EXTENDED SUPPLEMENTARY MATERIAL

Implementation details, supplemental tables, figures and diagnostics for the proposed SEIR model, as well as indicative figures for the SEIR model without vaccinations and the analogous SIR model with vaccinations. Analytical results on the posterior estimates of the multivariate regression coefficients. Detailed Data References.

S1. Implementation details. In order to improve efficiency while fitting the stochastic transmission SEIR model for an extended time period, we first fit the analogous SIR model and then use the posterior estimates to draw initial values for the SEIR model. For shorter time periods, the SIR model was less sensitive to initial values and computationally less intensive. Details on the SIR model's specification are available at https://github.com/anastasiachtz/seir-gbm.git.

In executing this analysis, we began with 4 chains each with 4500 iterations, a warm-up of 2000 and thinning rate equal to 5, leading to a total of 2000 posterior samples. However, time constraints led to the use of fewer iterations which were adequate to produce reliable estimates. Therefore, for some countries, we use 4 chains, each with 1000 iterations of which the first 500 are warm-up to automatically tune the sampler, leading to a total of 2000 posterior samples. We examine the convergence of the parameters by inspecting the trace plots of all chains, indicating that there is no lack of convergence, and by checking the $\hat{R}$ convergence statistic and effective sample sizes reported by Stan. In all cases it appears that the chains converged reasonably well with relatively low effective sample sizes only for the volatility parameters of the Brownian motion. Volatilities are top-level parameters in our hierarchical model and we have very little information for them. Other non-informative priors have been also tested for σ_w giving similar results. Analytical results are provided in the next section.

S2. Addition Tables and Figures. Figures S1a-S6b offer a thorough graphic presentation of the time course of estimated infections in parallel with some general control measures implemented in each country, for the time period between March and mid-October 2020 and between mid-October 2020 and September 2021. For ease of presentation, uncertainty in our results on new daily infections is expressed through 50% credible intervals (CI) derived from the 25% and 75% quantiles. Our initial estimates of the infections are uncertain, due to possible under-ascertainment in deaths, and likewise, when it comes to the estimated infections of the latest period under study, uncertainty exists due to the fact that deaths can only offer an accurate representation of infections during the past $2-3$ weeks. The estimated aggregate infections in each country from March 2020 to September 2021 are presented in Figure S7 offering an indication of the actual burden of the disease. Finally, Figure S8 presents a visual inspection of the model fit to the data on death counts for each country and Figure S9 sets out additional model's estimates on the unreported daily number of cases for each country. Tables S1, S2, S3 present posterior means and credible intervals for some indicative model parameters for each country, as well as effective sample sizes and $\hat{R}$s.

In all countries, during the first and second pandemic wave, the estimated daily new cases are significantly higher than the laboratory-confirmed cases. Also, both posterior medians and credible intervals are skewed to the left in comparison to the reported cases, which can be explained by possible reporting delays and by the fact that transmission also occurs through asymptomatic individuals (**?**).

(a) Greece - 07/03/20 - 15/10/20   (b) Greece - 16/10/20 - 30/09/21

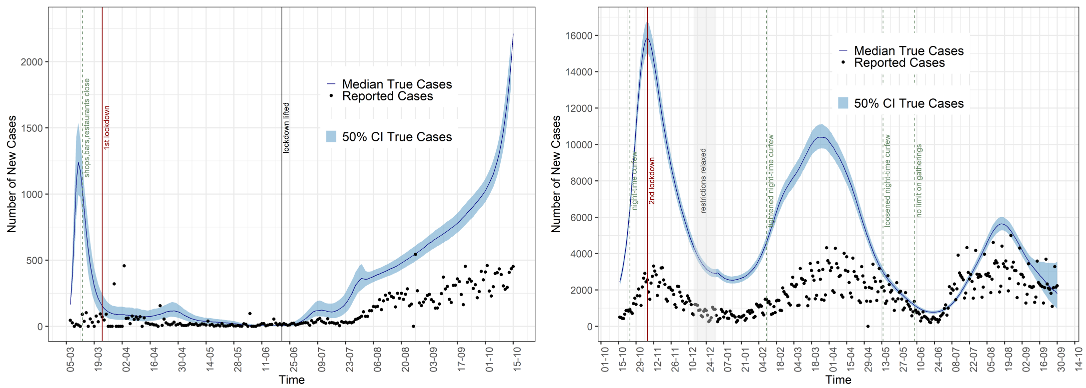


Fig S1: Daily estimated number of total cases, medians(line) and 50% CI(shaded areas) along with reported cases data(dots).

We estimate that during the first pandemic wave, Greece and Portugal having introduced several control measures well short of lockdown, were able to suppress infections early (Fig. S1a and S2a). With regard, however, to the resurgence of infections in fall 2020, stricter measures were necessary to stem the increase of infections. The notable difference between estimated and reported cases in Portugal in January of 2021 (Fig. S2b), indicates a possible change in the infection to death distribution, which we considered constant throughout our analysis. A shorter infection to death distribution is consistent with the extreme pressure in hospitals at that time in Portugal.

(a) Portugal - 04/03/20 - 15/10/20   (b) Portugal - 16/10/20 - 30/09/21

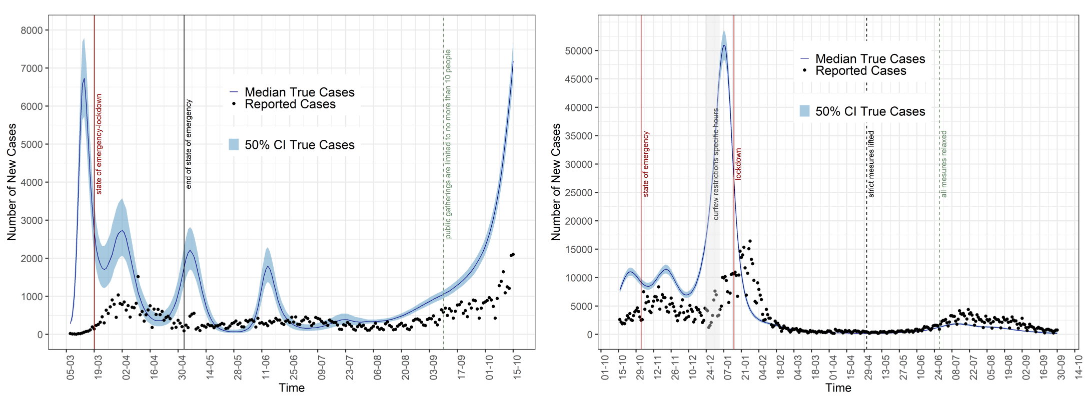


Fig S2: Daily estimated number of total cases, medians(line) and 50% CI(shaded areas) along with reported cases data(dots).

Regarding the estimated infections in Germany and the United Kingdom, during the first wave, a decrease in daily new cases appeared some days before the nationwide lockdown in both countries (Fig. S3a and S4a). However, during the subsequent pandemic waves infections are estimated to increase steadily although both countries had imposed nationwide lockdowns in November. The dominance of the alpha variant led to extended lockdowns which eventually reduced the number of infections as estimated.

(a) United Kingdom - 28/02/20 - 15/10/20 (b) United Kingdom - 16/10/20 - 30/09/21

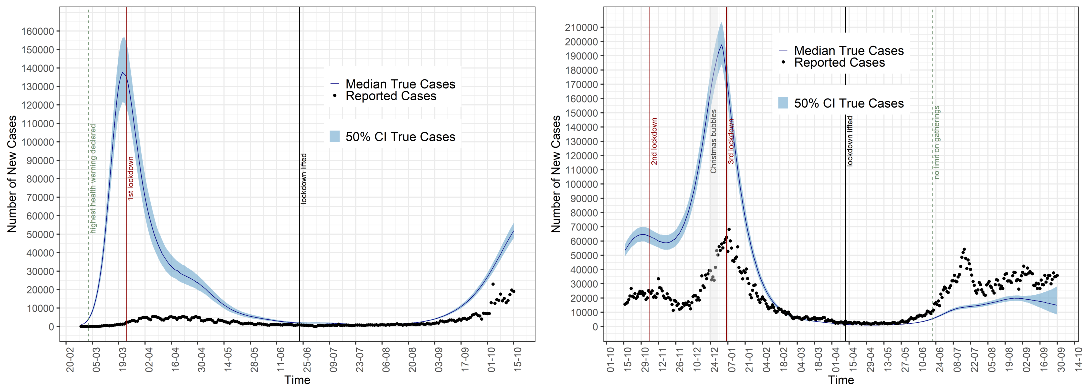


Fig S3: Daily estimated number of total cases, medians(line) and 50% CI(shaded areas) along with reported cases data(dots).

(a) Germany - 28/02/20 - 15/10/20 (b) Germany - 16/10/20 - 30/09/21

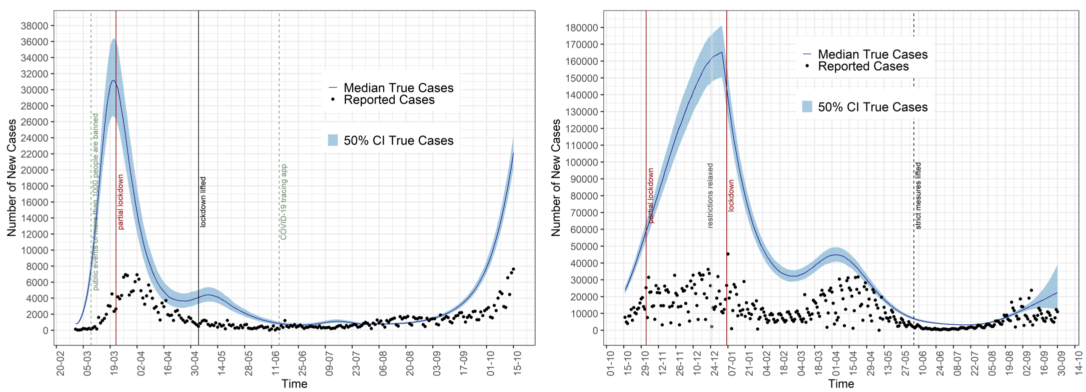


Fig S4: Daily estimated number of total cases, medians(line) and 50% CI(shaded areas) along with reported cases data(dots).

In Sweden, we estimate that a large proportion of total infections were undocumented during the first wave (Fig. S5a). Also, a substantial amount of these infections appear much earlier in the pandemic than what is reported. Poor monitoring procedures and uncontrolled outbreaks in care homes in Sweden can partly explain this significant mismatch, since older infected individuals may have a smaller infection to death distribution. The assessment of the subsequent waves, especially after January 2021 requires further investigation. The apparent inconsistency between estimated and reported cases may be the result of discrepancies in the data as well as several time-dependent factors not accounted for in our model. Estimates on the true cases in Norway must also be viewed with caution, given the sparsity of the reported data on deaths (Fig. S8f). Days with zero reported deaths were followed by days with high death counts particularly after September 2020. Norway is a case in point, indicating the strong dependence of our model on the quality of reported data. Regarding our estimates on the total infected population, Norway's increased testing capacity compared to the other countries under study, can explain the small difference between the estimated and reported number of individuals who have been infected, as presented in Figure S7f.

(a) Sweden - 04/03/20 - 15/10/20

(b) Sweden - 16/10/20 - 30/09/21

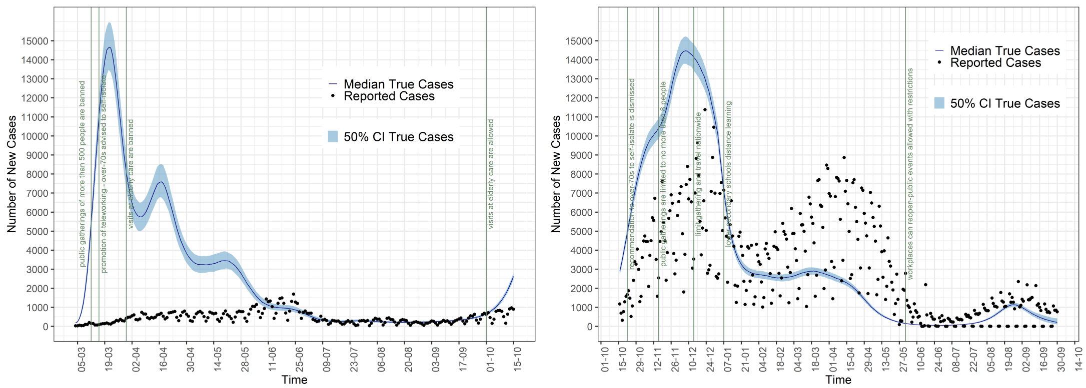


Fig S5: Daily estimated number of total cases, medians(line) and 50% CI(shaded areas) along with reported cases data(dots).

(a) Norway - 11/03/20 - 15/10/20

(b) Norway - 16/10/20 - 30/09/21

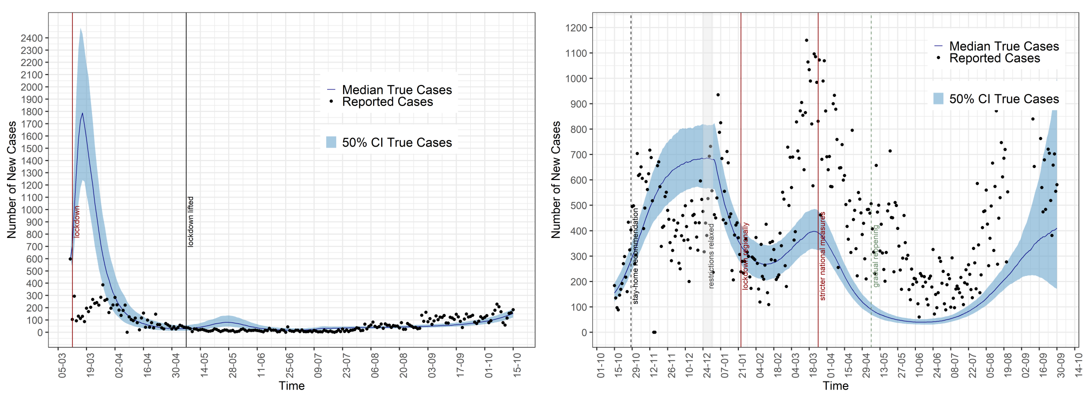
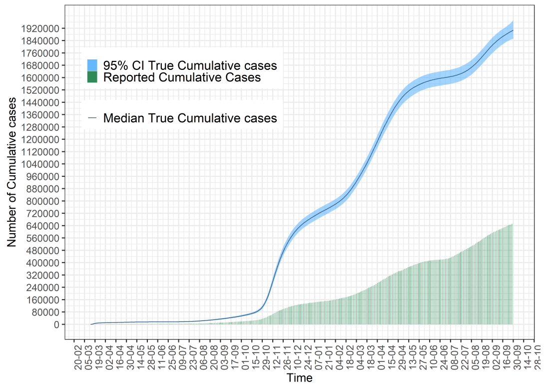
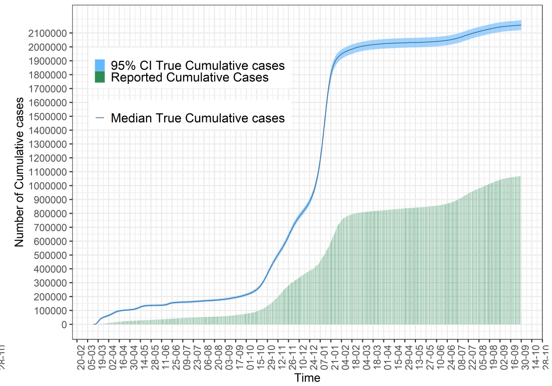


Fig S6: Daily estimated number of total cases, medians(line) and 50% CI(shaded areas) along with reported cases data(dots).

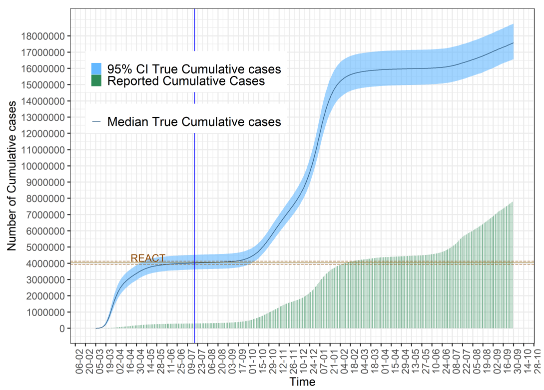
(a) Greece



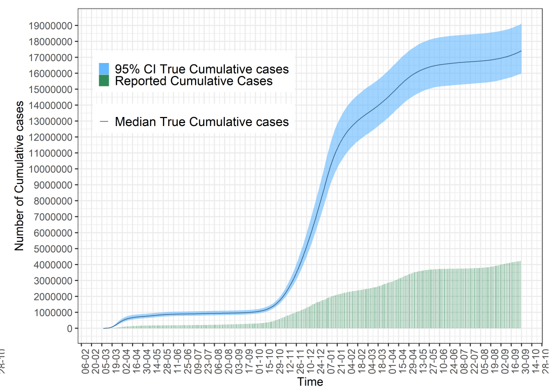
(b) Portugal



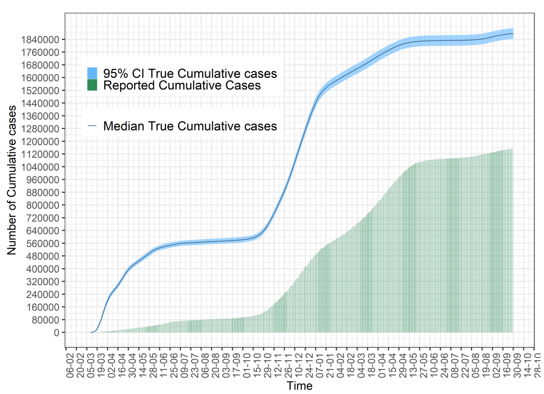
(c) United Kingdom



(d) Germany



(e) Sweden



(f) Norway

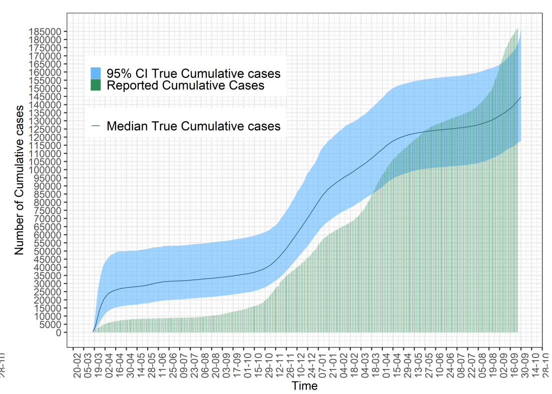


Fig S7: Total population infected, data(bars), median(lines) and 95% CI(shaded areas).

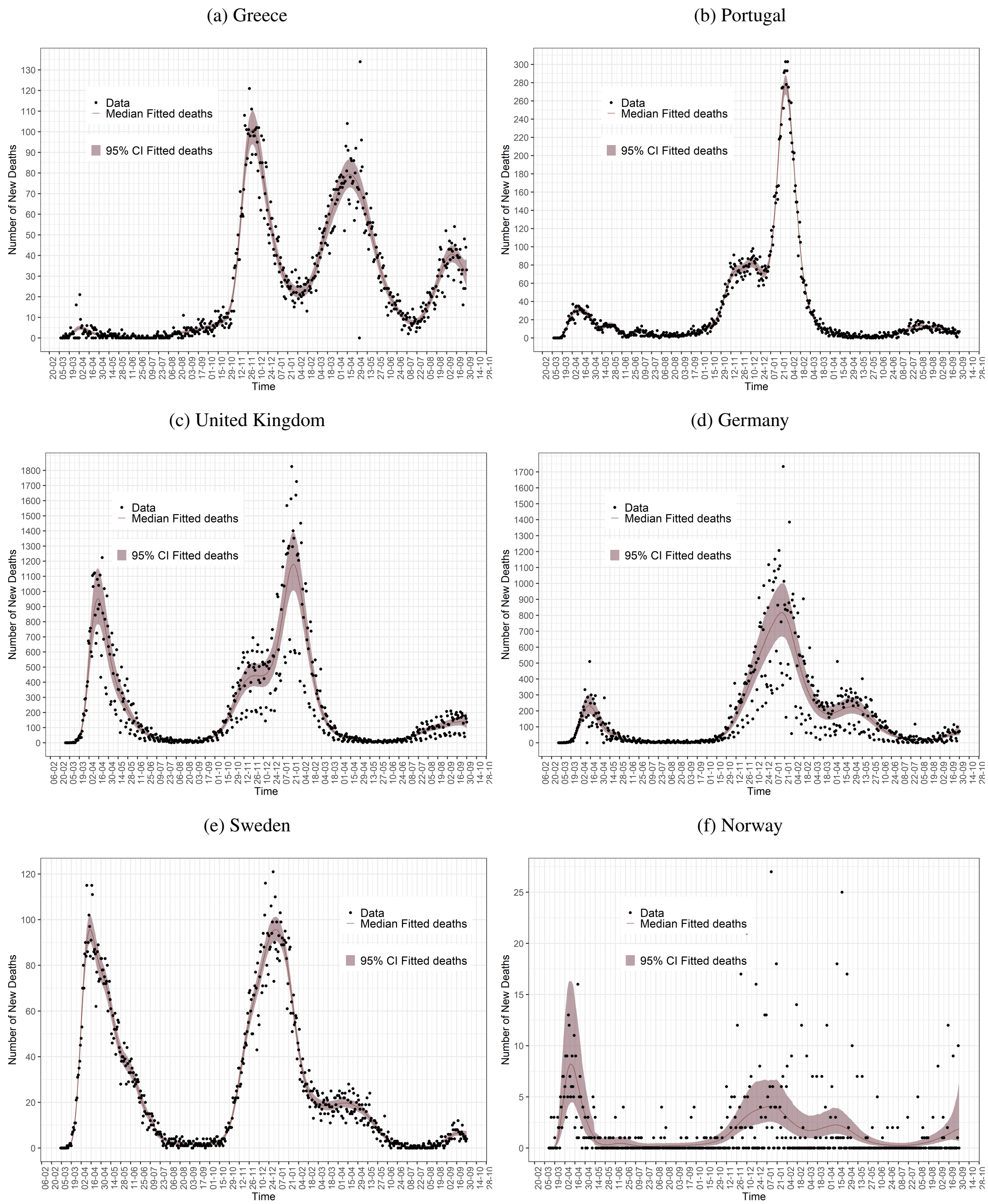


Fig S8: Goodness of fit to data on death counts. Medians(lines) and 95% CI(shaded area) along with reported deaths data(dots).

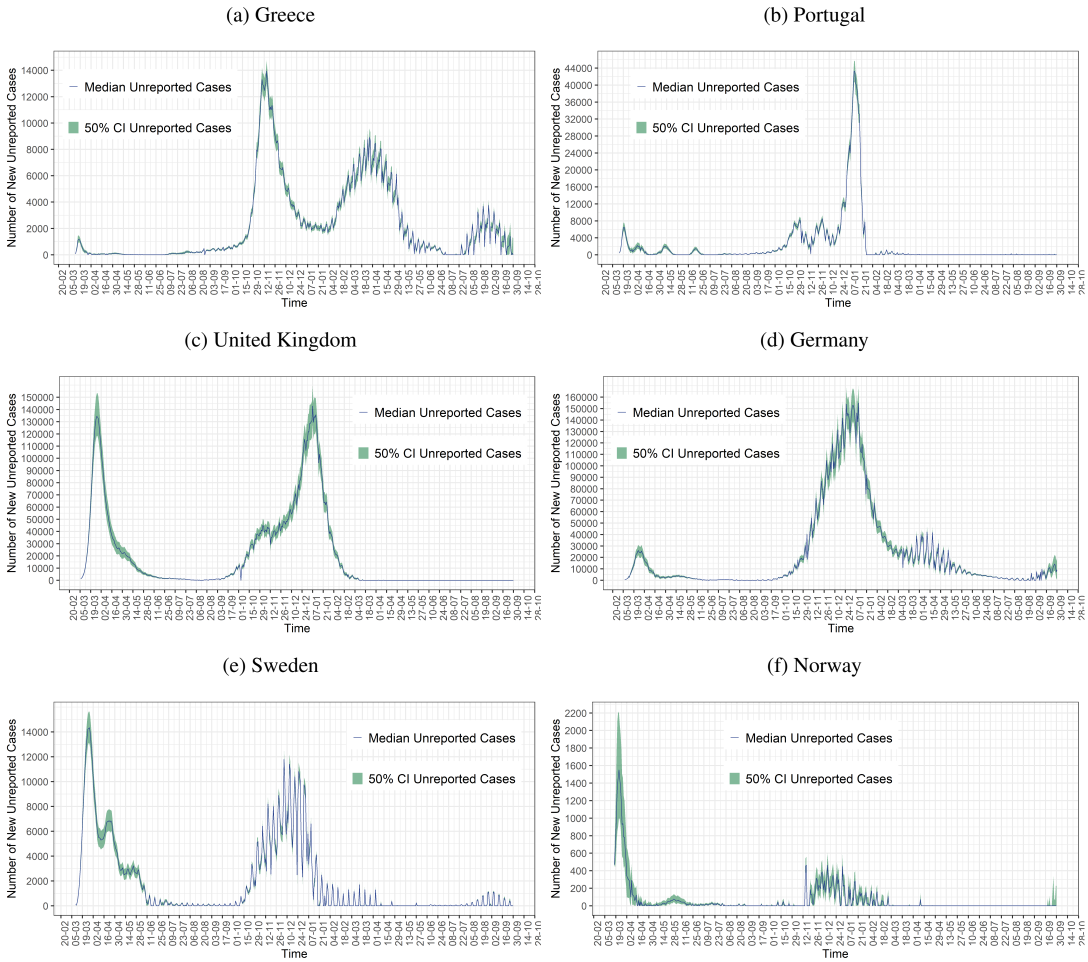


Fig S9: Estimated number of daily unreported cases $c_t^{unrep} = c_{t-L} - c_t^{rep}$, medians(lines) and 50% CI(shaded area).

TABLE S1

Greece-Portugal *- Inference results using HMC-NUTS, 4 chains, each with iter=4500; warmup=2000; thin=5; post-warmup draws per chain=500, total post-warmup draws=2000*

	Greece				Portugal			
	mean	**95% CI**	**ESS**	$\hat{R}$	**mean**	**95% CI**	**ESS**	$\hat{R}$
β_0	3.771	0.74343 - 11.538	1599	1	2.6763	0.5235 - 7.0250	1858	1
β_1	5.171	1.34765 - 17.586	339	1	3.2367	0.7409 - 7.7488	1995	1
β_{50}	0.344	0.01868 - 1.518	1189	1	0.3428	0.0331 - 1.2129	1740	1
β_{100}	0.180	0.00087 - 0.771	1686	1	0.2785	0.0312 - 0.8340	2004	1
β_{150}	0.223	0.15072 - 0.308	1876	1	0.2036	0.1168 - 0.3129	1924	1
β_{200}	0.225	0.17846 - 0.281	1867	1	0.2492	0.1800 - 0.3343	1947	1
β_{250}	0.192	0.15622 - 0.229	1519	1	0.2301	0.1762 - 0.2985	1676	1
β_{300}	0.209	0.17041 - 0.256	2049	1	0.3791	0.2957 - 0.4707	1952	1
β_{350}	0.320	0.26154 - 0.386	2119	1	0.2543	0.1805 - 0.3373	1931	1
β_{400}	0.275	0.22245 - 0.333	1674	1	0.2865	0.1979 - 0.4034	1810	1
β_{450}	0.267	0.21470 - 0.331	1973	1	0.4217	0.2937 - 0.5847	2072	1
β_{500}	0.488	0.39340 - 0.596	2218	1	0.3830	0.2768 - 0.5023	1995	1
β_{550}	0.388	0.28586 - 0.510	1855	1	0.4295	0.2374 - 0.6661	1672	1
β_{573}	0.419	0.20541 - 0.760	1706	1	0.4837	0.1413 - 1.1799	1853	1
γ_1	1.000	0.98054 - 1.020	1910	1	1.0003	0.9810 - 1.0204	1984	1
γ_2^1	0.401	0.38170 - 0.421	1966	1	0.3983	0.3795 - 0.4180	2003	1
γ_2^2	0.499	0.47870 - 0.519	1895	1	0.5003	0.4807 - 0.5193	1978	1
σ_1	0.733	0.31298 - 1.635	141	1	0.6875	0.3698 - 1.2435	211	1
σ_2	0.065	0.04584 - 0.095	171	1	0.1050	0.0702 - 0.1586	181	1
σ_3	33.665	0.18937 - 166.313	2000	1	17.9185	0.1704 - 103.9159	1914	1
σ_4	32.879	0.15691 - 135.099	1961	1	67.5083	0.2132 - 162.0682	2015	1
ifr_1	0.011	0.01142 - 0.011	2009	1	0.0116	0.0116 - 0.0116	1890	1
ifr_2	0.008	0.00799 - 0.008	1602	1	0.0082	0.0082 - 0.0082	2080	1
ifr_3	0.011	0.01142 - 0.011	2061	1	0.0116	0.0116 - 0.0116	1902	1
ifr_4	0.011	0.01150 - 0.012	2075	1	0.0050	0.0050 - 0.0050	1906	1
ifr_5	0.005	0.00500 - 0.005	2027	1	0.0010	0.0010 - 0.0010	2008	1
ϕ_d	35.717	25.77799 - 49.301	1749	1	994.0598	178.3404 - 4558.8504	1582	1

TABLE S2

United Kingdom *- Inference results using HMC-NUTS, 4 chains, each with iter=1000; warmup=500; thin=1; post-warmup draws per chain=500, total post-warmup draws=2000*

Germany *- Inference results using HMC-NUTS, 4 chains, each with iter=4500; warmup=2000; thin=5; post-warmup draws per chain=500, total post-warmup draws=2000*

	United Kingdom				Germany			
	mean	**95% CI**	**ESS**	$\hat{R}$	**mean**	**95% CI**	**ESS**	$\hat{R}$
β_0	1.685376	0.896673 - 2.855327	1158	1	1.099	0.522 - 2.045	1918	1
β_1	1.663571	1.010392 - 2.554535	1178	1	1.069	0.586 - 1.805	2067	1
β_{50}	0.173172	0.096332 - 0.279496	1765	1	0.154	0.065 - 0.279	1868	1
β_{100}	0.164774	0.085399 - 0.271964	1479	1	0.152	0.069 - 0.289	1823	1
β_{150}	0.181026	0.098053 - 0.306026	1507	1	0.175	0.087 - 0.285	1753	1
β_{200}	0.292794	0.235633 - 0.368226	1666	1	0.277	0.236 - 0.322	2101	1
β_{250}	0.294394	0.240203 - 0.359728	1565	1	0.253	0.214 - 0.293	1723	1
β_{300}	0.211272	0.166239 - 0.264423	1574	1	0.230	0.195 - 0.268	2119	1
β_{350}	0.298911	0.244495 - 0.365559	1284	1	0.265	0.221 - 0.311	1886	1
β_{400}	0.259699	0.200892 - 0.320179	1439	1	0.314	0.268 - 0.367	1992	1
β_{450}	0.752368	0.600701 - 0.945950	1126	1	0.277	0.232 - 0.327	1859	1
β_{500}	0.928370	0.462613 - 1.629142	714	1	0.409	0.340 - 0.482	1791	1
β_{550}	0.928370	0.462613 - 1.629142	714	1	0.584	0.475 - 0.709	1921	1
β_{579}	0.928370	0.462613 - 1.629142	714	1	0.584	0.350 - 0.877	1880	1
γ_1	0.999954	0.980884 - 1.020071	1486	1	1.000	0.980 - 1.020	1996	1
γ_2^1	0.399102	0.378741 - 0.418424	1052	1	0.400	0.382 - 0.421	1928	1
γ_2^2	0.500156	0.493429 - 0.519969	1441	1	0.500	0.481 - 0.520	2011	1
σ_1	0.187932	0.114836 - 0.305300	46	1.1	0.212	0.117 - 0.404	140	1
σ_2	0.059774	0.038995 - 0.097686	27	1.1	0.041	0.026 - 0.063	113	1
σ_3	18.113676	0.261822 - 114.199836	1070	1	49.643	0.174 - 138.969	2018	1
σ_4	18.113676	0.261822 - 114.199836	1070	1	30.238	0.173 - 109.620	2014	1
ifr_1	0.010350	0.010348 - 0.010352	1492	1	0.0110	0.0110 - 0.0110	1986	1
ifr_2	0.007245	0.007243 - 0.007247	1499	1	0.0053	0.0053 - 0.0053	1997	1
ifr_3	0.009500	0.009498 - 0.009502	1514	1	0.0115	0.0115 - 0.0115	1989	1
ifr_4	0.00004	0.00004 - 0.00004	1489	1	0.0050	0.0050 - 0.0050	1824	1
ifr_5	0.000018	0.000018 - 0.000018	1414	1	0.0020	0.0020 - 0.0020	1928	1
ϕ_d	4.674407	4.016512 - 5.374142	1808	1	2.426	2.123 - 2.753	1900	1

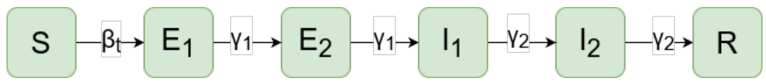
TABLE S3

Norway-Sweden *- Inference results using HMC-NUTS, 4 chains, each with iter=1000; warmup=500; thin=1; post-warmup draws per chain=500, total post-warmup draws=2000*

	Norway				Sweden			
	mean	**95% CI**	**ESS**	$\hat{R}$	**mean**	**95% CI**	**ESS**	$\hat{R}$
β_0	1.707614	0.3856671 - 5.5207998	1062	1	2.120	1.103 - 3.708	1569	1
β_1	1.693335	0.4198669 - 5.2110819	1392	1	2.087	1.253 - 3.501	1223	1
β_{50}	0.1758627	0.01062915 -0.60732157	1324	1	0.160	0.085 - 0.255	1641	1
β_{100}	0.1689712	0.007991932 - 0.589347510	1476	1	0.160	0.082 - 0.273	2278	1
β_{150}	0.2082668	0.1595065 - 0.2670340	1440	1	0.210	0.101 - 0.385	2399	1
β_{200}	0.2324948	0.1777623 - 0.2921005	1643	1	0.253	0.195 - 0.314	1444	1
β_{250}	0.2308807	0.1800157 0.2856003	1506	1	0.238	0.201 - 0.282	2131	1
β_{300}	0.204752	0.1577791 - 0.2455849	1611	1	0.204	0.170 - 0.244	2466	1
β_{350}	0.2715994	0.2186524 - 0.3457090	1446	1	0.293	0.239 - 0.353	1869	1
β_{400}	0.2151451	0.1616931 - 0.2642709	1457	1	0.297	0.244 - 0.356	1981	1
β_{450}	0.2672442	0.2070820 - 0.337667	1282	1	0.232	0.177 - 0.295	1808	1
β_{500}	0.3675575	0.2947958 - 0.4562313	1368	1	0.521	0.402 - 0.665	1433	1
β_{550}	0.4199968	0.2719112 - 0.6107680	1472	1	0.399	0.287 - 0.516	251	1
γ_1	1.000712	0.9821777 - 1.0205439	1479	1	1.000	0.981 - 1.019	2492	1
γ_2^1	0.3999274	0.3810979 - 0.4195019	1582	1	0.399	0.380 - 0.419	1453	1
γ_2^2	0.4996582	0.4808635 - 0.5194869	1546	1	0.501	0.482 - 0.519	1608	1
σ_1	0.496705	0.146708 - 1.061604	1441	1.1	0.219	0.134 - 0.366	48	1.1
σ_2	0.04428329	0.02197993 - 0.07513964	18	1.1	0.063	0.043 - 0.090	40	1.1
σ_3	35.44778	0.2422427 - 115.1708296	1405	1	36.689	0.218 - 115.128	1253	1
σ_4	55.85393	0.2728549 - 133.5904393	1359	1	32.480	0.165 - 175.773	1283	1
ifr_1	0.0090999950	0.009098239 - 0.009101872	1308	1	0.010	0.010 - 0.010	1971	1
ifr_2	0.006000053	0.005998532 - 0.006001660	1362	1	0.007	0.007 - 0.007	1856	1
ifr_3	0.005000007	0.004998602 - 0.005001457	1632	1	0.009	0.009 - 0.009	1934	1
ifr_4	0.002699965	0.002698917 - 0.002701040	1539	1	0.002	0.002 - 0.002	1992	1
ifr_5	0.001500001	0.001499296 - 0.001500763	1293	1	0.001	0.001 - 0.001	1897	1
ϕ_d	0.3438065	0.2720817 - 0.4217407	1530	1	738.007	139.573 - 3361.229	819	1

S3. Indicative figures for the SEIR model without vaccinations, the case of Greece. We consider that the transmission dynamics in the population are addressed using a compartmental SEIR model without vaccination. We divide individuals into six infection classes (Figure S10): susceptible S, exposed (but not yet infectious) $E_1 + E_2$, infectious $I_1 + I_2$, and removed R.

Fig S10: Schematic illustration of the transmission model.



In order to allow the latent and infectious periods to be gamma distributed, we assume that each of the E and I compartments are defined by two classes. Hence, γ_1 denotes the rate at which the exposed individuals become infective so that $\frac{2}{\gamma_1}$ is the mean latent period and γ_2 denotes the recovery rate so that $\frac{2}{\gamma_2}$ is the mean infectious period.

Thus, we fit the SEIR model without vaccination as described by

$$\begin{aligned}
\frac{\mathrm{d}S_t}{\mathrm{d}t} &= -\beta_t S_t \frac{(I_{1t} + I_{2t})}{N} \\
\frac{\mathrm{d}E_{1t}}{\mathrm{d}t} &= \beta_t S_t \frac{(I_{1t} + I_{2t})}{N} - \gamma_1 E_{1t} \\
\frac{\mathrm{d}E_{2t}}{\mathrm{d}t} &= \gamma_1 E_{1t} - \gamma_1 E_{2t} \\
\frac{\mathrm{d}I_{1t}}{\mathrm{d}t} &= \gamma_1 E_{2t} - \gamma_2 I_{1t} \\
\frac{\mathrm{d}I_{2t}}{\mathrm{d}t} &= \gamma_2 I_{1t} - \gamma_2 I_{2t} \\
\frac{\mathrm{d}R_t}{\mathrm{d}t} &= \gamma_2 I_{2t}
\end{aligned} \tag{1}$$

$$\begin{aligned}
\mathrm{d}\eta_t &= \mu(\eta_t, \theta_\eta) + \sigma(\eta_t, \theta_\eta)\mathrm{d}B_t \\
\eta_t &= g(\beta_t).
\end{aligned} \tag{2}$$

using HMC-NUTS with 4 chains, each with 1000 iterations of which the first 500 are warm-up to automatically tune the sampler, leading to a total of 2000 posterior samples. We graphically present our results on R_t and the daily number of estimated cases for the case of Greece.

Our results indicate that excluding the significant vaccine rollout, affects R_t by affecting the relationship between susceptible and infected. The observation process remains the same, therefore, according to our model, observed deaths are the result of the same past incidence. Failing to adopt the effect of vaccinations on the available pool of susceptible and consequently infected individuals, leads β_t to adjust accordingly in order to result to the same number of cases.

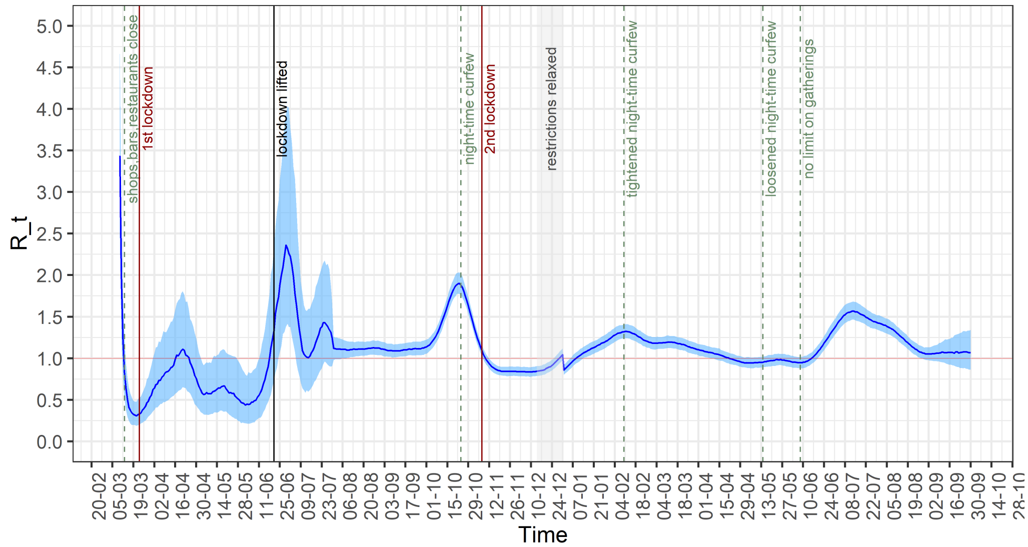


Fig S11: Greece - SEIR without vaccinations. Time-varying reproduction number.

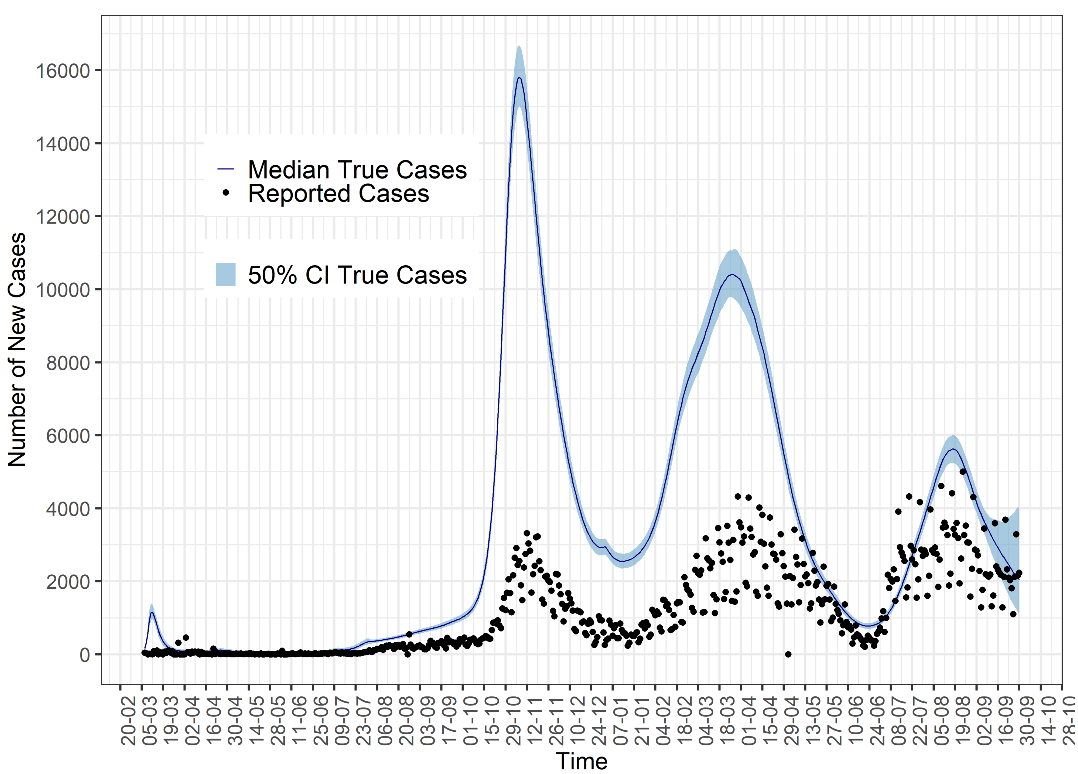


Fig S12: Greece - SEIR without vaccinations. Daily estimated number of total cases, medians(lines) and 50% CI(shaded area).

S4. Indicative figures for the SIR model with vaccinations, the case of Greece. We consider that the transmission dynamics in the population are addressed using a compartmental SIR model which can be described by a system of ODEs where we model the transmission rate β_t as a diffusion process as in the SEIR model

$$\begin{aligned}
\frac{\mathrm{d}S}{\mathrm{d}t} &= -\beta_t S_t \frac{(I_{1,t} + I_{2,t})}{N} - \rho\nu_{t-35} \\
\frac{\mathrm{d}I_1}{\mathrm{d}t} &= \beta_t S_t \frac{(I_{1,t} + I_{2,t})}{N} - \gamma I_{1,t} \\
\frac{\mathrm{d}I_2}{\mathrm{d}t} &= \gamma(I_{1,t} - I_{2,t}) \\
\frac{\mathrm{d}R}{\mathrm{d}t} &= \gamma I_{2,t} + \rho\nu_{t-35}
\end{aligned} \tag{3}$$

where S_t represents the number of susceptible, I_t the number of infected and R_t the number of removed individuals at time t. The total population size is denoted by N (with $N = S_t + I_t + R_t$), the vaccine efficacy is denoted by ρ and set equal to 50% and ν_{t-45} is the reported number of individuals who received the first dose of a vaccine 45 weeks prior to time t. The recovery rate is denoted by γ, for which we consider a Gamma prior distribution, reflecting 5-6 days average infectious period (**??**). We consider an average infectious period of 6 days during the first year of the pandemic, and we adopt a shorter average infectious period of 5 days for the last several months. In order to link with the available observations, the model-implied daily new infections, denoted by c_t, are needed i.e. $c_t = \int_{t-1}^{t} \beta_s S_s \frac{I_s}{N} \mathrm{d}s$. The rest of the model specification is the same as in the SEIR model.

We fit the model using HMC-NUTS with 4 chains, each with 1000 iterations of which the first 500 are warm-up to automatically tune the sampler, leading to a total of 2000 posterior samples. We graphically present our results on R_t and the daily number of estimated cases for the case of Greece. Our results indicate that compared to the SEIR model, using the SIR we underestimate R_t, especially during the first two pandemic waves.

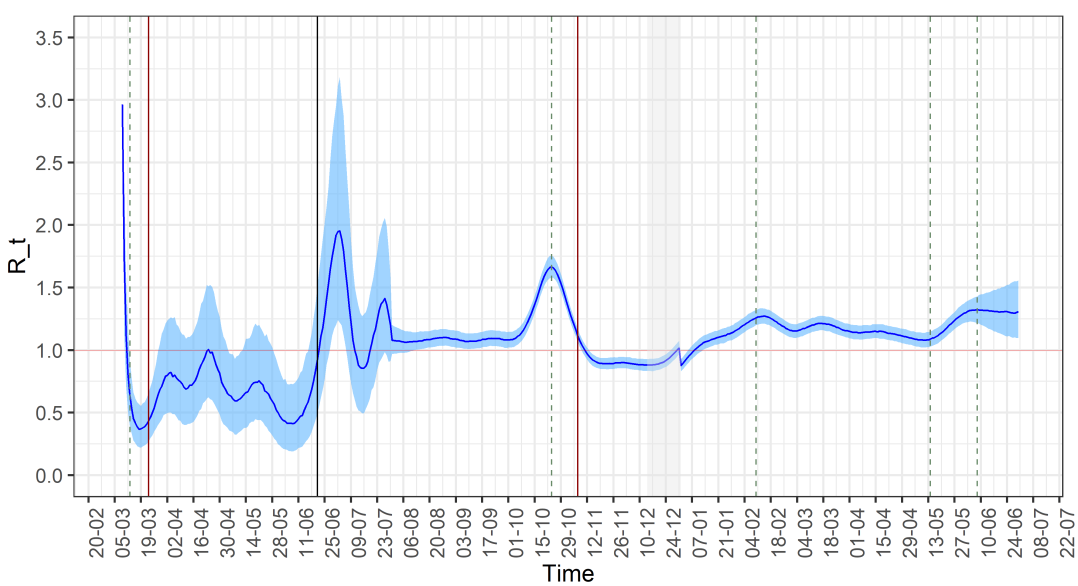


Fig S13: Greece - SIR. Time-varying reproduction number, median(line) and 95% CI(shaded area).

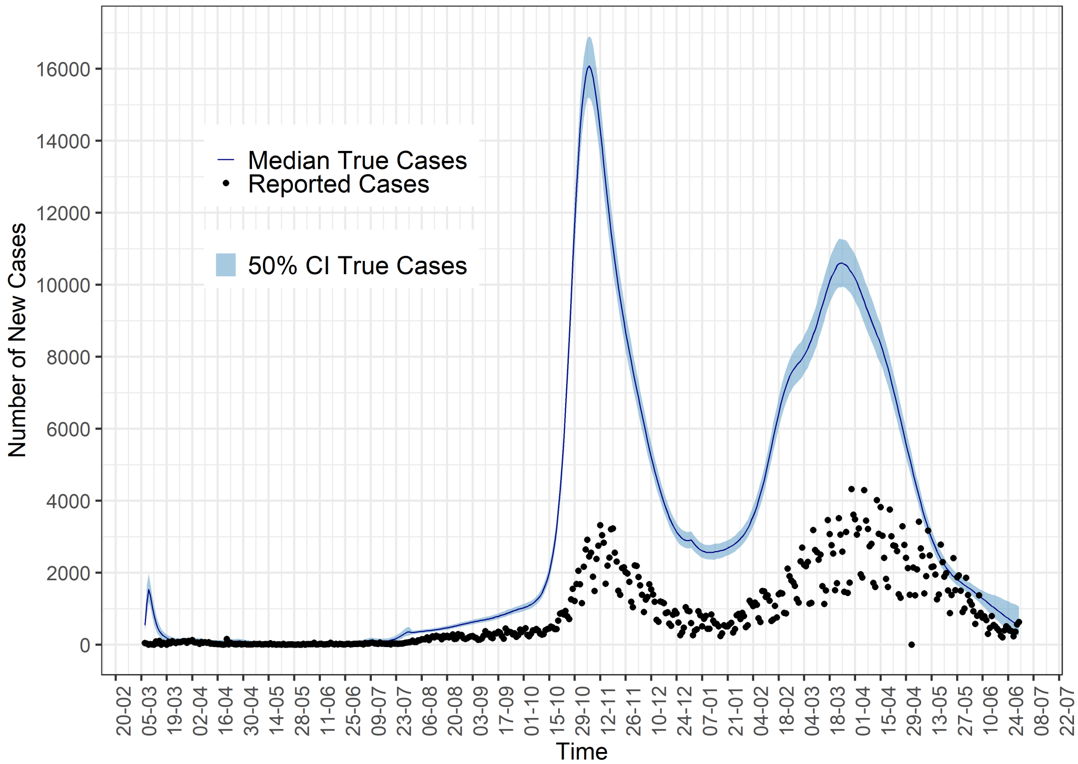


Fig S14: Greece - SIR. Daily estimated number of total cases, median(lines) and 50% CI(shaded area) along with reported cases data(dots).

S5. Posterior estimates of the multivariate regression coefficients.

TABLE S4

Greece - Portugal. Posterior estimates of the regression coefficients.

		Greece			Portugal		
		mean	**Quantile (2.5%)**	**Quantile (97.5%)**	**mean**	**Quantile (2.5%)**	**Quantile (97.5%)**
estimated cases cases c_t	m_t	-305.5209316	-346.8016685	-263.05011323	565.43419038	498.0638578	639.5915599
	$tests_{t-3}$	0.0332758	0.0281633	0.03854053	0.15014675	0.1335001	0.1663771
	$tests_{t-4}$	0.0296214	0.0238013	0.03541704	0.00298759	-0.0204751	0.0267850
	$tests_{t-5}$	0.0295127	0.0238182	0.03516845	0.04729566	0.0232935	0.0697046
	$tests_{t-6}$	0.0388913	0.0333549	0.04422814	0.04275811	0.0257584	0.0591668
$log(\beta_t)$	m_t	0.1636482	0.0987755	0.23229343	0.18939482	0.1306417	0.2479880
	$tests_{t-3}$	-0.0000102	-0.0000184	-0.00000222	-0.00002046	-0.0000344	-0.0000063
	$tests_{t-4}$	-0.0000076	-0.0000163	0.00000105	-0.00000339	-0.0000229	0.0000165
	$tests_{t-5}$	-0.0000077	-0.0000161	0.00000113	-0.00000656	-0.0000263	0.0000134
	$tests_{t-6}$	-0.0000090	-0.0000169	-0.00000081	-0.00001309	-0.0000270	0.0000012
$logit(r_t)$	m_t	0.1944768	0.1742544	0.21430218	-0.08884898	-0.1263013	-0.0516270
	$tests_{t-3}$	-0.0000063	-0.0000086	-0.00000389	0.00000712	-0.0000021	0.0000164
	$tests_{t-4}$	-0.0000048	-0.0000073	-0.00000224	-0.00000130	-0.0000147	0.0000117
	$tests_{t-5}$	-0.0000049	-0.0000074	-0.00000225	0.00000110	-0.0000111	0.0000138
	$tests_{t-6}$	-0.0000061	-0.0000085	-0.00000366	0.00000093	-0.0000082	0.0000100

TABLE S5

United Kingdom - Germany. Posterior estimates of the regression coefficients.

		United Kingdom			Germany		
		mean	**Quantile (2.5%)**	**Quantile (97.5%)**	**mean**	**Quantile (2.5%)**	**Quantile (97.5%)**
estimated cases cases c_t	m_t	-11346.097879251	-11347.894801618	-11342.968038468	-11330.440956363	-11432.05867151	-11230.71651415
	$tests_{t-3}$	0.020787562	0.019456420	0.022117471	-0.204996822	-0.23098906	-0.18073670
	$tests_{t-4}$	0.011664448	0.010265583	0.013047787	0.002412697	-0.03080075	0.03783370
	$tests_{t-5}$	0.011145400	0.009705955	0.012564121	0.011381746	-0.02231292	0.04663665
	$tests_{t-6}$	0.005578317	0.004237499	0.006943745	0.472476071	0.44738646	0.49756042
$log(\beta_t)$	m_t	0.3707722370564	0.308653156541	0.4299744469542	0.11073795829145	0.06555012263	0.1556088454654
	$tests_{t-3}$	-0.0000004502138	-0.000001086766	0.0000001719735	-0.00001002532107	-0.00002076157	0.0000006544087
	$tests_{t-4}$	-0.0000003929461	-0.000001067712	0.0000002889329	-0.00000007607124	-0.00001531955	0.0000151742979
	$tests_{t-5}$	-0.0000003873673	-0.000001053711	0.0000002787543	-0.00000023963588	-0.00001566531	0.0000153297057
	$tests_{t-6}$	-0.0000004445832	-0.000001077904	0.0000001833765	0.00000183365895	-0.00000908187	0.0000132600924
$logit(r_t)$	m_t	0.57870821178456	0.550340957334462	0.6077705105949	0.50836673474680	0.455975164317	0.558241125086
	$tests_{t-3}$	-0.00000008211772	-0.000000383602414	0.0000002202527	-0.00000525116602	-0.000017288392	0.000006250945
	$tests_{t-4}$	0.00000030680633	-0.000000001617983	0.0000006295052	-0.00000007441294	-0.000016918137	0.000016800461
	$tests_{t-5}$	0.00000033612270	0.000000017772295	0.0000006613334	-0.00000069907271	-0.000018303461	0.000015987902
	$tests_{t-6}$	0.00000085290131	0.000000552813275	0.0000011533828	0.00000531795339	-0.000006509538	0.000017828802

TABLE S6

Sweden - Norway. Posterior estimates of the regression coefficients.

		Sweden			Norway		
		mean	**Quantile (2.5%)**	**Quantile (97.5%)**	**mean**	**Quantile (2.5%)**	**Quantile (97.5%)**
estimated cases cases c_t	m_t	-485.54489886	-562.532181	-396.6808861	-50.152025	-57.724137	-42.6484322
	$tests_{t-3}$	-0.17825069	-0.255815	-0.0976484	0.005151	0.003383	0.0070145
	$tests_{t-4}$	0.01877700	-0.094372	0.1279793	0.003084	0.000765	0.0053917
	$tests_{t-5}$	0.02837194	-0.086436	0.1413764	0.002950	0.000735	0.0051451
	$tests_{t-6}$	0.29499502	0.214201	0.3788469	0.005288	0.003479	0.0070858
$log(\beta_t)$	m_t	-0.26248922	-0.312431	-0.2125731	-0.062763	-0.141699	0.0148645
	$tests_{t-3}$	0.00000756	-0.000049	0.0000649	-0.000028	-0.000046	-0.0000091
	$tests_{t-4}$	-0.00000057	-0.000082	0.0000805	-0.000015	-0.000039	0.0000084
	$tests_{t-5}$	0.00000269	-0.000077	0.0000809	-0.000015	-0.000039	0.0000077
	$tests_{t-6}$	-0.00006312	-0.000119	-0.0000076	-0.000027	-0.000046	-0.0000081
$logit(r_t)$	m_t	0.44346740	0.356620	0.5295625	0.386359	0.247363	0.5246463
	$tests_{t-3}$	0.00008121	-0.000016	0.0001746	0.000048	0.000016	0.0000824
	$tests_{t-4}$	0.00000589	-0.000126	0.0001431	0.000026	-0.000014	0.0000671
	$tests_{t-5}$	0.00000052	-0.000128	0.0001338	0.000027	-0.000015	0.0000681
	$tests_{t-6}$	-0.00002825	-0.000119	0.0000663	0.000051	0.000018	0.0000840

S6. Detailed data.

TABLE S7

Detailed Data References

Data	References
Population	
All countries	Worldometer. https://www.worldometers.info/world-population/population-by-country/
Cumulative deaths	
Greece, Portugal, United Kingdom, Germany, Norway	COVID-19 Data Repository by the Center for Systems Science and Engineering at Johns Hopkins University. https://github.com/CSSEGISandData/COVID-19/tree/master/csse$_{c}ovid_{1}9_{d}ata$
Sweden	Folkhälsomyndigheten, Public Health Agency of Sweden. https://www.folkhalsomyndigheten.se/smittskydd-beredskap/utbrott/aktuella-utbrott/covid-19/statistik-och-analyser/bekraftade-fall-i-sverige/
Cumulative cases	
Greece, Portugal, United Kingdom, Germany, Norway	COVID-19 Data Repository by the Center for Systems Science and Engineering at Johns Hopkins University. https://github.com/CSSEGISandData/COVID-19/tree/master/csse$_{c}ovid_{1}9_{d}ata$
Sweden	Folkhälsomyndigheten, Public Health Agency of Sweden.https://www.folkhalsomyndigheten.se/smittskydd-beredskap/utbrott/aktuella-utbrott/covid-19/statistik-och-analyser/bekraftade-fall-i-sverige/
Age distribution of cases	
Greece	Hellenic National Public Health Organization.https://eody.gov.gr/epidimiologika-statistika-dedomena/ektheseis-covid-19/
Portugal	Directorate General for Health via Data Science for Social Good. https://github.com/dssg-pt/covid19pt-data
United Kingdom	Public Health England. https://coronavirus.data.gov.uk/details/download
Germany	Robert Koch Institute, Federal Ministry of Health. https://www.rki.de/DE/Content/InfAZ/N/Neuartiges$_{C}oronavirus/Daten/Altersverteilung.html$
Sweden	COVerAGE-DB. https://timriffe.github.io/covid$_{a}ge/GettingStarted.html$
Norway	Norwegian Institute of Public Health. https://www.fhi.no/en/id/infectious-diseases/coronavirus/daily-reports/daily-reports-COVID19/covid19associated-deaths-by-age-and-sex
Daily vaccinations with 1st dose	
Greece	Hellenic National Public Health Organization. Retrieved from: https://docs.google.com/spreadsheets/d/14rKl4TAM05YWj94u3rAkS2PKTSIqYzdCeuXVMtV6ptM/editgid=782062930
Portugal	Directorate General for Health via Data Science for Social Good. https://github.com/dssg-pt/covid19pt-data
United Kingdom	Public Health England. https://coronavirus.data.gov.uk/details/vaccinations
Germany, Sweden, Norway	Our World In Data. https://ourworldindata.org/grapher/people-vaccinated-covid
Daily tests	
Greece, Portugal, United Kingdom, Sweden, Norway	Our World In Data. https://ourworldindata.org/grapher/full-list-covid-19-tests-per-day
Germany	Robert Koch Institute, Federal Ministry of Health. https://www.rki.de/DE/Content/InfAZ/N/Neuartiges$_{C}oronavirus/Testzahl.html;jsessionid=821BB52428F222307CBE3BA46A8A4106.internet091?nn=13490888$
Mobility trends	
All countries	COVID-19 Community Mobility Report (**?**). https://www.google.com/covid19/mobility/?hl=en
Government responses	
All countries	**?**. https://www.bsg.ox.ac.uk/research/research-projects/covid-19-government-response-tracker