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1 **Interrupting vaccination policies can greatly spread SARS-CoV-2**  
2 **and enhance mortality from COVID-19 disease: the AstraZeneca**  
3 **case for France and Italy**

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## Abstract

Several European countries have suspended the inoculation of the AstraZeneca vaccine out of suspicion of causing deep vein thrombosis. In this letter we report some Fermi estimates performed using a stochastic model aimed at making a risk-benefit analysis of the interruption of the delivery of the AstraZeneca vaccine in France and Italy. Our results clearly show that excess deaths due to the interruption of the vaccination campaign injections largely overrun those due to thrombosis even in worst case scenarios of frequency and gravity of the vaccine side effects.

As of March 2021, the spread of the SARS-CoV-2 virus [1] has caused more than 120 millions infections worldwide with a total death toll of more than 2 millions. Up to the end of 2020, the only effective measures to contain the spread of the virus were based on social distancing, wearing face masks and more/less stringent lockdown [2–4]. Later on, a massive vaccination campaign kicked off in several countries thanks to the availability of a variety of vaccines (e.g., AstraZeneca, Johnson&Johnson, Moderna, Pfizer/BionTech, Sputnik V). Such vaccines differ substantially in terms of efficacy, legal status, availability, and logistics needed for their delivery to patients. According to various estimates [5], vaccinations would produce a reduction in infections, and eventually yield to "herd immunity" when  $\approx 70\%$  of the population gets fully vaccinated. When such a large fraction of the population becomes immune to the disease, its spread from person to person becomes very unlikely, and the whole community becomes protected. By allowing for an earlier easing of non-medical measures against the SARS-CoV-2 virus, vaccination is also expected to significantly reduce the economical, social and psychological impacts of lockdown measures [6]. Those estimates assume that there is no break in the supply of vaccines or any other suspension in the procedure due to side effects from vaccination. Unfortunately, on March 15th 2021 several European countries suspended the use of AstraZeneca COVID-19 vaccine as a precaution in order to investigate the death of a few dozens of patients developing blood clots - associated with Deep Vein Thrombosis (DVT) [7] - after such vaccine, despite no proof of causal link between vaccination and DVT [8]. Health personnel who inoculated the vaccine to those who died as a result of DVT are being investigated in Italy for manslaughter [9]. The contingent situation with the widespread COVID-19 pandemic naturally raises the question of whether a prolonged stop in vaccinations coming from adopting the precautionary principle [10]

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57 could cause an excess mortality beyond that caused by the hypothetical side effects of  
58 the vaccines. The European Medicines Agency (EMA) is currently assessing whether the  
59 vaccine can continue to be used despite possibly causing this very rare side effect. In this  
60 Letter we aim at exploring this issue by computing future COVID-19 epidemic scenarios by  
61 comparing i) the excess mortality caused by reducing the vaccinations using the stochastic  
62 Susceptible-Exposed-Infected-Recovered (SEIR) model [11], and ii) the estimates of the  
63 possible casualties caused by side effects of a vaccine, namely those associated with DVT.  
64 We remark that the additional, longer-term effect of the presence of higher infection rates,  
65 i.e., the increased risk of virus mutations leading to possibly more malignant and/or more  
66 infectious variants, is not included in our treatment. Our analysis focuses on France and  
67 Italy, which have been among the countries that have been most severely impacted by the  
68 COVID-19 pandemic [12]. An important remark follows. Our goal is not to provide an exact  
69 estimate of both i) and ii) but rather to perform an order-of-magnitude comparison between  
70 excess deaths resulting from different scenarios of vaccination policy. In other terms, we will  
71 approach the problem by performing Fermi estimates [13] where the classical back-of-the-  
72 envelope calculations are performed via the SEIR model, which allows to take into account  
73 the uncertainties in both model parameters and data. *In nuce*, we perform a counterfactual  
74 analysis based on a story-line approach, which has become a powerful investigation method  
75 for assessing risks coming from extreme events [14]. While the quantitative consolidation of  
76 our results clearly requires extensive data analysis and modelling, our findings show with  
77 a large confidence that excess deaths due to the interruption of the vaccination campaign  
78 largely override those due to DVT even in the worst case scenarios of frequency and gravity  
79 of the vaccine side effects. Fermi estimates can provide valuable input for an efficient and  
80 pragmatic application of the precautionary principle able to reduce the negative impacts of  
81 hazards of various nature, as done in economics [15].

82 The model [16] with time-dependent control parameters can mimic the dependence ad-  
83 ditional/external factors such as variability in the detected cases, different physiological re-  
84 sponse to the virus, release or reinforcement of distancing measures[11]. Our compartmental  
85 model [17] divides the population into four groups, namely, Susceptible (S), Exposed (E),  
86 Infected (I), and Recovered (R) individuals, according to the following evolution equations:

$$S_{t+1} = S_t - \lambda(1 - \alpha) \frac{I_t S_t}{N_t} - \lambda\alpha(1 - \sigma) \frac{I_t S_t}{N_t} + (1 - \sigma\alpha) S_t \quad (1)$$

$$E_{t+1} = E_t + \lambda(1 - \alpha) \frac{I_t S_t}{N_t} + \lambda\alpha(1 - \sigma) \frac{I_t S_t}{N_t} + (1 - \epsilon) E_t \quad (2)$$

$$I_{t+1} = I_t + \epsilon E_t + (1 - \alpha - \beta) I_t \quad (3)$$

$$R_{t+1} = R_t + \sigma\alpha S_t + \beta I_t \quad (4)$$

87 In the SEIR model above, the classical parameters are the recovery rate ( $\beta$ ), the inverse  
 88 of the incubation period ( $\epsilon$ ), and the infection rate ( $\lambda$ ). Here we have generalized the the  
 89 model presented in [11] by introducing two additional parameters able to succinctly mimic  
 90 the strategies of a vaccination campaign, namely the vaccination rate per capita  $\alpha$  and  
 91 the vaccine efficacy  $\sigma$ , see Sun and Hsieh [18]. To consider uncertainties in long-term  
 92 extrapolations and time-dependent control parameters a stochastic approach is used though  
 93 which the control parameters  $\kappa \in \{\alpha, \beta, \epsilon, \lambda, \sigma\}$  are described by an Ornstein-Uhlenbeck  
 94 process [19] with drift as follows:

$$95 \quad d\kappa = -\kappa(t)dt + \kappa_0 dt + \varsigma_\kappa dW_t, \quad (5)$$

96 where  $\kappa_0 \in \{\alpha_0, \beta_0, \epsilon_0, \lambda_0, \sigma_0\}$ ,  $dW_t$  is the increment of a Wiener process. We re-  
 97 mind that the basic reproduction number [20] is written  $R_0 = \beta_0/\lambda_0$ . In Eqs. (1)-(5)  
 98 we set  $dt = 1$ , which is the highest time resolution available for official COVID-19-  
 99 related counts and is relatively small compared to the characteristic times associated  
 100 with COVID-19 infection, incubation, and recovery/death. In our simulations we set  
 101  $\{\alpha_0, \beta_0, \epsilon_0, \sigma_0\} = \{0.0015, 0.37, 0.27, 0.59\}$ ;  $\{\varsigma_\alpha, \varsigma_\beta, \varsigma_\epsilon, \varsigma_\sigma\} = \{0.25, 0.2, 0.2, 0.1\}$  a mortality  
 102 rate  $m_0 = 0.015$  [21]. While  $\beta_0$  and  $\epsilon_0$  and the associated  $\varsigma$  are the same as in [11], the  
 103 values of  $\sigma_0$  and respective  $\varsigma$  are derived from the range given for the AstraZeneca vaccine  
 104 phase 3 tests for the first dose [22] and  $\alpha_0$  and  $\varsigma_\alpha$  supposing that both Italy and France  
 105 keep vaccinating  $10^5$  individuals per day with a 20% daily fluctuation [23]. As in [11], we  
 106 also set  $\varsigma_\lambda = 0.2$  allowing for 20% daily fluctuations in the infection rate. Note that here  
 107 we restrict to Gaussian fluctuations: as shown in [11], allowing for log-normal fluctuations

108 of the parameters does not change the average results but slightly enhance their dispersion.  
109 See Supplementary Material for the numerical code.

110 Figure 1 reports the daily number of deaths  $m_0 \times I(t)$  as a function of time for Italy (a) and  
111 France (b). Initial conditions are set for both countries to the values reported on March 15th  
112 as follows: for Italy we set  $N = 60 \cdot 10^6$  population,  $E(t) = I(t) = 20 \cdot 10^4$  as the infected  
113 and exposed populations,  $R(t) = 11 \cdot 10^6$  as the sum of  $9 \cdot 10^6$  recovered estimated from  
114 serologic tests and  $2 \cdot 10^6$  immunized from 2 doses of either Pfizer/BioNTech, Moderna or  
115 AstraZeneca vaccines and  $R_0 = 1.16$ . For France we set  $N = 67 \cdot 10^6$ ,  $E(t) = I(t) = 25 \cdot 10^4$ ,  
116  $R(t) = 13.2 \cdot 10^6$  as the sum of  $11 \cdot 10^6$  recovered estimated from serologic tests and  $2.2 \cdot 10^6$   
117 immunized from vaccines and  $R_0 = 1.02$ . For both France and Italy, we assume that the  
118 virus, after the second wave, has infected the 15% of the population. This estimates are  
119 based on Pullano *et al.* [24] who reported a  $7\% \pm 3\%$  total infections for France after the  
120 first wave, assuming that the second wave had a similar magnitude for both countries. We  
121 remark however, that our results are basically insensitive to oscillation of  $S(1)$  of order of  
122 5 millions individuals (cfr. Supplementary Material Figure S1). Rather than integrating  
123 the Fokker-Planck equation [25] corresponding to the system of equations given above, we  
124 follow a Monte Carlo approach and we perform two sets of  $N_r = 1000$  realizations (see  
125 supplementary material Figure S2 for a justification of this value): stopping (red) and  
126 continuing (blue) the vaccination campaign at the same rate. The model is integrated for  
127 500 days, that is about the time it would take to vaccinate the rest of the susceptible population  
128 with AstraZeneca at the rate of  $10^5$  individuals per day.

130 First, we observe a monotonic decrease in the daily deaths for all scenarios considered  
131 from the initial date  $t = t_0$  corresponding to March 15, 2021. This is in agreement with  
132 actual estimates that for Italy and France the so-called third wave should reach its peak by  
133 the end of March, 2021 [26]. Moreover, we observe that the cumulative number of deaths  
134 significantly reduce if vaccinations are continued at 100000 doses per day with respect to the  
135 scenario where vaccination is stopped. For Italy (France) completely halting the vaccination,  
136 at the actual epidemic rate, the number of excess deaths from COVID19 would amount to  
137  $9 \pm 3 \cdot 10^3$  ( $1.2 \pm 0.4 \cdot 10^3$ ) excess deaths from COVID19. The difference between the two  
138 countries is largely due to the value of  $R_0$ , which is larger for Italy. This suggests that  
139 halting vaccination in a growing epidemics phase (Italy) has more dramatic consequences  
140 than in a more controlled scenario of  $R_0 \approx 1$  (France).

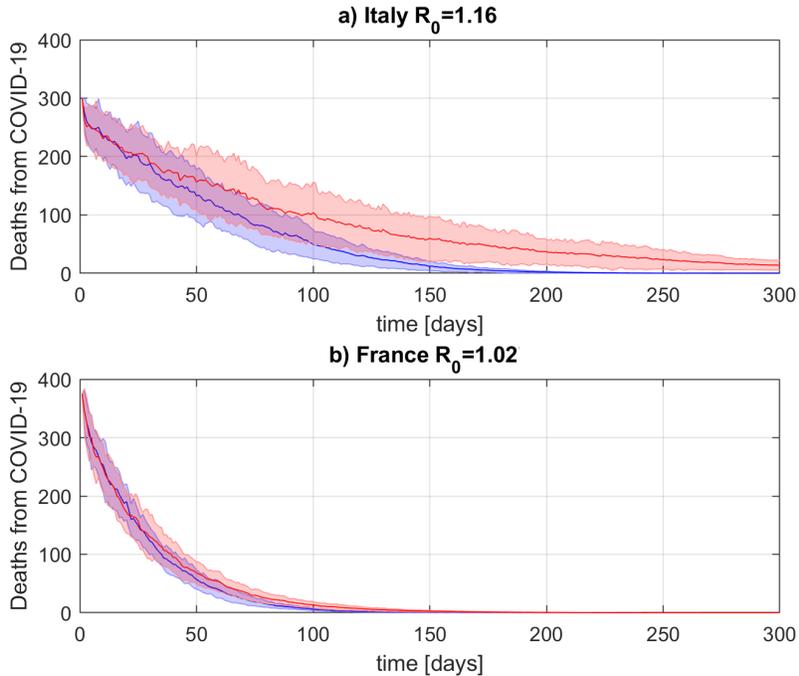


FIG. 1. The number of daily deaths  $m \times I(t)$  as a function of time (300 out of 500 days shown) for Italy (a) and France (b) using the values of  $R_0 = 1.16$  (Italy) and  $R_0 = 1.02$  reported respectively for the 15th of March countries. Solid lines show the ensemble average, dotted lines extend to one standard deviation of the mean. Red and blue curves refer respectively to no vaccination and a vaccination campaign whose efficacy is 59%.

141 Our previous analysis is based on a total stop of AstraZeneca vaccination. However, a  
 142 more realistic scenario is to assume that AstraZeneca vaccination will resume after a limited  
 143 number of days used for verification. We investigate this effect in Fig. 2. There we consider  
 144 the average excess deaths as a function of the interruption length in number of days (x-axis)  
 145 and  $R_0$  (y-axis) for Italy (a) and France (b). The excess deaths are computed with respect  
 146 to a base scenario where vaccine injections are never interrupted and they are averaged over  
 147 1000 realizations of the SEIR model. Figure 2 shows that the longer is the vaccine injections  
 148 disruption, the higher is the number of excess deaths. The impact is stronger for higher  
 149 values of  $R_0$ . A focus on the actual values for Italy and France is reported in Fig. 3.

150 The final step in our investigation is to compare the previous estimates of excess deaths  
 151 with an order of magnitude estimate of deaths due to DVT resulting from side effects  
 152 of the AstraZeneca vaccine. In order to make a meaningful comparison, in a case where

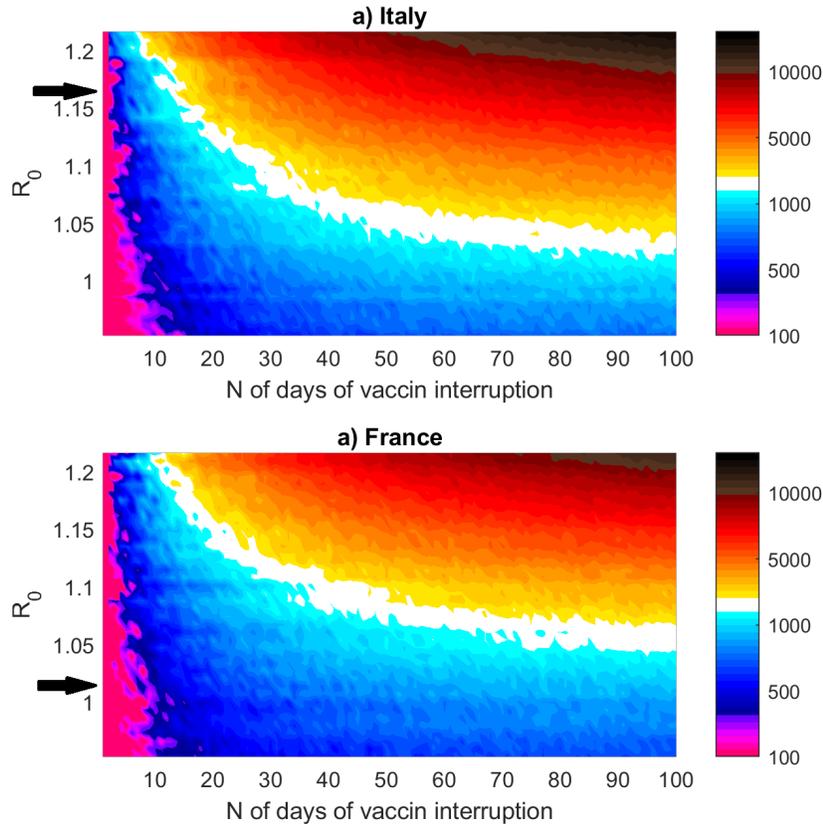


FIG. 2. Average over  $N_r = 1000$  realizations of the stochastic SEIR model showing the excess deaths  $m \times I(t)$  as a function of the number of the days of interruption of AstraZeneca vaccinations (x-axis) and  $R_0$  (y-axis) for Italy (a) and France (b). The excess deaths are computed with respect to a base scenario where vaccine injections are never interrupted. Arrows indicate the values of  $R_0$  chosen for Figs. 1-3. Each realization of the SEIR model is integrated for 500 days.

153 uncertainties are very large and hard to quantify, we will consider a worst case scenario for  
 154 the impacts of the side effects. This scenario relies on the unrealistic hypothesis that the  
 155 totality of susceptible population to DVT suffers from DVT shortly after being vaccinated,  
 156 and the lethality rate is similar to the one observed in the overall population.

157 As of March 15th 2021, 30 suspect cases of DVT have been reported over a number of  
 158 5 millions vaccinated people with AstraZeneca in Europe[27]. By suspect cases we mean  
 159 people who have developed DVT in the few days following the vaccination. This leads us to  
 160 an estimate of a frequency of 6 cases per million of vaccines. Let's call this rate  $r_{AZ}^{DVT}$ . Let's  
 161 also consider that in the case of France the incidence of DVT has been estimated to 1800

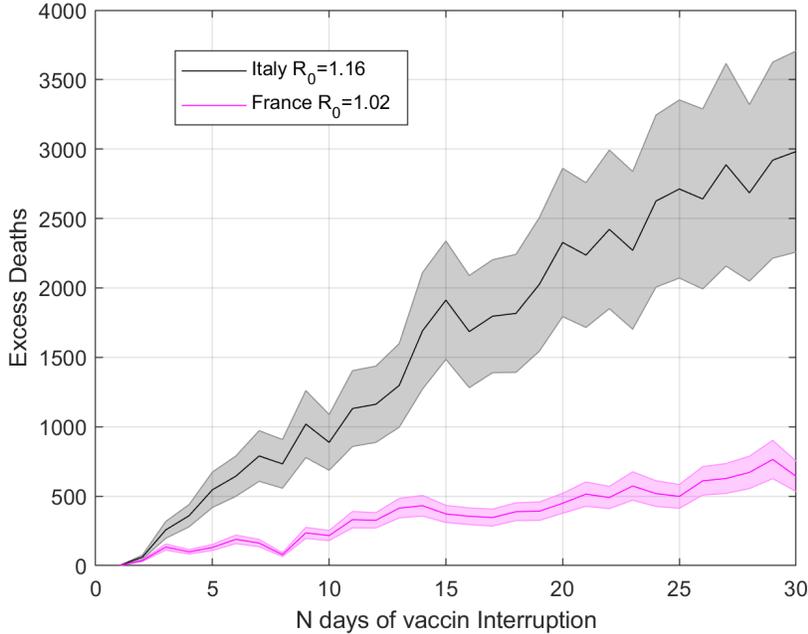


FIG. 3. Average over  $N_r = 1000$  realizations (same as those presented in Fig. 2) of the stochastic SEIR model showing the excess deaths  $m \times I(t)$  as a function of the number of the days of interruption of AstraZeneca vaccinations for Italy  $R_0 = 1.16$  (a) and France  $R_0 = 1.02$  (b) with . Error bars are computed as the mean relative error.

162 people per 1 million inhabitants per year ([28]), with a lethality rate after three months of  
 163 5% [29], raising to 30% when a period of 5 years is considered [7]. This leads to estimating  
 164 a total of the order of 10000 deaths per year as a result of DVT. Even assuming that all the  
 165 DVT cases following the inoculation of the AstraZeneca vaccine would have not manifested  
 166 themselves in absence of the injection, we have that  $N$  vaccination would lead to an extra  
 167  $N \times r_{AZ}^{DVT}$  DVT cases. Let's assume that all of these cases result into death[30]. We then  
 168 have that  $10^5$  daily vaccination would result into a maximum of 0.6 daily death. In 500 days,  
 169 which is the time needed to cover the entire French population, this leads to an upper bound  
 170 of 300 deaths. Considering a death rate of 30%, the number scales down to approximately  
 171 100, while considering a death rate of 5% the number scales down to approximately 15.  
 172 Similar figures apply for Italy.

173 Decision-making in presence of strong uncertainties associated with health and environ-  
 174 mental risks is an extremely complex process resulting from the interplay between science,  
 175 politics, stakeholders, activists, lobbies, media, and society at large [31–33]. In this letter we

176 have aimed at contributing to the debate on different strategies for combating, in conditions  
177 of great uncertainties in terms of health and social response, pandemic like the current one  
178 caused by the SARS-CoV-2 virus. We have focused on the case of the AstraZeneca COVID-  
179 19 vaccine and on the locales of Italy and France, for the period starting on March 15th  
180 2021. Here, the goal is provide a semi-quantitative comparison, based on Fermi estimates  
181 informed by a simple yet robust stochastic model, between the excess deaths due to tempo-  
182 ral restriction to the deployment of a still experimental vaccine with respect to the excess  
183 deaths due to its possible side effects. Given the many uncertainties on the (possible) side  
184 effects of the vaccine, we have resorted to making worst case scenario calculations in order  
185 to provide a robust upper bound to the related excess deaths. Our results are preliminary  
186 and should be supplemented by more detailed modelling and data collection exercises. Our  
187 results are preliminary and should be supplemented by more detailed modelling and data  
188 collection exercises. Indeed: i) we assume a single vaccine with the nominal AstraZeneca  
189 efficacy, neglecting the other available vaccines, ii) we consider a fixed vaccination rate, iii)  
190 for AstraZeneca DVT side effects we consider French data and rescale them for the Italian  
191 populations, iv) we focused our analysis on DVT side effects, but other pathologies could be  
192 considered with the same approach. Yet, they clearly suggest - see a useful summary in Ta-  
193 ble I - that the benefits of deploying the vaccine greatly outweigh the associated risks, and  
194 that the relative benefits are wider in situations where the reproduction number is larger,  
195 and they increase with the temporal duration of the vaccine ban.

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200 820970).

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201 [1] J. Wu, W. Cai, D. Watkins, and J. Glanz, How the virus got out, The New York Times  
202 (2020).

Excess Deaths	Italy	France
Stop AZ for $t = 500$ days	$9000 \pm 3000$	$1200 \pm 400$
Stop AZ for $t = 14$ days	$1700 \pm 500$	$430 \pm 70$
Stop AZ for $t = 7$ days	$790 \pm 90$	$160 \pm 30$
Stop AZ for $t = 3$ days	$260 \pm 50$	$130 \pm 20$
Worst case DVT deaths due to AZ	$\approx 280$	$\approx 300$
High fatality DVT deaths due to AZ	$\approx 90$	$\approx 100$
Standard fatality DVT deaths due to AZ	$\approx 13$	$\approx 15$

TABLE I. The first 4 lines of the table indicate the excess deaths due to the interruption of AstraZeneca compared to a reference scenario where the vaccine injections are never interrupted. The SEIR model is integrated for 500 days with  $R_0 = 1.16$  for Italy and  $R_0 = 1.02$  for France. The last 3 rows of the table show the deaths from deep vein thrombosis (DVT) that could be due to the vaccine in three different scenarios: the worst case (100% mortality rate), a high mortality scenario (death rate of 30%) and a standard mortality scenario (5% mortality rate) assuming a period of 500 days.

- 203 [2] R. M. Anderson, H. Heesterbeek, D. Klinkenberg, and T. D. Hollingsworth, How will country-  
204 based mitigation measures influence the course of the covid-19 epidemic?, *The Lancet* **395**,  
205 931 (2020).
- 206 [3] M. Chinazzi, J. T. Davis, M. Ajelli, C. Gioannini, M. Litvinova, S. Merler, A. Pa-  
207 store y Piontti, K. Mu, L. Rossi, K. Sun, C. Viboud, X. Xiong, H. Yu, M. E.  
208 Halloran, I. M. Longini, and A. Vespignani, The effect of travel restrictions on the  
209 spread of the 2019 novel coronavirus (covid-19) outbreak, *Science* **368**, 395 (2020),  
210 <https://science.sciencemag.org/content/368/6489/395.full.pdf>.
- 211 [4] H.-Y. Yuan, G. Han, H. Yuan, S. Pfeiffer, A. Mao, L. Wu, and D. Pfeiffer, The importance  
212 of the timing of quarantine measures before symptom onset to prevent covid-19 outbreaks -  
213 illustrated by hong kong’s intervention model, medRxiv 10.1101/2020.05.03.20089482 (2020),  
214 <https://www.medrxiv.org/content/early/2020/05/06/2020.05.03.20089482.full.pdf>.
- 215 [5] D. Sridhar and D. Gurdasani, Herd immunity by infection is not an option, *Science* **371**, 230  
216 (2021), <https://science.sciencemag.org/content/371/6526/230.full.pdf>.

- 217 [6] N. Fernandes, Economic effects of coronavirus outbreak (covid-19) on the world economy,  
218 Available at SSRN 3557504 (2020).
- 219 [7] M. Cushman, Epidemiology and risk factors for venous thrombosis, *Seminars in hematology*  
220 **44**, 62 (2007).
- 221 [8] [https://apnews.com/article/germany-suspends-astrazeneca-vaccine-blood-clotting-](https://apnews.com/article/germany-suspends-astrazeneca-vaccine-blood-clotting-0ab2c4fe13370c96c873e896387eb92f)  
222 [0ab2c4fe13370c96c873e896387eb92f](https://apnews.com/article/germany-suspends-astrazeneca-vaccine-blood-clotting-0ab2c4fe13370c96c873e896387eb92f).
- 223 [9] [https://www.ansa.it/english/news/general\\_news/2021/03/15/aifa-stops-astrazeneca-jab-as-](https://www.ansa.it/english/news/general_news/2021/03/15/aifa-stops-astrazeneca-jab-as-precautionary-measure_5114cf0b-2575-4ea7-8eb7-9bd556a435c5.html)  
224 [precautionary-measure\\_5114cf0b-2575-4ea7-8eb7-9bd556a435c5.html](https://www.ansa.it/english/news/general_news/2021/03/15/aifa-stops-astrazeneca-jab-as-precautionary-measure_5114cf0b-2575-4ea7-8eb7-9bd556a435c5.html).
- 225 [10] K. Steele, The precautionary principle: a new approach to public decision-  
226 making?, *Law, Probability and Risk* **5**, 19 (2006), [https://academic.oup.com/lpr/article-](https://academic.oup.com/lpr/article-pdf/5/1/19/6207484/mgl010.pdf)  
227 [pdf/5/1/19/6207484/mgl010.pdf](https://academic.oup.com/lpr/article-pdf/5/1/19/6207484/mgl010.pdf).
- 228 [11] D. Faranda and T. Alberti, Modeling the second wave of COVID-19 infections in France and  
229 Italy via a stochastic SEIR model, *Chaos* **30**, 111101 (2020), arXiv:2006.05081 [q-bio.PE].
- 230 [12] T. Alberti and D. Faranda, On the uncertainty of real-time predictions of epidemic growths: A  
231 covid-19 case study for china and italy, *Communications in Nonlinear Science and Numerical*  
232 *Simulation* **90**, 105372 (2020).
- 233 [13] S. Mahajan, *The Art of Insight in Science and Engineering: Mastering Complexity* (The MIT  
234 Press, Cambridge, USA, 2014).
- 235 [14] T. G. Shepherd, A common framework for approaches to extreme event attribution, *Current*  
236 *Climate Change Reports* **2**, 28 (2016).
- 237 [15] P. M. Anderson and C. A. Sherman, Applying the fermi estimation technique to business  
238 problems., *Journal of Applied Business & Economics* **10** (2010).
- 239 [16] D. Faranda, I. P. Castillo, O. Hulme, A. Jezequel, J. S. W. Lamb, Y. Sato, and E. L. Thomp-  
240 son, Asymptotic estimates of sars-cov-2 infection counts and their sensitivity to stochastic  
241 perturbation, *Chaos: An Interdisciplinary Journal of Nonlinear Science* **30**, 051107 (2020),  
242 <https://doi.org/10.1063/5.0008834>.
- 243 [17] F. Brauer, Compartmental models in epidemiology, in *Mathematical epidemiology* (Springer,  
244 2008) pp. 19–79.
- 245 [18] C. Sun and Y.-H. Hsieh, Global analysis of an seir model with varying population size and  
246 vaccination, *Applied Mathematical Modelling* **34**, 2685 (2010).

- 247 [19] G. E. Uhlenbeck and L. S. Ornstein, On the theory of the brownian motion, Phys. Rev. **36**,  
248 823 (1930).
- 249 [20] Paul L. Delamater et al., Complexity of the basic reproduction number ( $r_0$ ) - volume 25,  
250 number 1-january 2019 - emerging infectious diseases journal - cdc (2019).
- 251 [21] D. Fanelli and F. Piazza, Analysis and forecast of COVID-19 spreading in China, Italy and  
252 France, Chaos Solitons and Fractals **134**, 109761 (2020), arXiv:2003.06031 [q-bio.PE].
- 253 [22] Merryn Voysey et al., Safety and efficacy of the chadox1 ncov-19 vaccine (azd1222) against  
254 sars-cov-2: an interim analysis of four randomised controlled trials in brazil, south africa, and  
255 the uk, *The Lancet*, The Lancet **397**, 99 (2021).
- 256 [23] L. Salvioli, Il vaccino anti covid in italia in tempo reale: Il sole 24 ore (2021).
- 257 [24] G. Pullano, L. Di Domenico, C. E. Sabbatini, E. Valdano, C. Turbelin, M. Debin, C. Guerrisi,  
258 C. Kengne-Kuetché, C. Souty, T. Hanslik, *et al.*, Underdetection of cases of covid-19 in france  
259 threatens epidemic control, Nature **590**, 134 (2021).
- 260 [25] H. Risken, *The Fokker-Planck equation* (Springer, Berlin, 1996).
- 261 [26] Third covid wave sweeps across eu and forces new restrictions (2021).
- 262 [27] Here, we use European data accessible at [34] to average out the large spread of national data.
- 263 [28] S. Bouée, C. Emery, A. Samson, J. Gourmelen, C. Bailly, and F.-E. Cotté, Incidence of venous  
264 thromboembolism in France: a retrospective analysis of a national insurance claims database,  
265 Thrombosis Journal **14**, 4 (2016).
- 266 [29] J. A. Heit, Epidemiology of venous thromboembolism, Nature Reviews Cardiology **12**, 464  
267 (2015).
- 268 [30] Current data suggest that this is manifestly a gross worst case approximation.
- 269 [31] Anonymous, Agu statement: Investigation of scientists and officials in l’aquila,  
270 italy, is unfounded, Eos, Transactions American Geophysical Union **91**, 248 (2010),  
271 <https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1029/2010EO280005>.
- 272 [32] A. Benessia and B. De Marchi, When the earth shakes . . . and science with it. the management  
273 and communication of uncertainty in the l’aquila earthquake, Futures **91**, 35 (2017), post-  
274 Normal science in practice.
- 275 [33] J. Reis and P. S. Spencer, Decision-making under uncertainty in environmental health policy:  
276 new approaches, Environmental Health and Preventive Medicine **24**, 57 (2019).

277 [34] Covid-19 vaccine astrazeneca: Prac investigating cases of thromboembolic events - vaccine's  
278 benefits currently still outweigh risks update european medicines agency, European Medicines  
279 Agency (2021).