Simulation Card: Pandemic and Economic Simulation for COVID-19 in the United States

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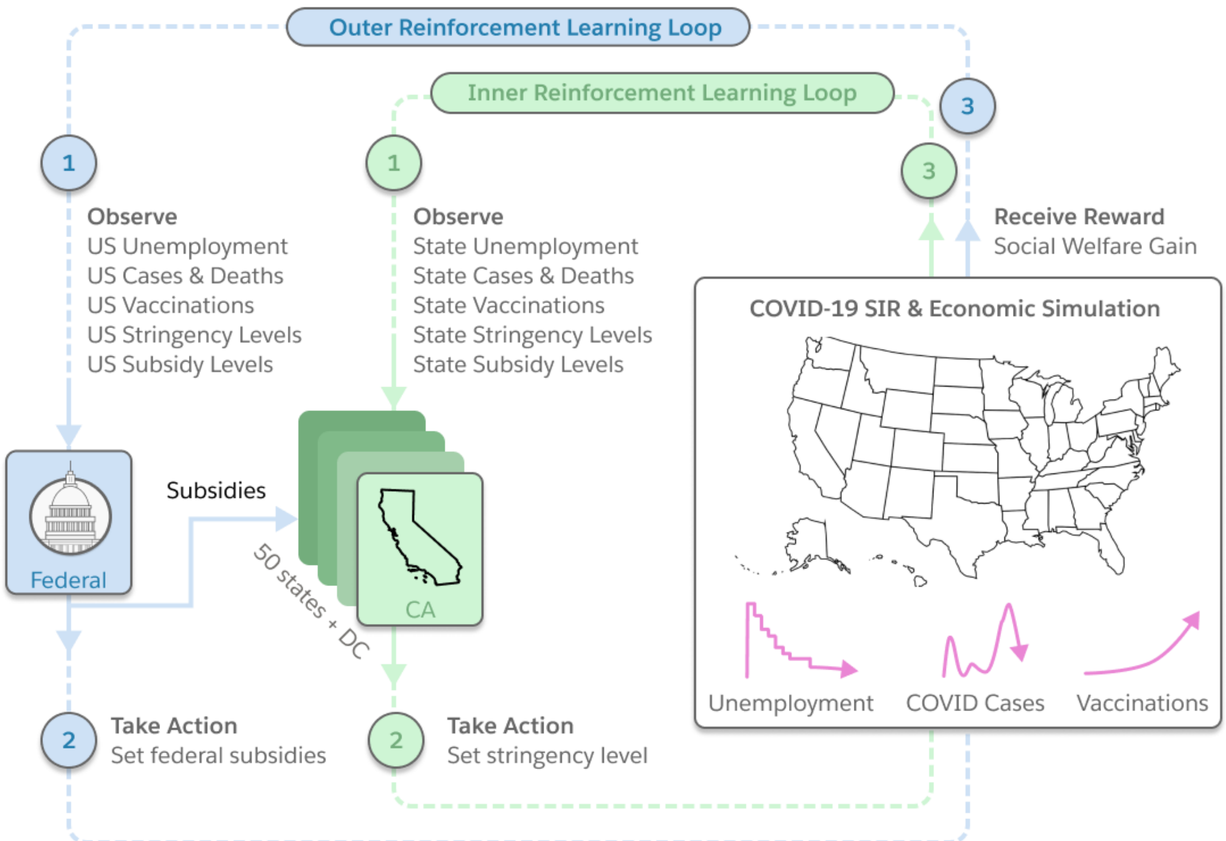
Basic Information

This simulation code implements a combined epidemiology and economy model for the United States, covering all 50 states and Washington, DC. Specifically, it includes an augmented version of the standard SIR model (Susceptible, Infected, Recovered) and basic economic processes. The augmented SIR model emulates the COVID-19 pandemic, including the effect of vaccinations. Economic processes include productivity, unemployment, and subsidies.



Intended Use

The simulation was designed as a **proof-of-concept** with the primary goal of using the AI Economist framework to design and evaluate public health and economic policy in response to pandemics like COVID-19.

Given comprehensive data, it would enable analysis of public health and economic metrics under various pandemic response policies. This includes policies at both the US state and federal levels. Both the US state and federal policy models are trained using reinforcement learning. This enables users to study the behavior of US states given different federal policies, within the assumptions and modeling choices of the simulation.

The primary intended users of this simulation are researchers (e.g., computer scientists, economists, public health) and policymakers.

Factors

The simulation is based on key modeling assumptions that are common in neoclassical economics and public health.

- Each time step represents one calendar day.
- In the public health domain, we use the standard SIR model, which models how susceptible (healthy) individuals become infected and ill, and then recover. Individuals who recover and

those who die are all considered `recovered', following the standard definition in the SIR model.

- We only model the outbreak of one COVID-19 variant. We do not model multiple outbreaks.
- In addition, vaccinations are distributed, and vaccinated individuals move from susceptible to recovered. This implements the assumption that vaccinated individuals cannot get infected again by the variant that they have been vaccinated for, i.e., no breakthrough infections. Note: this does not consider that vaccinated individuals may get infected with other COVID-19 variants they have not been vaccinated for.
- The model assumes vaccines are distributed at a configurable, constant pace after a configurable start date. This is a modeling assumption, vaccination rates are not necessarily constant in the real world.
- The public health policy lever is abstracted as a stringency level of the response by US states, ranging from 1 (lowest) to 10 (highest). This follows the Oxford Government Response Tracker. The stringency level summarizes a number of policy measures (e.g., imposing mask mandates, closing businesses, subsidizing small businesses) that have been implemented during the pandemic. Understanding and disambiguating the effects of individual policy levers is not supported by the available data.
- The economic processes included are labor, productivity, and the social welfare objectives of US state and federal policy. The productivity for each US state is computed by multiplying the size of the healthy and employed labor force (susceptible and alive recovered individuals) with the average wage in that US state.
- The unemployment rate for each state, for each month, is computed using a model fitted to real data. The model takes the SIR and current public health policy
- Wages are assumed constant and are set at the average wage in each US state.
- The economic policy lever is the level of subsidy given by the federal government, i.e., the amount of direct payments given to all eligible individuals in the US. The total subsidy is computed by summing all individual subsidies.

The simulation implements multiple interactions between public health and the economy.

- First, it assumes that infected individuals do not work; hence more infections imply drops in labor and productivity.
- Second, it assumes that subsidies can be given by the federal government to all individuals in the labor force in the US, and that each individual receives the same amount. In the real world, subsidy amounts vary by income.
- Third, it models the relationship between unemployment and the stringency level of US state policy. For example, increasing stringency (forcing business closures, etc.) increases unemployment in a non-linear fashion.

However, there are likely many factors that cannot be accounted for in a fine-grained manner in this simulation. We want to call attention to a few in particular.

- We don't know human behavior in response to the stringency measures and can't model it due to a lack of data.
- We don't know to what extent employed people are more susceptible and how this depends on the nature of their work.

To what extent these modeling limitations matter for predicting the chosen outcomes and metrics in our simulation, such as unemployment, is hard to determine due to a lack of counterfactual data.

All parameters of this model have been fit or taken from real data.

- US Census Data, US Census Bureau.
- COVID-19 Data, COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University.
- US Unemployment Data, U.S. Bureau of Labor Statistics.
- Federal and state COVID-19 policy, Oxford Covid-19 Government Response Tracker.
- Direct Payments and Federal Policy, Committee for a Responsible Federal Budget.
- Vaccination Data, Our World in Data.

Metrics

- Social welfare is defined as a weighted average of a public health index and an economic index.
    - *Note: This definition is used to study the trade-offs between public health and the economy. It is highly stylized. In the real world, the factors that contribute to social welfare are not uniquely defined and social welfare may depend on many more variables.*
- The US state public health index is defined as deaths as a fraction of each US State's population.
- The economic index is defined as a CRRA (constant relative risk aversion) nonlinearity applied to the per-capita productivity with subsidies added. Mathematically, given input x, the CRRA function computes $x^{1-a} / (1-a)$, where $a > 0$ is a risk-aversion parameter. In particular, both unemployment and subsidies can impact the economic index.
- At the federal level, the economic and public health indices are similarly defined using national counts.

Quantitative Analyses

The simulation allows the user to generate plots and other visualizations over all observables, metrics, and policy behaviors. This includes the number of susceptible, infected, and recovered individuals, the level of policy stringency and subsidies, and how these affect social welfare. For details, see the technical paper.

Ethical Considerations

This work should be regarded as a proof of concept. There are aspects of the real-world that no AI simulation can capture as of yet. As a result, the simulations proposed here, and the insights that come from them, are not designed to inform, evaluate, or develop real-world policy. All data have their limitations and those used to model complex systems like health and the economy may fail to model impacts on specific segments of the population (e.g., historically marginalized or other vulnerable groups).

We are very clear that there are known and unknown risks in the publication of research around the use of AI to weigh the policy tradeoffs in potentially sensitive areas like health, employment, education and the environment. In recognition of the potential risks, we commissioned Business for

Social Responsibility (BSR) to conduct an ethical and human rights impact assessment of this research before its release.

Some, though not all, of the risks they noted are associated with the use of the simulation beyond its intended purpose and overreliance on, or overconfidence in, its AI-driven policy recommendations. In BSR's words, they are as follows:

1. **Policymakers may use the simulation and/or underlying research to inform decision-making.** There is a risk that policymakers may use the simulation directly to test potential policies. Policymakers may also use insights and findings from published reports or press coverage to inform public policy.
2. **The simulation and research may be used for purposes other than those originally intended**. There is a risk that the limitations of the simulation and guidance on appropriate use are misunderstood, misinterpreted, or ignored by readers, leading to inappropriate usage of the simulation for purposes other than intended. This could include using the simulation to create policy responses for future cases not covered by the simulations conducted here.
3. **Humans may over-rely on insights from the simulation**. A simulation provides a veneer of precision and objectivity that imbues a high level of confidence in AI policies. This may result in humans using outputs directly, without external validation or review, and without testing the recommendations in real-world scenarios. Humans often over-rely on AI, sometimes with grave results. This is particularly concerning in the context of a "moral" or "ethical" tradeoff between economic health and public health and safety.
4. **The simulation may be manipulated to 'optimize' for specific policies or outcomes.** Policymakers or government actors may use a simulation to justify policy decisions, giving people a false sense of confidence in the policy without insight into the limitations of the simulation. Alternatively, policymakers may use open-source code to develop new models that optimize for their own self-interest, tweaking parameters and outcomes until they achieve the desired outcome.
5. **The AI Economist open-source code may be altered for use in new geographies or to guide policy responses in future pandemics.** If the underlying code and datasets for the AI Economist's COVID simulation are made publicly available, there is a risk that it could be altered for use in other geographies without the appropriate data inputs, or that it could be used to guide policy making and decisions in future pandemics, without the appropriate data on the disease.

These risks could be associated with the following adverse human rights impacts:

- **Right to Equality and Non-Discrimination (UDHR Article 2 / ICCPR Article 2):** Failure to disaggregate data by race, gender, age, or other protected categories, limits a simulation's ability to extrapolate policy impacts on specific groups or populations. If a simulation is used to make policy decisions without taking into consideration policy impacts on specific segments of the population, there is a risk of discrimination and adverse human rights impacts on higher risk populations.
- **Right to Life and Right to Health (UDHR Articles 3, 25 / ICCPR Article 6 / ICESCR Article 12):** If a policymaker or government actor uses outcomes from a simulation to justify less stringent public health policies, it could lead to severe adverse health impacts, including long term illness or death. Furthermore, if the underlying code is used to create simulations that inform policy decisions in future pandemics, it may lead to similar adverse health impacts,

particularly if the new model fails to integrate data sources and context specific to the disease.
- **Right to Work and Adequate Standard of Living (UDHR Articles 23, 35 / ICESCR Article 6):** Policymakers and government actors may use the model in ways that result in job loss and adverse impacts on the right to work. For example, if a policymaker or government actor uses the simulation to justify stringent public health measures that lead to lockdowns, this could result in significant job loss. These impacts may be particularly severe if the policy response does not include financial support or subsidies for individuals experiencing financial hardship. Violations of these rights may also have knock-on impacts on other human rights.
- **Freedom of Movement, Freedom of Assembly, and Access to culture (UDHR Articles 13, 20, 27 / ICCPR Articles 12, 21, 27):** In addition to the rights above, stringent public health policies, including lockdowns, will impact individuals' freedom of movement, freedom of assembly, and access to cultural life of the community.
- **Right to Education, Healthcare, and other Public Services (UDHR Articles 26, 25, 21b / ICESCR Articles 13, 15):** Depending on the context, public health policies may also impact access to education, healthcare, or other public services.

These adverse impacts are more likely to affect at-risk and vulnerable populations with less access to resources that would allow them to sustain themselves through job loss, economic shutdowns, and health complications.

To mitigate these risks to the extent possible, we have taken the following steps:

1. Limiting the public web demo to insights
   a. The public website does not include any interactive elements, which allows individuals to optimize for variables or tradeoffs, so as to limit its potential use as a policy-making tool. Instead, it includes a summary of research findings and accompanying visuals.
2. Gating the code
   a. Before gaining access to the simulation code, we have required an individual to provide their name, email address, affiliation and intended use of the code. In addition, we are asking users to attest to a Code of Conduct in its use. By doing so, we hope to significantly mitigate risks of misuse, abuse, or use beyond originally intended purposes, while still enabling the sharing of research to advance the field and providing the opportunity for replicability.
3. Detailing limitations (see our blog for more details)
   a. We have made every effort to be as transparent and clear as possible about the limitations of this simulation and the datasets which inform it. Our disclaimers include the intended use of the simulation, its limitations in modeling real-world effects, and the lack of disaggregated datasets.
4. Creating a simulation card
   a. We are publishing this simulation card that provides a description of the COVID simulation's data sources and inputs, limitations, and presents basic performance metrics. It also provides 1) a concise overview of the simulation and accompanying research, its key audience, and intended use cases, 2) a description of the limitations and assumptions (both explicit and implicit) of the model, 3) clear definitions of the variables and descriptions of what the variables mean, as well as 4) clear communications on how it works. We hope that "model cards" and "simulation

cards” of this nature become a standardized practice across technology companies and research institutions.

We expect and hope to engage users of the AI Economist research, simulation, and underlying code to understand how it is being used and expanded upon outside of Salesforce. We approach this work with humility and hope to hear from the scientific community about its limitations and applications.

More information

- Code: https://www.github.com/salesforce/ai-economist
- Tutorials: https://www.github.com/salesforce/ai-economist/tutorials
- Demo: https://einstein.ai/the-ai-economist/ai-policy-foundation-and-covid-case-study
- Blog: https://blog.einstein.ai/ai-economist-covid-case-study-ethics
- Paper: Building a Foundation for Data-Driven, Interpretable, and Robust Policy Design using the AI Economist
- Paper: The AI Economist: Improving Equality and Productivity with AI-Driven Tax Policies
- General information: https://www.einstein.ai/the-ai-economist