Understanding Cross-Country Heterogeneity of Health and Macroeconomic Outcomes during the COVID-19 Pandemic

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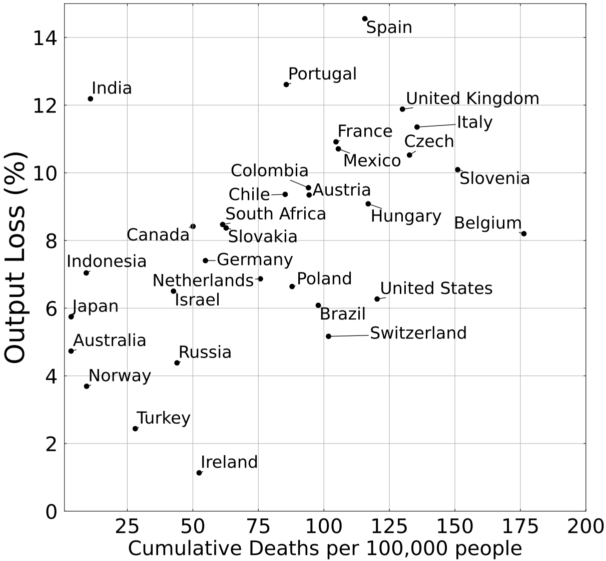
August 2, 2023

Question

What accounts for cross-country (or -region) differences in health and economic outcomes during the COVID-19 crisis?

Cross-country



What we do

- We present a framework to understand cross-country heterogeneity in health and economic outcomes.
- ...in which we describe a realized outcome as a function of (i) preference and (ii) constraints.
- ...which allows us to describe the difference in outcomes across any two countries as consisting of (i) the difference in preference and (ii) the difference in constraints.

What We Do—A Revealed-Preference Exercise—

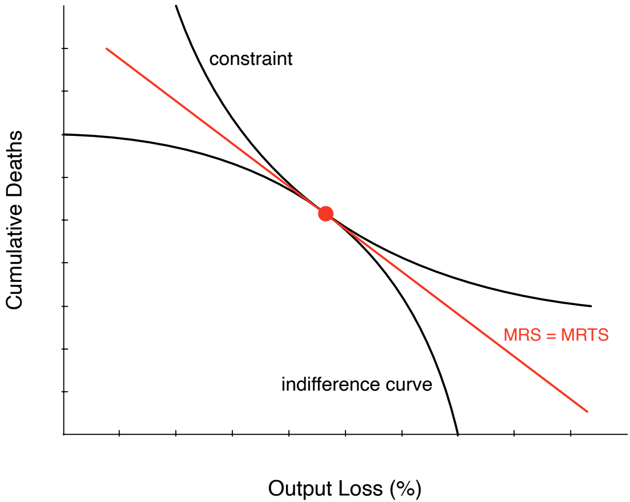
Step 1: For each country, we construct a "health-economic possibility frontier," or more simply, "'tradeoff curve."

- ...using an estimated epi-macro model fitted to each country's time-series data on infection and economy.
- ...and conducting a series of counterfactual experiments asking "how many more people would have died if economic activity had been higher."

Step 2: We compute the marginal rate of substitution (MRS) at the realized pair of economic activity and COVID-19 deaths.

- MRS can be interpreted as society's willingness-to-pay (WTP) to reduce a COVID-19 death subject to various caveats.

Idea



- Black: Tradeoff curve—a constraint—
- Red: Marginal Rate of Substitution (MRS)—preference—

Constraints?

In our model, a few parameters affect the location and shape of the tradeoff curve.

In reality, a myriad of factors likely affect the location and shape of the tradeoff curve.

- Vaccination, medical capacity, Non-Pharmaceutical Interventions (NPIs), behavioral/cultural differences, people's susceptibility to the disease, factors affecting the death rate (for example, high-BMI population), economic policy (fiscal and monetary), economic structures (proportion of contact-intensive workers and availability of remote work), and luck, etc.
- We call them "technology and policy" factors.

Preference?

Our model-implied MRS or WTP measure likely captures a myriad of factors in reailty:

- Value of Statistical Life.
- Desire to avoid stigma associated with COVID-19 in certain societies that value conformity.
  - Ostracization in Japanese countrysides early 2020.
  - In some societies, there might be the opposite stigma.
- Desire to avoid being quarantined for several days by getting infected with COVID-19.
- Desire to avoid particular tragedy associated with dying from COVID-19.
  - Patients might have to pass away in isolation from loved ones.
- Fear of the unquantifiable risk.
- Misspecification of our model.
- ...among many others.

Key Results

There is a large cross-country heterogeneity in both (i) the location and shape of the tradeoff curve and (ii) the implied MRS.

- For example, the U.S. curve was located in a substantially worse position than the Japanese curve.
- ...and the implied WTP is much lower in the U.S. than in Japan.
  - 1 million $ in the U.S.; 13 million $ in Japan.

Literatures

- Optimal lockdown policy in epi-macro models
  - Acemoglu et al. (2022), Alvarez et al. (2022), Eichenbaum et al. (2021), and Farboodi et al. (2022), etc.
  - Our paper reverse-engineers the implied value of life from data.
- Cross-country comparisons
  - Fernandez-Villaverde and Jones (2020)
  - Our paper provides a framework to quantitatively understand the sources of cross-country differences.

Outline of the Talk

- Framework
- Results
- Accounting for the difference between Japan and the U.S.

Epi-Macro Model

SIRD model in which infection rate depends on economic activity.

- Formulated in discrete time with infinite horizon.
- Weekly frequency.
- Reduced-form.
  - ...as in Acemoglu et al. (2022), Atkeson (2020), Alvarez et al. (2022), and Farboodi et al. (2021).
  - ...not micro-founded, unlike Eichenbaum et al. (2021).

Epi-Macro Model

$$
\begin{aligned}
S_{t+1} &= S_t - N_t - V_t \\
I_{t+1} &= I_t + N_t - N_t^{IR} - N_t^{ID} \\
R_{t+1} &= R_t + N_t^{IR} + V_t \\
D_{t+1} &= D_t + N_t^{ID} \\
N_t^{IR} &= \gamma_t I_t \\
N_t^{ID} &= \delta_t I_t
\end{aligned}
$$

S_t: Susceptible, I_t: Infected, R_t: Recovered, D_t: Dead

N_t: Newly infected, N_t^{IR}: Newly recovered, N_t^{ID}: Newly dead

V_t: Newly vaccinated (effective)

γ_t: recovery rate, δ_t: death rate

Epi-Macro Model

$$N_t = \frac{\tilde{\beta}_t}{POP_0} I_t S_t$$
$$\tilde{\beta}_t = \beta_t (1 - h\alpha_t)^2$$

- POP_0: Total population at time 0
- $\tilde{\beta}_t$: Infection rate
- β_t: Raw infection rate that would prevail in the absence of any decline in economic activity
- α_t: Decline in economic activity (from pre-crisis trend)
  - $Y_t := (1 - \alpha_t)\bar{Y}_t$
- h governs the elasticity of $\tilde{\beta}_t$ to economic activity.

Estimation

From a set of observed variables/parameters:

$$N_t, N_t^{ID}, V_t, Y_t, \bar{Y}_t, POP_0,$$

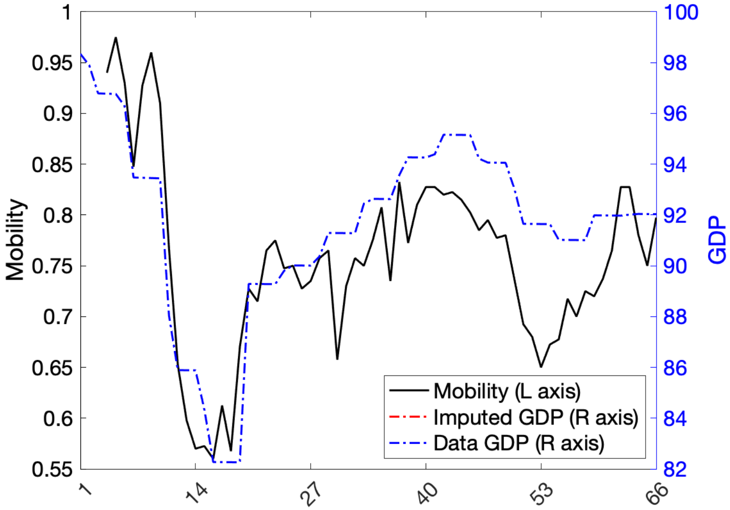
we compute variables or time-varying parameters:

$$\{S_t, I_t, R_t, D_t, N_t^{IR}, \alpha_t, \beta_t, \tilde{\beta}_t, \delta_t\}_{t=1}^{T}$$

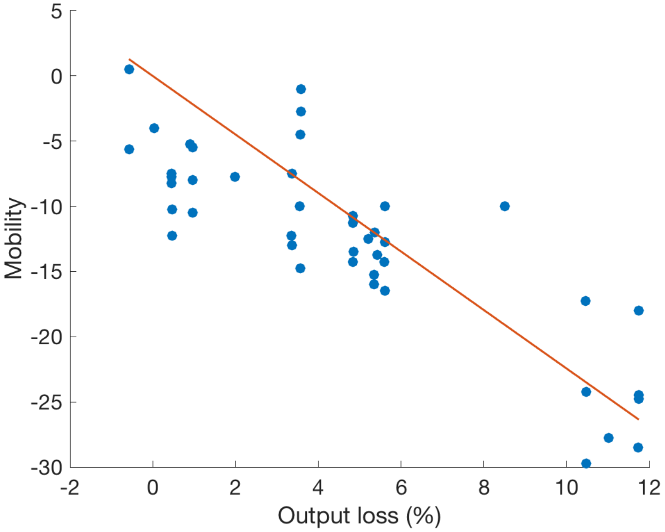
- We set a sequence of γ_t (recovery rate) to a constant based the medical literature.
- We calibrate h using the estimated elasticity of mobility to output.

See Fernandez-Villarverde et al. (2021) for a similar estimation of time-varying parameters in a SIR model.

Output and Mobility



Output and Mobility



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N_t^{IR} &= \gamma_t I_t \\
N_t^{ID} &= \delta_t I_t \\
N_t &= \frac{\tilde{\beta}_t}{POP_0} I_t S_t \\
\tilde{\beta}_t &= \beta_t (1 - h\alpha_t)^2 \\
Y_t &:= (1 - \alpha_t) \bar{Y}_t
\end{aligned}
$$

Assume initial conditions (S_0, I_0, R_0, D_0). Then, we can find $\{S_t, I_t, R_t, D_t\}_{t=1}^{T}$.

$$
\begin{aligned}
S_{t+1} &= S_t - N_t - V_t \\
I_{t+1} &= I_t + N_t - N_t^{IR} - N_t^{ID} \\
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\tilde{\beta}_t &= \beta_t (1 - h\alpha_t)^2 \\
Y_t &:= (1 - \alpha_t)\bar{Y}_t
\end{aligned}
$$

Combined with an estimate of h, we can find $\{\delta_t, \beta_t, \tilde{\beta}_t\}_{t=1}^{T}$.

$$\begin{aligned}
S_{t+1} &= S_t - N_t - V_t \\
I_{t+1} &= I_t + N_t - N_t^{IR} - N_t^{ID} \\
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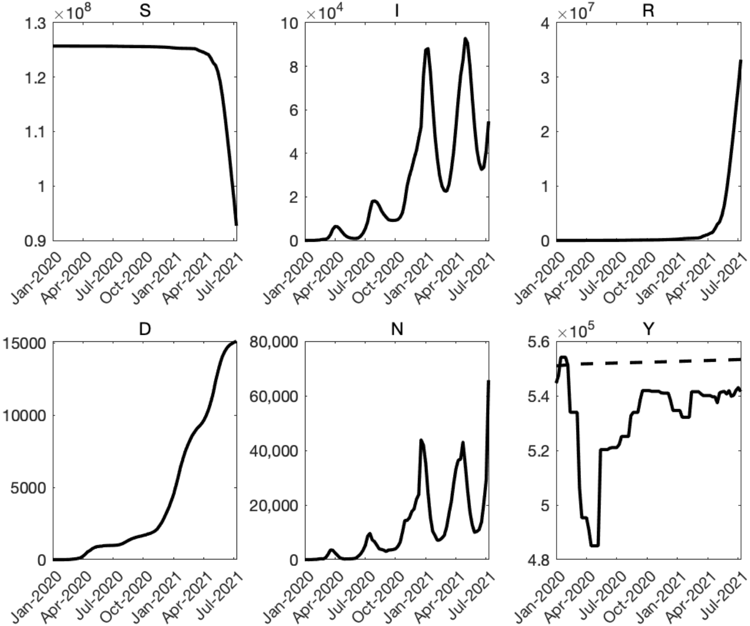
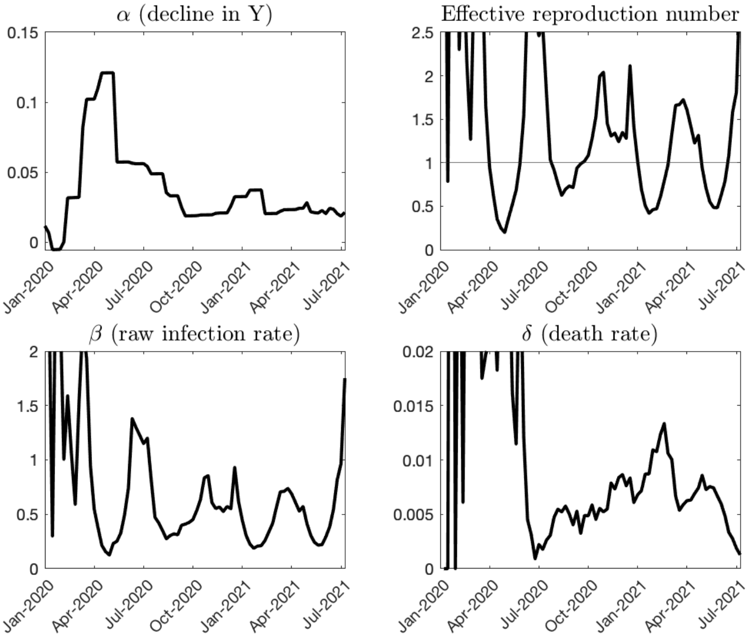
\tilde{\beta}_t &= \beta_t (1 - \mathbf{h}\alpha_t)^2 \\
Y_t &:= (1 - \alpha_t)\bar{Y}_t
\end{aligned}$$

Estimation: Japan

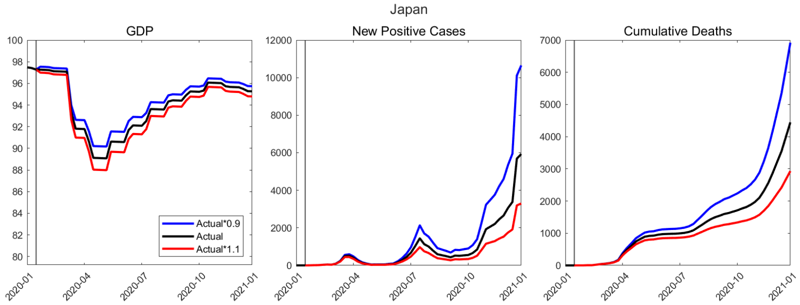


Estimation: Japan



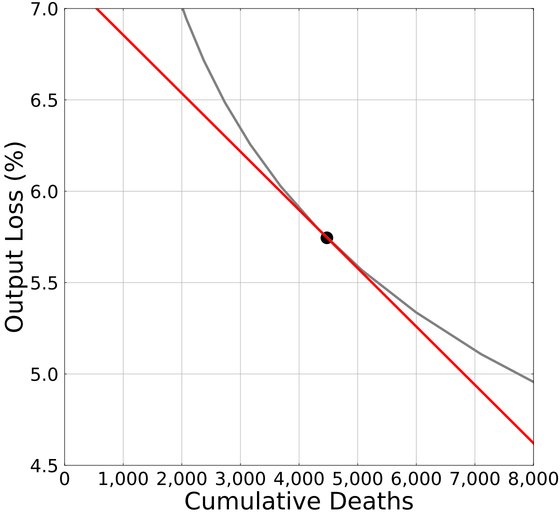
Counterfactual Experiments: Japan

How many more people would have died if more economic activity?
How many more lives could have been saved if less economic activity?



- We only consider proportional changes to α path, keeping the path's contour unchanged.

Tradeoff Curve: Japan



- Black: Tradeoff curve—a constraint—
- Red: Marginal Rate of Substitution (MRS)—preference—

Outline of the Talk

- Framework
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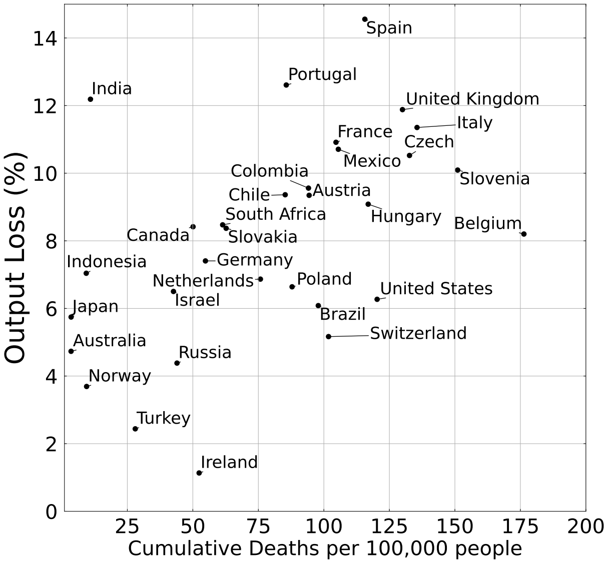
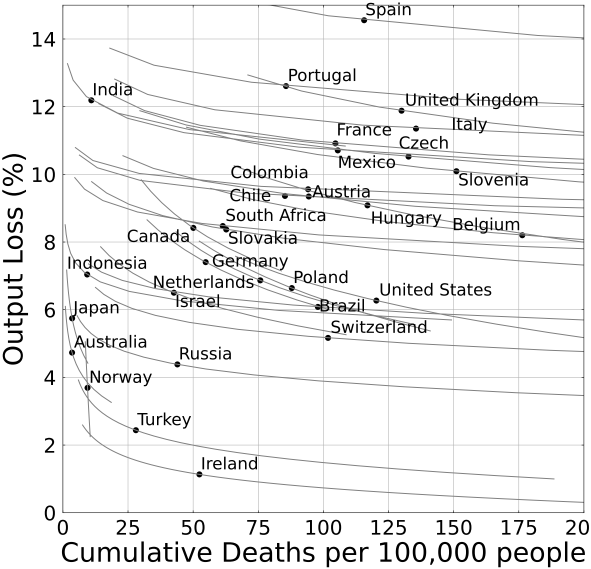
- Accounting for the difference between Japan and the U.S.

Data Sources

- New Cases and Deaths—WHO COVID-19 Dashboard
- Vaccination—A global database of COVID-19 vaccinations (Mathieu et.al., 2021)
- Monthly GDP—OECD Main Economic Indicators Publication
  - Create monthly GDP by multiplying trend and ratio to trend
- Mobility—Google COVID-19 Community Mobility Reports
  - Mobility on retail, parks, stations, workplaces, and residential
- Population—World Population Prospects

Sample period: From the fourth week of January 2020 to the second week of January 2021. (52 weeks)


Output Loss (%)
Cumulative Deaths per 100,000 people
0
2
4
6
8
10
12
14
25
50
75
100
125
150
175
200
Spain
Portugal
India
United Kingdom
Italy
France
Czech
Mexico
Slovenia
Colombia
Austria
Chile
South Africa
Hungary
Belgium
Canada
Slovakia
Indonesia
Germany
Netherlands
Poland
United States
Israel
Japan
Brazil
Switzerland
Australia
Russia
Norway
Turkey
Ireland



Spain
Portugal
India
United Kingdom
Italy
France
Czech
Mexico
Slovenia
Colombia
Austria
Chile
Hungary
South Africa
Belgium
Canada
Slovakia
Germany
Indonesia
Poland
Netherlands
United States
Israel
Brazil
Japan
Switzerland
Australia
Russia
Norway
Turkey
Ireland
Output Loss (%)
Cumulative Deaths per 100,000 people
0
2
4
6
8
10
12
14
0
25
50
75
100
125
150
175
200

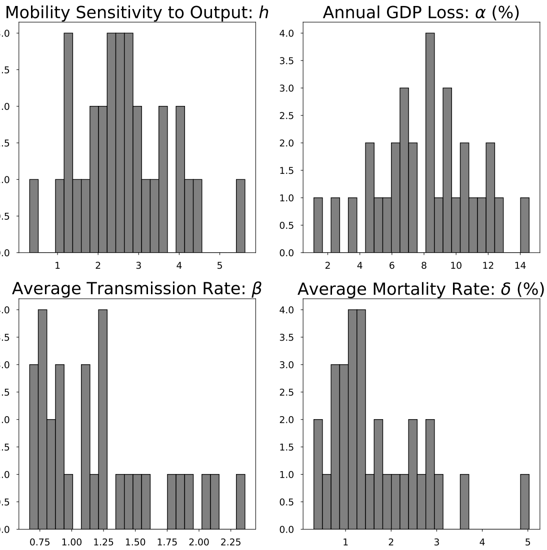
Result 1:

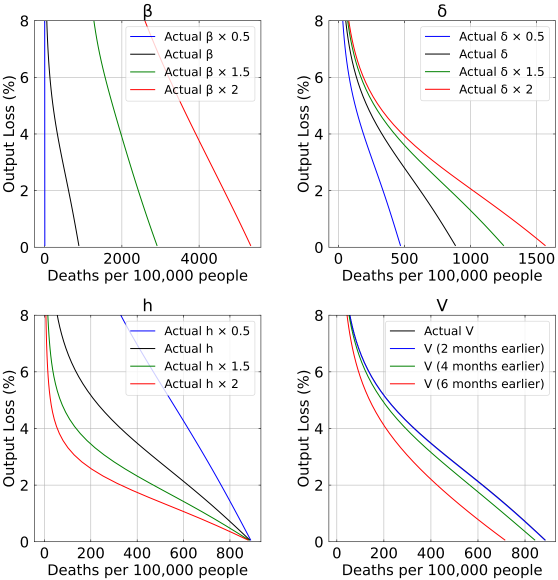
The location and shape of the tradeoff curve vary a lot across countries.

Why do the location and shape of the tradeoff curve vary a lot across countries?

In our model, the location and shape depend importantly on the following factors.

- Sequence of β (infection rate)
- Sequence of δ (death rate)
- h: elasticity of infection rate to economic activity


Mobility Sensitivity to Output: h
Annual GDP Loss: α (%)
Average Transmission Rate: β
Average Mortality Rate: δ (%)
0.0 0.5 1.0 1.5 2.0 2.5 3.0
1 2 3 4 5
0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0
2 4 6 8 10 12 14
0.75 1.00 1.25 1.50 1.75 2.00 2.25
1 2 3 4 5



β
Actual β × 0.5
Actual β
Actual β × 1.5
Actual β × 2
Output Loss (%)
Deaths per 100,000 people
δ
Actual δ × 0.5
Actual δ
Actual δ × 1.5
Actual δ × 2
Output Loss (%)
Deaths per 100,000 people
h
Actual h × 0.5
Actual h
Actual h × 1.5
Actual h × 2
Output Loss (%)
Deaths per 100,000 people
V
Actual V
V (2 months earlier)
V (4 months earlier)
V (6 months earlier)
Output Loss (%)
Deaths per 100,000 people

Result 1: The location and shape of the tradeoff curve vary a lot across countries.

Result 2:

MRS varies a lot across countries.

Table: Model-Implied MRS (Million US dollars)

Country	MRS	Country	MRS	Country	MRS
Japan	13.61	Austria	0.37	Italy	0.14
Australia	13.23	Turkey	0.32	Russia	0.13
Canada	2.19	France	0.27	India	0.1
Germany	1.70	Belgium	0.26	Chile	0.07
Netherlands	1.45	Hungary	0.26	Mexico	0.05
Israel	1.08	Spain	0.24	South Africa	0.05
United States	1.01	Slovakia	0.23	Brazil	0.04
Ireland	0.90	Indonesia	0.20	Colombia	0.03
United Kingdom	0.54	Slovenia	0.18		
Switzerland	0.49	Portugal	0.16		
Poland	0.44	Czech	0.14		

Outline of the Talk

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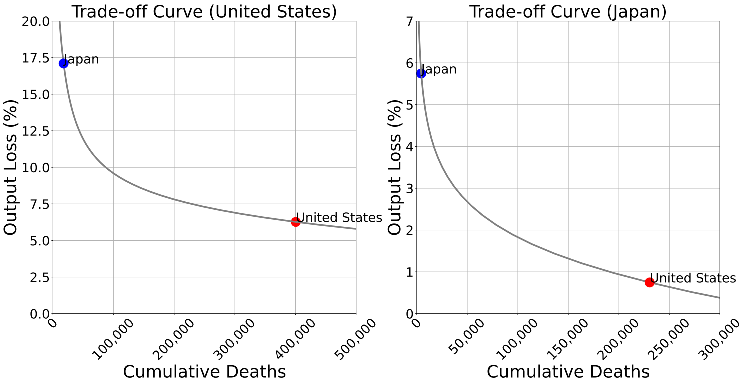
Accounting for the difference b/w Japan and the U.S.

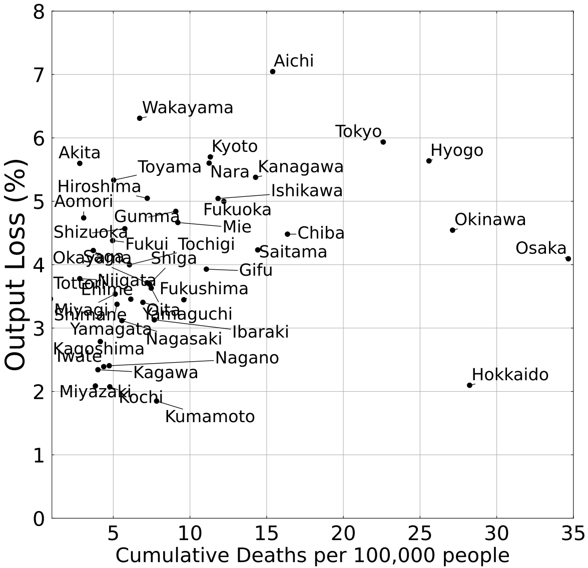


Summary

- We found a large cross-country heterogeneity in both (i) the location and shape of the tradeoff curve and (ii) the MRS—the implied WTP to reduce a COVID-19 death.
- We showed how to decompose the difference in the realized outcome between two countries into a part related to preference and a part related to constraints.
- Heated debate during the COVID-19 crisis about how to balance controlling infection and protecting ordinary ways of life. Our framework is a step toward objectively assessing the balance.

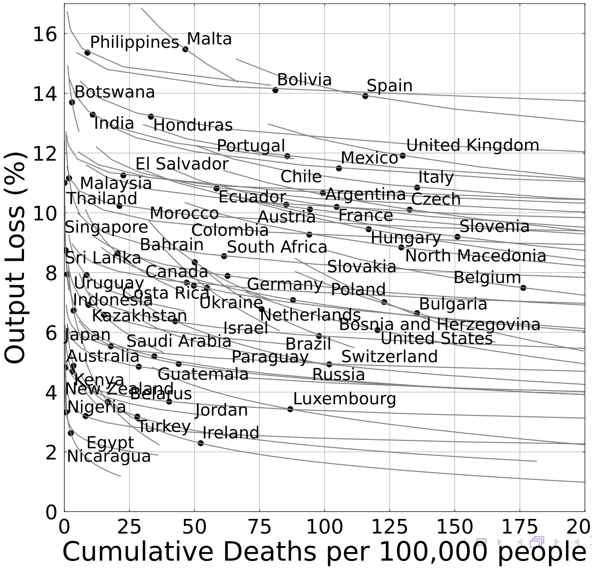
Extra Slides

Cross-region in Japan



Robustness

Figure: Tradeoff curve: Quarterly GDP



Robustness

Table: Table on the Values of Life (per million, 2010 USD)

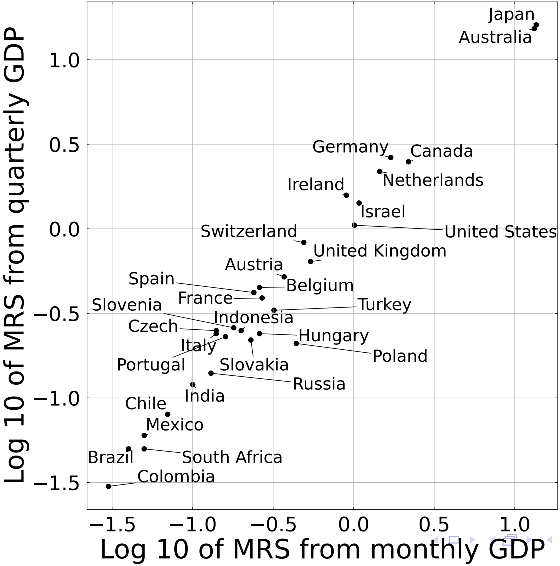
Country	VoL	Country	VoL	Country	VoL
Singapore	118.10	Lithuania	0.58	India	0.09
New Zealand	81.87	Turkey	0.42	Egypt	0.08
Thailand	36.87	United Kingdom	0.41	Paraguay	0.08
Japan	18.56	Belgium	0.40	Costa Rica	0.06
Australia	13.26	Nicaragua	0.39	Ukraine	0.06
Canada	6.31	Austria	0.35	Morocco	0.06
Malaysia	4.46	Slovenia	0.32	Chile	0.06
Botswana	3.86	Hungary	0.32	South Africa	0.05
Netherlands	2.51	France	0.31	North Macedonia	0.05
Malta	2.40	Spain	0.28	Mexico	0.05
Germany	2.12	Czech Republic	0.27	El Salvador	0.04
Luxembourg	1.96	Russia	0.24	Argentina	0.04
Israel	1.31	Romania	0.23	Brazil	0.04
Latvia	1.13	Indonesia	0.20	Guatemala	0.03
Kazakhstan	1.05	Slovakia	0.20	Ecuador	0.03
United States	1.03	Italy	0.18	Colombia	0.03
Bahrain	0.97	Portugal	0.17	Honduras	0.02
Uruguay	0.88	Poland	0.16	Jordan	0.02
Ireland	0.75	Philippines	0.12	Peru	0.01
Switzerland	0.67				

Table: Distribution Table on the Value of Life (per million, 2010 USD)

Mean	Variance	50 %	5 %	95 %
5.28	19.20	0.30	0.03	29.55

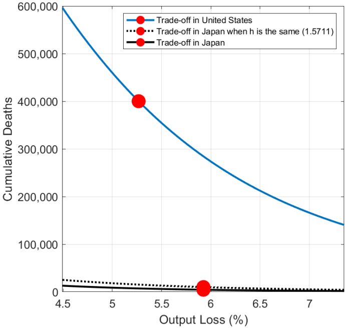
Robustness

Figure: WTP (Monthly GDP vs Quarterly GDP)



Accounting for the difference b/w Japan and the U.S.

Figure: Original tradeoff curves and tradeoff curve with an alternative *h*



Note: The left panel shows the tradeoff curve with the United States' *h* and the original parametrization in Japan for the others. The right panel shows the tradeoff curve with Japan's *h* and the original parametrization in the United States for the others.