# Response to COVID-19 with Probabilistic Programming

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The COVID-19 pandemic left its unique mark on the 21st century as one of the most significant disasters in history, triggering governments all over the world to respond with a wide range of interventions. However, these restrictions come with a substantial price tag. It is crucial for governments to form anti-virus strategies that balance the trade-off between protecting public health and minimizing the economic cost. This abstract introduces our probabilistic programming approach to evaluate the strategies imposed by different countries and point out which policies were the most efficient in fighting the crisis. Our work provides insights on the effectiveness of national responses to the pandemic from 10 countries. Moreover, we present a method to balance economic trade-offs of adopting specific policies. Our method includes three main steps: (1) inferring parameters for COVID-19 simulation, (2) evaluating the efficacy of the COVID-19 policies, and (3) simulating policies considering the economic loss.

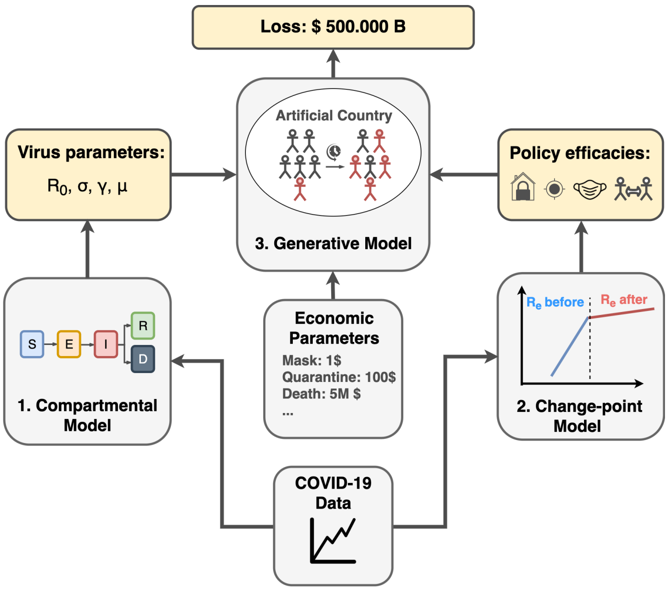
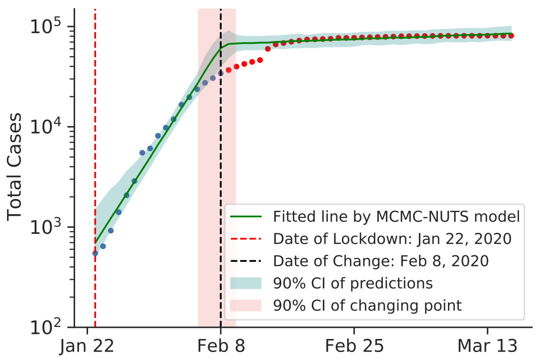
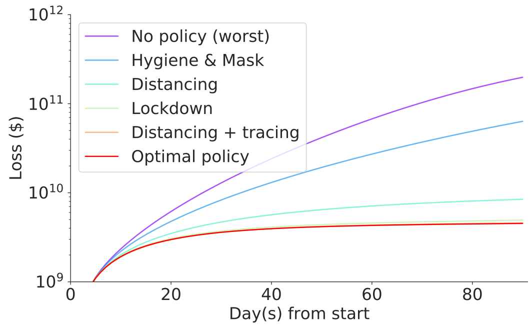



Figure 1: Project pipeline. First, we inferred COVID-19 related parameters such as basic reproduction number $R_0$, incubation rate $\sigma$, recovery rate $\gamma$, and mortality rate $\mu$ using the compartmental model. Second, we applied the change-point model to infer policy efficiencies from different countries. Finally, using inferred parameters from previous steps and economic parameters from real-world data, we ran the generative model in artificial country simulation to estimate the economic cost for different policy combinations.

First, we inferred related parameters to simulate the COVID-19 using SEIRD epidemiology model [1], and perform inference by MCMC-NUTS probabilistic model [2]. Then, we identified the efficacy of the common policies applied by countries: lockdown, contact tracing and




(a) China applied a stringent lockdown from Jan 23, 2020. With the change-point estimated around Feb 8, 2020 resulting in 96% efficiency.




(b) Accumulated loss incurred in each intervention. Social distancing coupled with contact tracing and mask mandate incurred the least loss.

Figure 2: Fitting the number of confirmed cases and measuring the effect of various policies.

quarantine, social distancing, masks and hygiene. We used MCMC-NUTS to detect the amount of time the policy will take effect, so called change-point [3] in virus transmission rate due to policy establishment. Then, we evaluated the policy's effect by comparing transmission rates before and after the change-point. The effect of lockdown in China is shown in Figure 2(a).

Finally, using these statistics, we conducted some experiments on the policies and performed simulations to develop the optimal policy with minimal economic loss. We designed an imaginary country and estimated economic loss based on several sources [4]. The country had a population of 1 million, and the simulation span three months. We assumed that policy-makers revised the policy every month, and a policy is applied exhaustively, partially (50% efficacy), or not applied at all. Policies could be applied together. The result for some policies after three months is shown in Figure 2(b). We found that social distancing coupled with contact tracing and mask mandate is the most successful policy, with a 98% reduction in economic and human capital loss. Indeed, we could see that countries that enjoyed the initial success in controlling the virus cases, e.g., South Korea applied quarantine and contact tracing as their primary policies.

Together with experimental results, we open-sourced a framework to test the efficacy of each policy combination. For reproducibility, the code and datasets used in the paper are available at `https://git.io/JGcPW`. Decision-makers can simulate some hypothetical situations and see the resulting cases, deaths, and capital loss, which assist them in making informed decisions for their citizens. Our full paper is available at `http://arxiv.org/abs/2106.00192`.

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