# The S-I-R (suspected-infected-recovered) model of the pandemic and the Philippines' quarantined economy

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13 July 2021

BSP RESEARCH ACADEMY

# Introduction

- Covid-19 cases and deaths (11 July 2021, Google)
  - Philippines: 1.5 million cases; 25,921 deaths
  - World: 187 million cases; 4.0 million deaths

- Lockdown severity (27 June 2021, Bloomberg)
  - Philippines: ranks as 52nd / 53 countries

- Economic declines (2020)
  - Philippines: -9.5 percent, Philippine Statistical Authority
  - World: -3.3 percent, International Monetary Fund

- Vaccination (Reuters, 12 July 2021)
  - Philippines: 12.9 million doses, 241,427 doses per day
  - World: 3.4 billion doses

*score is 72 index points, better than only one country (Argentina, with a score of 78 index points) among 53 countries being ranked as of the date indicated. A high score indicates that social and economic activities are tightly restricted by government policy and guidance. It means people are experiencing greater disruption in their lives.

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- Research Questions
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- Data and Estimates of Containment Measures
- SIR Model of an Economy
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# Motivation and background

- Kermack and McKendrck (1927)
  - Susceptible-Infected-Removed (S-I-R) model of an epidemic

- Sicat (2003)
  - At the end of the war (World War II), national output was at least 30 percent of the level of the prewar output

- 2020: absence of information, knowledge, experience, and analysis
  - the virus
  - good quarantine measures
  - impact on the economy

# Motivation and background

- By 2021,
  - raw information and experience on infections, recoveries and deaths are now available
  - containment policies have included business and consumption restrictions; vaccination and other non-pharmaceutical interventions policies (e.g. face mask)

- Business disruptions and economic declines can be documented for current policy analysis and for future research

- Pandemic models have been expanded to include economic variables (and vice versa)

# Research Question and hypothesis

- Are there tradeoffs between containment policies and aggregate economic performance ?
  - What are the tradeoffs ?

- What are the counterfactuals …
  - had containment policies were more or less restrictive ?
  - had containment policies been delayed or too early ?
  - that can help estimate the impact of containment policies on infections, deaths and economic declines (i.e. aggregate consumption) ?

# Methodology

- Measurement of containment policies
  - Government directives such as IATF Resolutions and Circulars and Advisories coming from DTI, DOH, DOLE, DOTr (LTFRB, MRTA, LRTA, PNR, CAB, Marina), DOT, CHED, DepED; press releases and pronouncements of institutions
    - ✓ types of businesses that are allowed to operate
    - ✓ maximum capacities within which businesses can operate
  - Annual Survey of Philippine Businesses (of the Philippine Statistics Authority)
  - National Income Accounts (of the Philippine Statistics Authority)

Obtain a per industry and aggregate measure of "containment policy" in the Philippines

- Application of the Eichenbaum, Rebelo and Trabandt (2020) macroeconomic model of/with a pandemic
  - incorporates the S-I-R pandemic model of Kermack and McKendrick (1927)

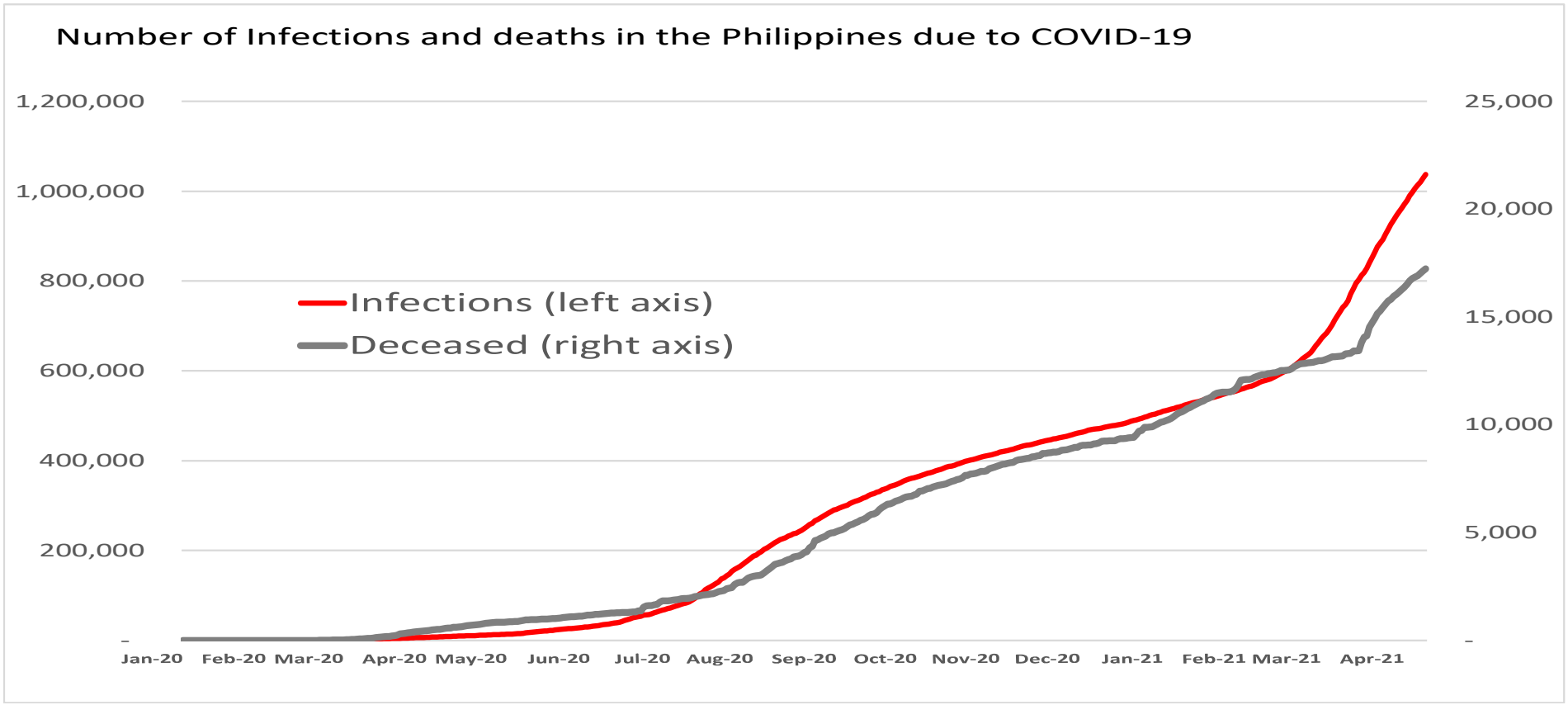
Use the measure of "containment policy" and other Philippine data to simulate the dynamics between infections and aggregate consumption, among others

# Methodology

- Part I - Process two major sets of Philippine data/information sets
  - Pandemic data: daily infections, deaths and recoveries, among others
  - Containment policy rates (aggregate measure containment policies)

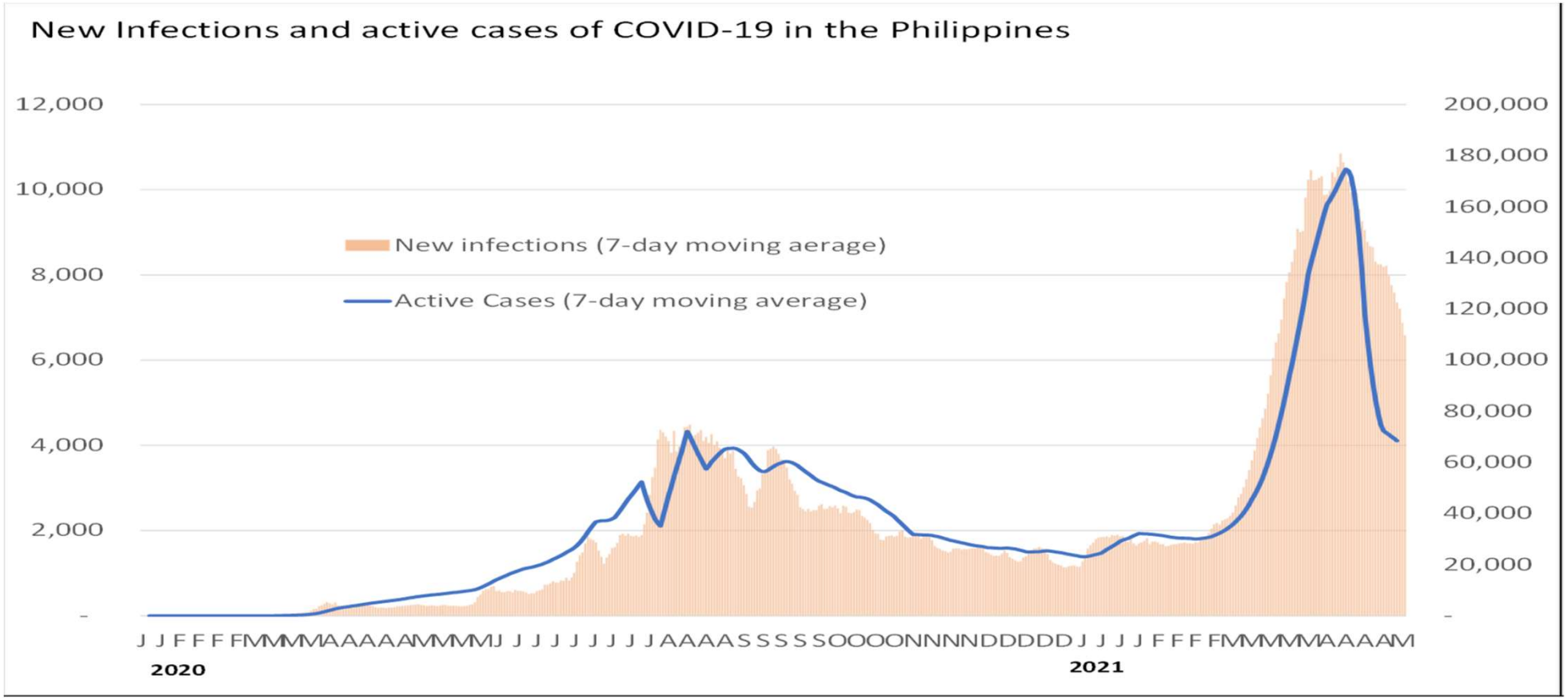
- Part II - Simulations / calibration of a simple model of a macroeconomy that incorporates a the (S-I-R) model of a pandemic.
  - using Philippine data as inputs

# Recorded Number of Infections and Deaths due to Covid-19, Philippines




Sources: DOH, JHU

# New Infections and Active Cases of Covid-19, Philippines




Sources: DOH, JHU and author calculations

# Evolution of business restrictions / containment policies in NCR (figures are in percent as a share of respective industry capacities)

| | 2020 | | | | 2021 | | |
|---|---|---|---|---|---|---|---|
| | ECQ | MECQ | GCQ | GCQ | GCQ | ECQ | MECQ |
| | March | May | June | August | January | April | April |
| Industries | 17 | 31 | 1 | 4 | 1 | 4 | 30 |
| Agriculture, fisheries and forestry | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Mining and quarrying | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Manufacturing | 23.0 | 64.9 | 100.0 | 64.9 | 100.0 | 23.0 | 64.9 |
| Electricity, Gas ... | 30.0 | 100.0 | 100.0 | 100.0 | 100.0 | 50.0 | 100.0 |
| Water supply sewerage ... | 30.0 | 100.0 | 100.0 | 100.0 | 100.0 | 50.0 | 100.0 |
| Construction | 25.0 | 25.0 | 65.0 | 25.0 | 100.0 | 25.0 | 50.0 |
| Wholesale and retail trade ... | 46.1 | 72.0 | 74.3 | 74.3 | 87.8 | 46.1 | 59.3 |
| Transportation and storage | 46.2 | 45.2 | 54.1 | 45.2 | 63.7 | 45.5 | 64.2 |
| Accomodation and food service | 19.7 | 23.4 | 23.4 | 43.2 | 56.6 | 42.2 | 42.2 |
| Information and communication | 22.6 | 84.8 | 84.8 | 84.8 | 100.0 | 22.6 | 84.8 |
| Financial and insurance | 20.7 | 84.8 | 84.8 | 84.8 | 100.0 | 20.9 | 84.8 |
| Real estate | 30.0 | 75.0 | 100.0 | 75.0 | 100.0 | 30.0 | 100.0 |
| Professional, scientific and tech. | 0.1 | 50.1 | 50.1 | 50.1 | 100.0 | 0.1 | 100.0 |
| Administrative and support services | 66.2 | 87.0 | 87.7 | 87.0 | 99.3 | 66.2 | 97.3 |
| Education | 0.0 | 7.9 | 26.0 | 38.1 | 100.0 | 90.0 | 90.0 |
| Human health and social work | 85.7 | 100.0 | 100.0 | 85.7 | 100.0 | 85.7 | 100.0 |
| Arts, entertainment and recreation | 0.0 | 1.3 | 1.3 | 0.0 | 24.1 | 0.0 | 0.0 |
| Other srvice activities | 15.9 | 48.1 | 48.1 | 32.5 | 73.7 | 15.9 | 38.4 |

Source: author's own estimates

- In the absence of a significant share of the "vaccinated" among the susceptible population, severe and painful business restrictions remain, in order to contain infections...

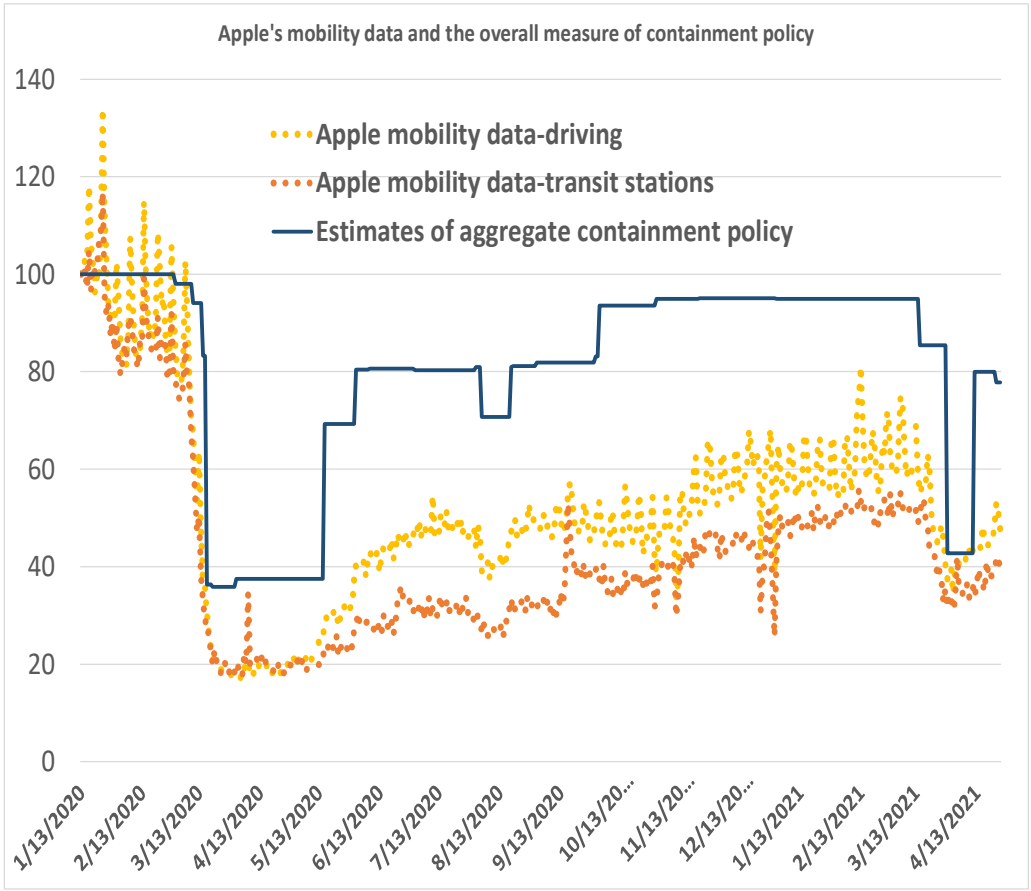
## How do we measure the containment rate "$\mu_t$"?

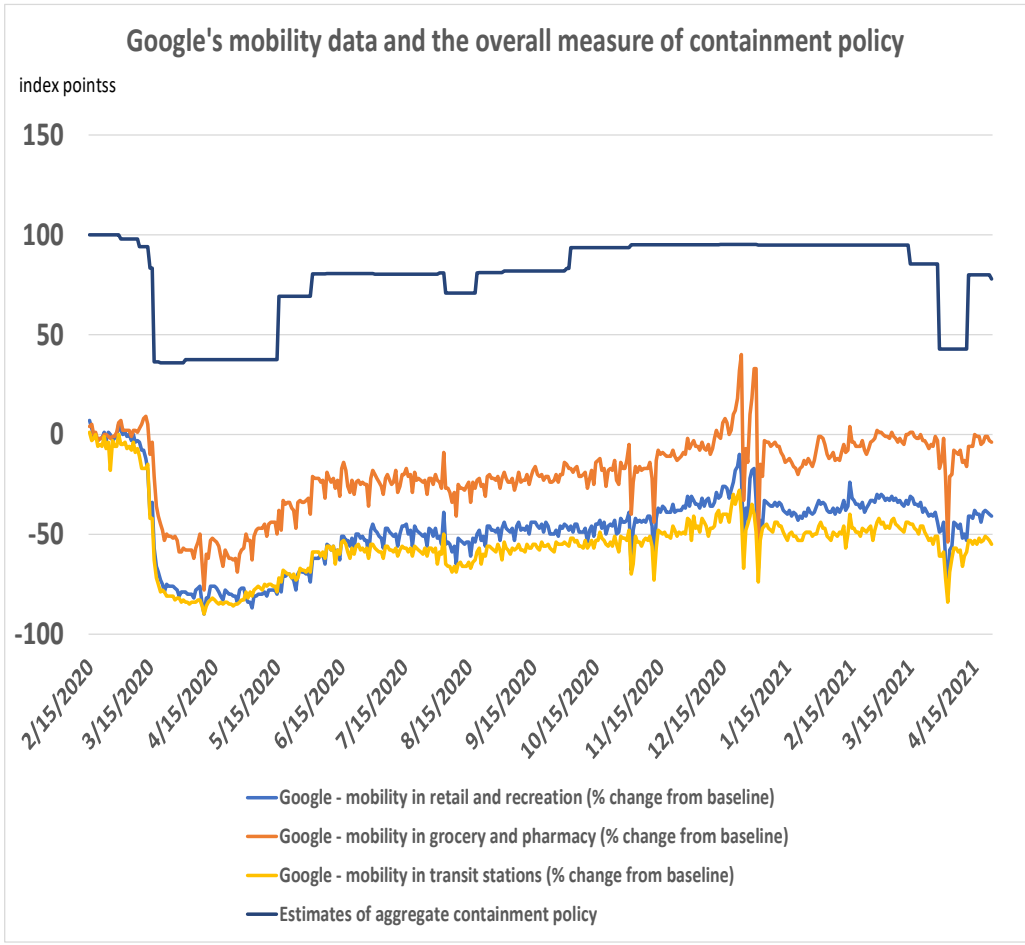
- Measure the containment rate (business restrictions) per industry
  - collect information on the maximum capacity at which businesses can operate
  - daily basis (based on the ECQ/MECQ/GCQ configuration at each time period)
  - about 400+ industry/subindustry categories of businesses
  - NCR restrictions to represent economywide restrictions

- Aggregate "per industry containment rates" into an economywide containment rate "$\mu_t$"
  - industry share in the country's GDP as weights per country

Source: author's own estimates

# Containment policy measure (μ) compares well with mobility data from Google and Apple




Sources: author's own estimates, Google and Apple

The Kermack and McKendrick (1927) S-I-R Pandemic Model in Eichenbaum, Rebelo and Trabandt (2020)

New infections

$$T_t = \pi_1(S_t C_t^s)(I_t C_t^i) + \pi_2(S_t N_t^s)(I_t N_t^i) + \pi_3 S_t I_t \quad (1)$$

Susceptibles

$$S_{t+1} = S_t - T_t \quad (2)$$

Infected

$$I_{t+1} = I_t + T_t - (\pi_r + \pi_d) I_t \quad (3)$$

Recovered

$$R_{t+1} = R_t + \pi_r I_t \quad (4)$$

Deceased

$$D_{t+1} = D_t + pi_d I_t \quad (5)$$

Economic dynamics: budget constraint and utility functions

U(.) of the Susceptibles

$$U_t^s = u(c_t^s, n_t^s) + \beta[1 - \tau_t]U_{t+1}^s + \tau_t U_{t+1}^i \quad (6)$$

U(.) of the Infected

$$U_t^i = u(c_t^i, n_t^i) + \beta[1 - \pi_r - \pi_d]U_{t+1}^i + \pi_r U_{t+1}^r \quad (7)$$

U(.) of the Recovered

$$U_t^r = u(c_t^r, n_t^r) + \beta U_{t+1}^r \quad (8)$$

Individual budget constraint

$$(1 + \mu_t)c_t^j = w_t \phi^j n^j + t + \Gamma_t \quad (9)$$

The Kermack and McKendrick (1927) S-I-R Pandemic Model in Eichenbaum, Rebelo and Trabandt (2020)

Containment rate (restriction to consumption activities): $\mu_t$

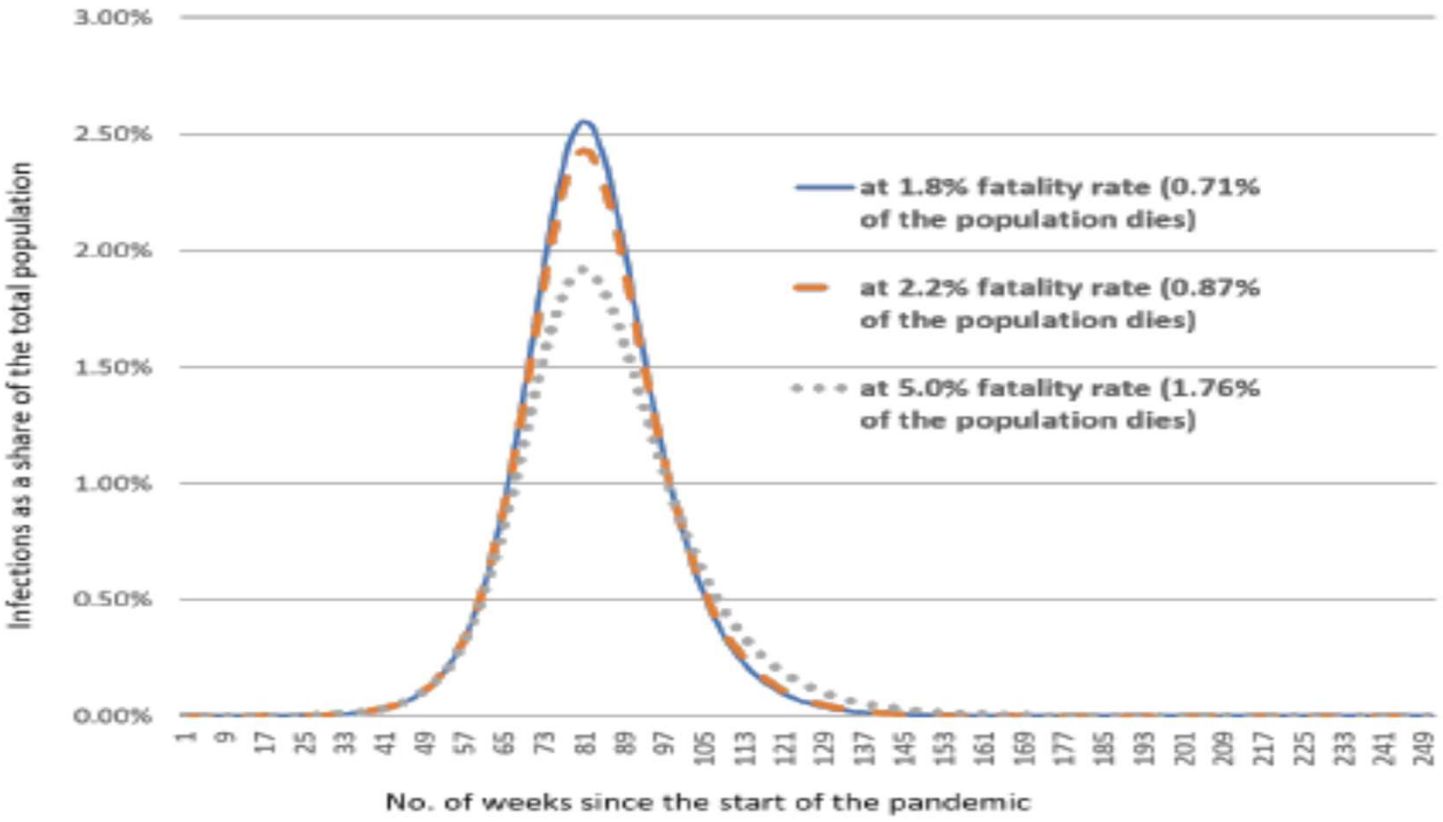
Equilibrium conditions

- each individual solves his/her maximization problem
- government budget is satisfied
- goods and labor markets clear

$$S_t C_t^s + I_t C_t^i + R_t C_t^r = A N_t \tag{10}$$

$$S_t N_t^s + I_t N_t^i \phi^i + R_t N_t^r = N_t \tag{11}$$

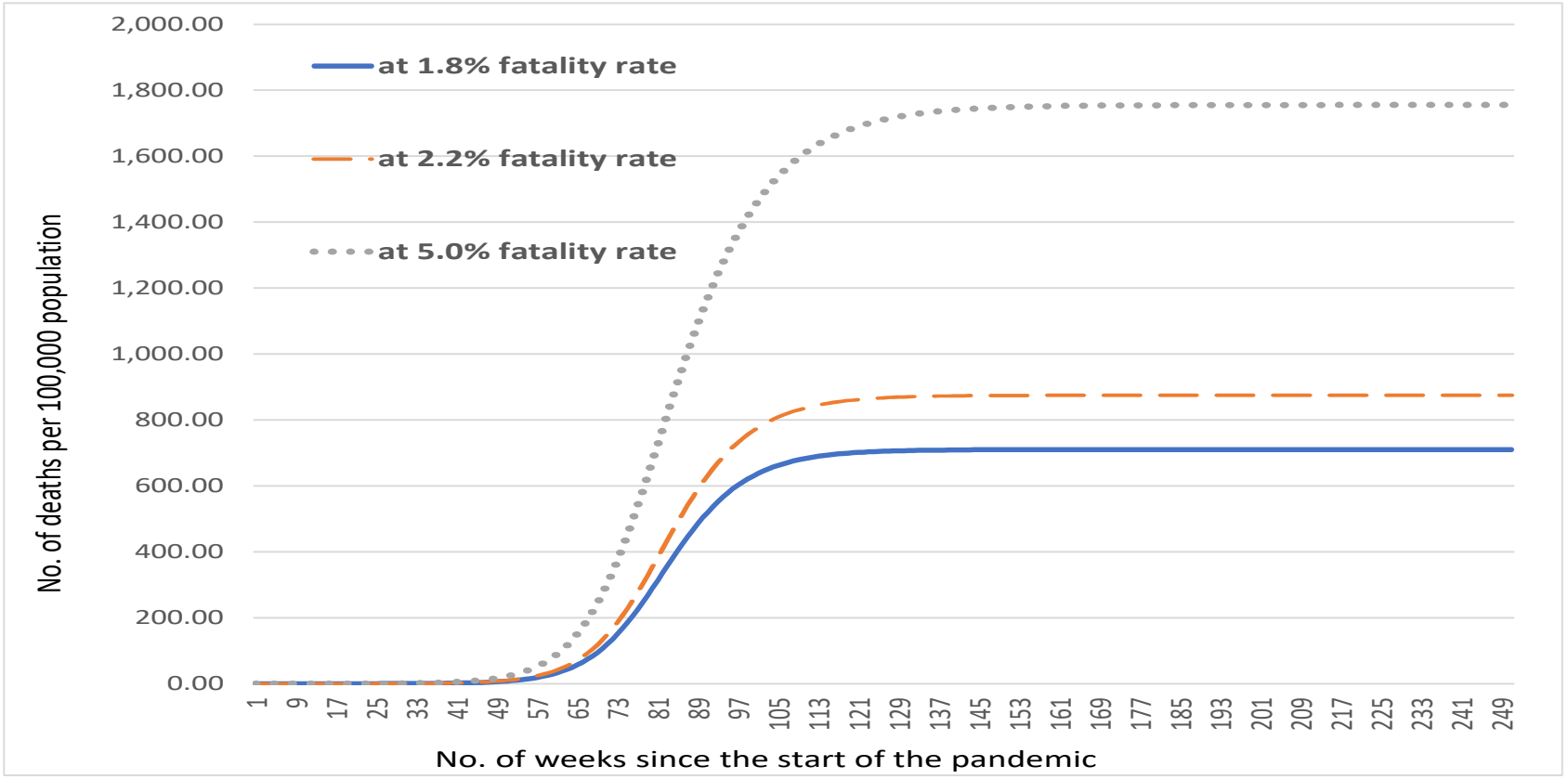
# Preliminary Findings: Simulations on the number of infections without containment, Philippines




- Without continued containment policies and vaccines, deaths and infections would have been much higher.

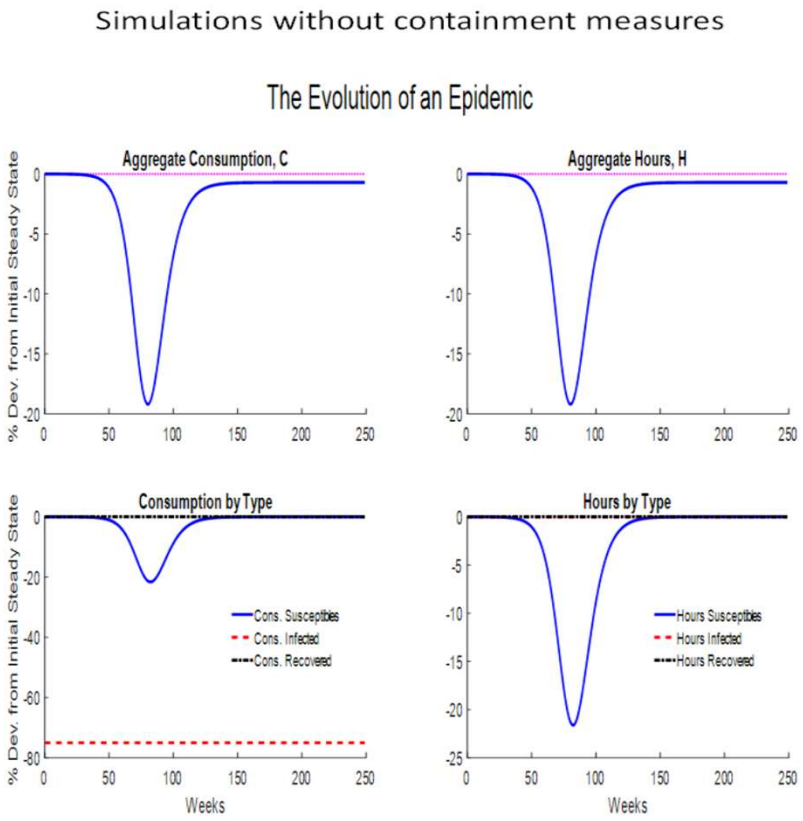
- Infections would have peaked at 2.5 % of the population and

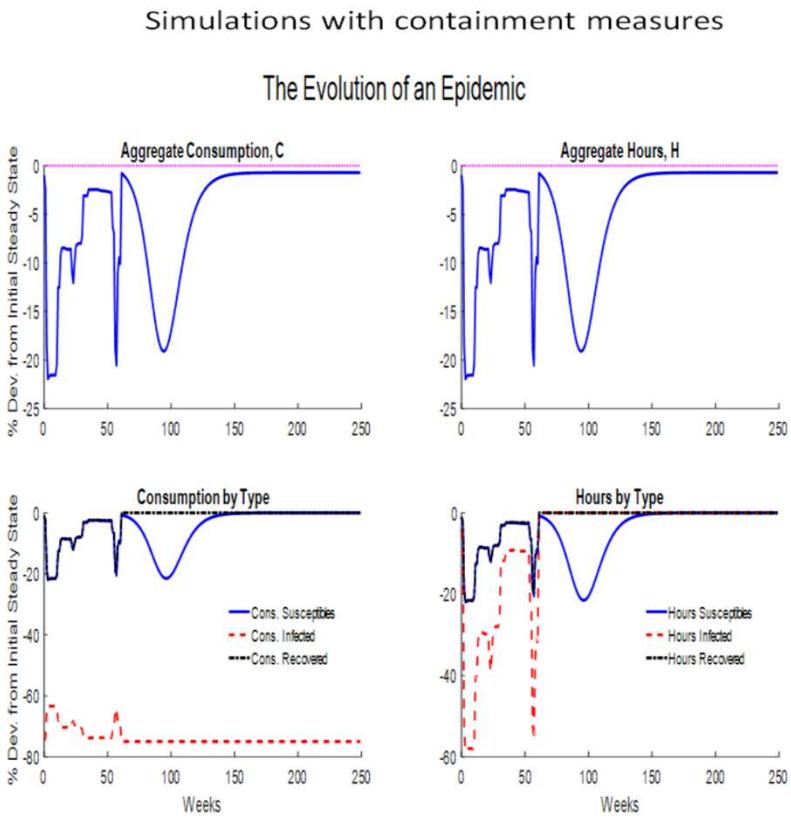
# Preliminary Findings: Simulations on the crude death rates without containment, Philippines




- Deaths would have peaked at 0.7 % of the population (at 1.8 fatality rate)

# Preliminary Findings: Simulation results on consumption and work hours, Philippines




- Without containment policies and vaccines, decline in aggregate consumption could have been less and recession could have been delayed.

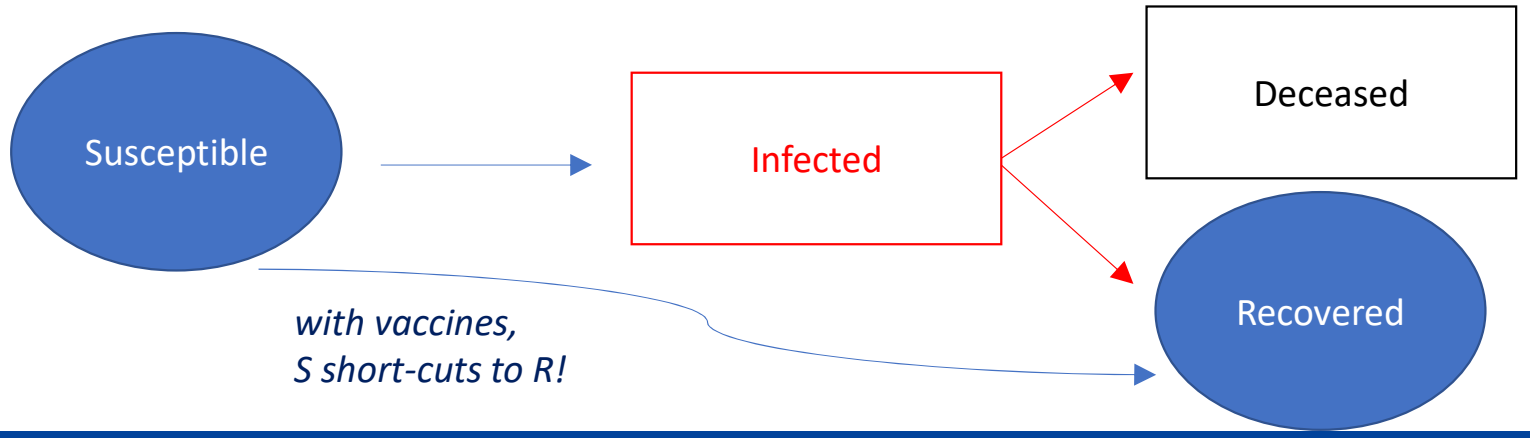
# Vaccines as short-cut to recovery.

**Next period**

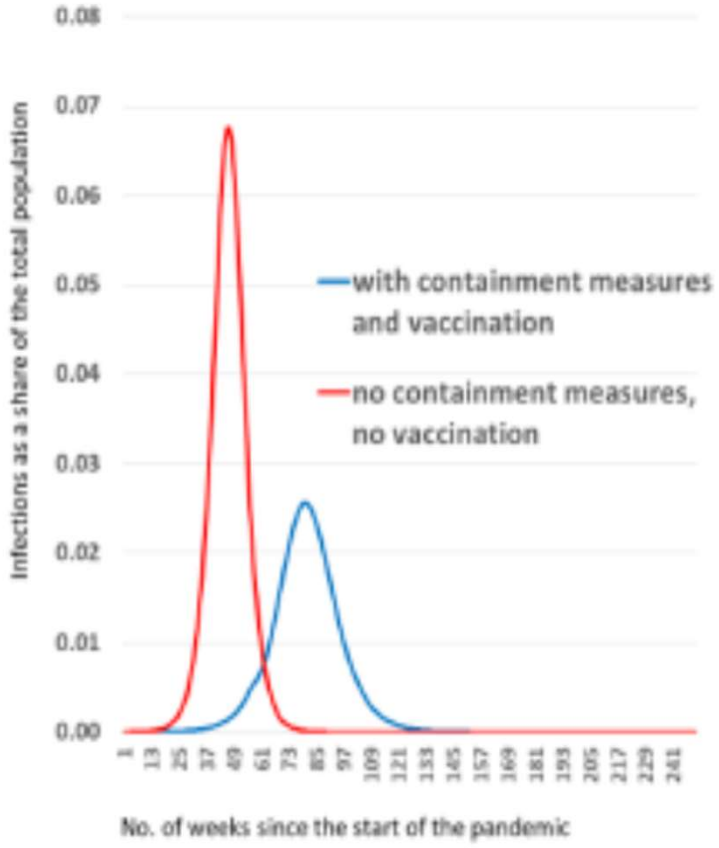
$$U_t^s = u(c_t^s, n_t^s) + (1-\delta_v)\left[(1-\tau_t)\beta U_{t+1}^s + \tau_t \beta U_{t+1}^i\right] + \delta_v \beta U_{t+1}^r.$$

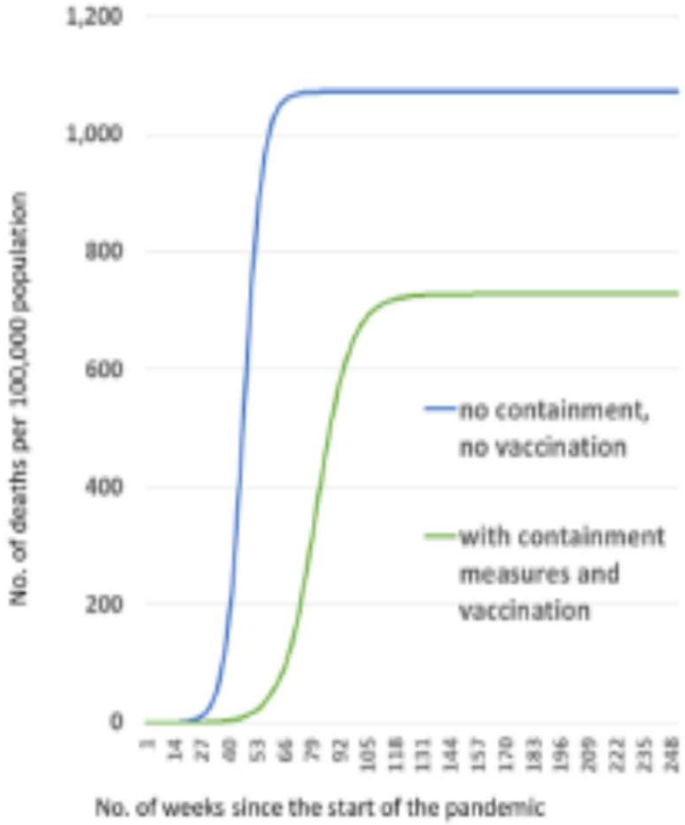
If not vaccinated (remains susceptible or gets infected)

If vaccinated



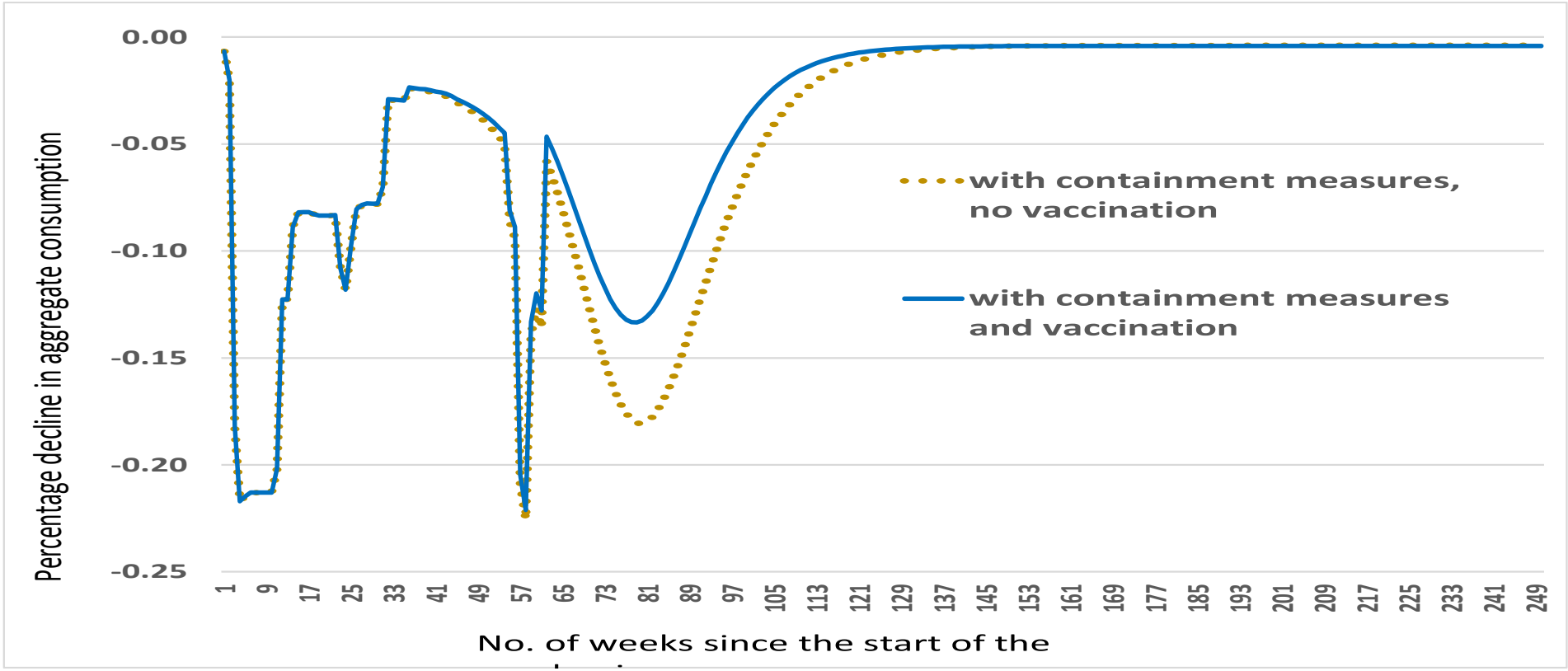
# How would a vaccination program change the dynamics?
# Infections and fatalities with and without a vaccination program




- The reduction in infections and deaths would initially depend on containment policies in the absence of vaccines.
- Containment measures will continue to be the line of defense while the vaccination program has not yet fully materialized

# How would a vaccination program change the dynamics?
# Vaccination program and aggregate consumption



# Takeaways

- There is now sufficient information to make smart containment policies and minimize infections and deaths
  - PH experience is not far from a textbook case of a pandemic cum containment policies.

- Containment policy measures may have significantly affected the aggregate performance of the economy, including aggregate consumption activities and working hours.
  - Counterfactuals, however, show that containment policies may have helped achieve its goals of minimizing infections and fatalities while likewise limiting the impact on the economy, especially in the absence of vaccination during the first few waves of the pandemic.

- What happens beyond 2021? – would depend on the choices made in 2021
  - fast vaccination program
  - counter the current/projected losses in consumption, businesses and employment
  - agents still need to continue learning and internalizing “containment”

Thank you