 100 times to calculate the average of the indices and the corresponding 95% confidence intervals.

# Information obtained directly or by simple transformation from
# https://github.com/CSSEGISandData/COVID-19 # file Europe has been obtained using information download from this web page
# https://ec.europa.eu/eurostat # variable Census is download from this web page
# https://www.ine.es # variable Census is download from this web page
# https://data.humdata.org/dataset/acaps-covid19-government-measures-dataset # file Measures has been obtained using information download from this web page

## Merging countries with their phase-out measures

head(Europe,0)
>  country date confirmed newcases census
Europe<-Europe[order(Europe$country,Europe$date),]
head(Measures)
>  country description date_implemented
phase_out<-merge(Measures,Europe, by country)

## Initial parameters

follow<-Europe[!duplicated(Europe$date),]; I<-nrow(follow)
countries<-Europe[!duplicated(Europe$country),]; C<-nrow(countries)
K<-30
week<-7

# Matrices and vectors needed
incidenceCases <- matrix(data=NA, nrow=I, ncol=K)
incidenceCasesL<- vector(mode="numeric", length=C*I*K)
replicates<- vector(mode="numeric", length=C*I*K)
projection <- vector(mode="numeric", length=week)

# Packages needed
require(geepack)
require(splines)
require(pscl)

# Step 2: Repeat step (1) K=30 times. They are representing repeated measures for each day and country
for(k in 1:K){
    # Step 1: Simulate, for each day and country, random samples that represent the number of inhabitants with event (new positive cases) and the number of inhabitants without event, from a Binomial distribution. The country size and the ratio between daily incidence and country size are the parameters.
    for(c in 1:C){
        for(i in 1:I){
            n<- Europe$census[1+I*(c-1)]
cases_sim<-matrix(data=NA, nrow = n, ncol = I)
cases_sim[,i]<-rbinom(n,1,Europe$newcases[i]/n)
        }
        incidenceCases[,k]<-apply(cases_sim,2,sum,na.rm=TRUE)
    }
    # Reshape from wide to long format
    for (c in 1:C){
        for (i in 1:I){
            incidenceCasesL[(c-1)*K*I+(k-1)*I+i]<-incidenceCasesL[i+(c-1)*I,k]
            replicates[(c-1)*K*I+(k-1)*I+i]<-k+(c-1)*K
        }
    }
    day<-rep(1:I, times=C*K)
country<-rep(Name_countries$country,times=1,each=K*I)
aux1<-data.frame(cbind(incidenceCasesL,replicates,country,day))
EuropeComplete<-merge(Europe,aux1, by=c("country","day")

# Step 3. Define the shortest follow up period, T1, starting on day zero, February 20th 2020, and finishing one week after the implementation date of the measure.
Italy_measures<-phase_out[phase_out$country=="Italy",]  # select phase-out measures for Italy
T1<- Italy_measures$date_implemented[1]+week  # one week after the first measures for Italy

# Step 4: Fit regression model considering only observations of the shortest period, T1. This is M1 model.
EuropeR<-EuropeComplete[EuropeComplete$day<=T1,]
I_P<-60  # Select the inflection point, 21st March in this case
M1reduced<-geeglm(incidenceCasesL~country+ns(day,knots=I_P):country+offset(log(census)),
               id=replicates, corstr="exchangeable", family=poisson, data=EuropeR, scale.fix=F)

# Step 5: Predict the daily incidence of new events in a 7 day window using M1. One week projection
newdata1<- EuropeR[EuropeR$country=="Italy",]
for (i in 1:week){
  newdata1<- newdata1[newdata1$day==T1,]
  newdata1$day<-newdata1$day+i
  projection[i]<-as.integer(predict(M1reduced, newdata =newdata1, type = c("response")))}

# Step 6: Repeat step (4) for the longest follow up period, T2, starting on day zero, February 20th 2020, and finishing 2 weeks after the implementation date of the measure. This is the full model.
T2<- Italy_measures$date[1]+2*week  # two weeks after the first phase-out measures
Europefull<-EuropeComplete[EuropeComplete$day<=T2,]
M2full<-geeglm(incidenceCasesL~country+ns(day,knots=I_P):country+offset(log(census)),
               id=replicates, corstr="exchangeable", family=poisson, data=Europefull, scale.fix=F)

# Step 7: Use M2 for predicting the daily incidence of new cases in the longest period, T2
newdata2<- Europefull[Europefull$country=="Italy",]
prediction<-as.integer(predict(M2full, newdata =newdata2, type = c("response")))
# Step 8: Compare last week predictions obtained on step (7) with the 7-day projections obtained on step (5).

day<-seq(1,T2)
plot(day,prediction, main="Italy:New Cases", xlab="Dates", axes=FALSE,
frame.plot=TRUE, ylab="", ylim=c(0,6600), xlim=c(39,105), type="l")
Axis(side=1, at=c(20,40,60,80,105), labels=c("10-02-2020","01-03-2020","21-03-2020",
"10-04-2020","05-05-2020"))
Axis(side=2, at=c(1000,2000,3000,4000,5000,6000), labels=c("1000","2000","3000","4000","5000","6000"))
legend("topleft", legend=c("Model","Phase-out measure","7-day projection"),
 lty=c(1,2,2), col=c("black","black","red"), bty = "n")
abline(v = Italy_measures$date[1], col="black", lw=1, lty=2, lwd=2)
x2<-seq((T1+1),(T1+7))
xx<-c(min(x2),x2,max(x2))
yy<-c(projection[1],prediction[(T1+1):T2],projection[7])
polygon(xx, yy, col="lightcoral")

# Step 9: Define the number increased (NI) as the difference between the estimated incidence rate obtained using M2, step (7),
and the estimated incidence rate obtained using M1, step (5). Number increased per population, (NIPP), is the number increased
per 100.000 inhabitants.

NI<-sum(prediction[(T1+1):T2])-sum(projection)
NIPP<-((NI*100000)/newdata$census)

# Step 10: Determine the percentage increase, PI, comparing the observed IR(7d) with the NIPP.

aux2<-Europe[Europe$country=="Italy",]
IR<-(sum(aux2$newcases[(T1+1):T2])*1000000)/aux2$census[1]
PI<-(IR/(IR-NIPP))-1)*100

# Step 11: Repeat steps (1)-(10), 100 times to calculate the average of the indices and the corresponding 95% confidence intervals.
Appendix C. Observed versus estimated cumulated cases for Spain.

Figure C1. Observed hospital admission, intensity care unit and death versus predicted values by Spanish regions. Observations correspond with dates 06-04-2020 until 12-04-2020.
### Appendix D: Model Performance Errors

Table D1. Average of the mean absolute percentage error (MAPE) and mean absolute error (MAE) of the Spanish model from 1 to 7 day window, since April 6th to mid-May, 2020.

| Horizon | Confirmed Cases MAPE% (MAE) | Hospital admission MAPE% (MAE) | ICU Admission MAPE% (MAE) | Deaths MAPE% (MAE) |
|---------|-----------------------------|-------------------------------|---------------------------|-------------------|
| 1       | 0.73% (1684)                | 0.48% (411)                   | 0.33% (31)                | 0.35% (80)        |
| 2       | 1.21% (2735)                | 0.94% (813)                   | 0.48% (45)                | 0.66% (155)       |
| 3       | 1.68% (3824)                | 1.28% (1162)                  | 0.63% (64)                | 0.94% (226)       |
| 4       | 2.29% (5256)                | 3.29% (2800)                  | 3.23% (272)               | 2.03% (472)       |
| 5       | 2.83% (6568)                | 5.34% (4489)                  | 3.88% (332)               | 3.30% (764)       |
| 6       | 3.18% (7505)                | 5.85% (4982)                  | 4.47% (390)               | 3.86% (912)       |
| 7       | 3.62% (8584)                | 6.40% (5485)                  | 5.03% (441)               | 4.59% (1102)      |
Appendix E: Phase-out measures with slight or no impact for Italy, Spain and France

23-04-2020: For the national Liberation Day certain forms of celebrations have been allowed. Observed IR(7d.)=17.22. PI= 4.7%.

19-03-2020: Children that were not allowed to leave home are now allowed to accompany their parent (limited to single parents). Observed IR(7d.)=115.6. No impact.

13-04-2020: Some sectors, including construction and manufacturing were allowed to go back to work. Observed IR(7d.)=41.1. PI= 8.2%.

20-04-2020: Visits to elderly homes will be allowed again under certain restrictions. No impact.

Figure E1. Models and projection for Italy, Spain and France.
Appendix F: Impact by countries where significant phase-out measures have been implemented

14-04-2020 Slow increase of public transport network, in combination with gradual opening
14-04-2020 Companies may bring employees back from home office, under certain circumstances and with certain measures. Companies may bring employees back from home office, under certain circumstances and with certain measures.
15-04-2020: Day cares and primary schools to re-open.
Observed IR(7d.)=18.91. Pi= 15.5%.

20-04-2020 Gradual opening for a number of providers, including psychologists, physiotherapists, private hospitals and clinics, etc.
Observed IR(7d.)=16.74. Pi= 14.7%.

Figure F1: Models and projection for Denmark.
15-04-2020. Stores, apart from food stores, allowed to reopen, if they have a separate direct entrance from the outside and are able to regulate the flow of customers and other visitors; Operation of non-food stores in entertainment centres and supermarkets remains prohibited. Stationary service provision settings (supermarkets), such as cleaning services, key making, repair services, etc. generally allowed to reopen, even if they don’t have separate entrance and can control flow of persons; however maximum contact with customers set at 20 minutes (thus beauty salons and sports clubs remains prohibited). Observed IR(7d.)=3.9. No impact.

Figure F2: Models and projection for Lithuania.
30-03-2020. A number of shops to reopen, including opticians, leasing services, bike shops, DIY stores, hardware stores, key services and similar; though limits on the number of persons in store limited to 1 per 25m². Observed IR(7d.)=4.3. No impact.

21-04-2020. Outdoor sports are allowed again under certain restrictions and hygiene measures (including limited contact, availability of disinfectants, etc.). Observed IR(7d.)=0.7. No impact.

22-04-2020. Long-term accommodation (>10 days) to reopen (though not their restaurants). Observed IR(7d.)=0.69. No impact.

Figure F3. Models and projection for Slovakia