

# The welfare cost of vaccine misallocation, delays and nationalism

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# Covid research by economists around the world

- Economists use climate modeling for policy recommendations on climate change (carbon pricing).
- Economists use epidemiologic modeling to better understand the economic consequences of the covid-19.
  - Because epidemiologists are not interested in the economic consequences of their policy recommendations, economists are the only one to combine the two dimensions of the crisis: health and wealth.
- Because of the high uncertainty related to many parameters of the model, this work can at best provide orders of magnitudes.
- Race between the virulence of the B117 variant and the speed of vaccination.

- What is the optimal policy to fight covid-19, taking account of lives and incomes lost?
- I use the SIR model used by epidemiologists, in which I add a vaccination process and an economic module.
- Questions:
  - What is the welfare benefit of a covid vaccine?
  - What is the welfare benefit of speeding vaccination?
  - What is the welfare cost of antivax?
  - What is the welfare cost of vaccine nationalism?

# An efficient allocation is crucial

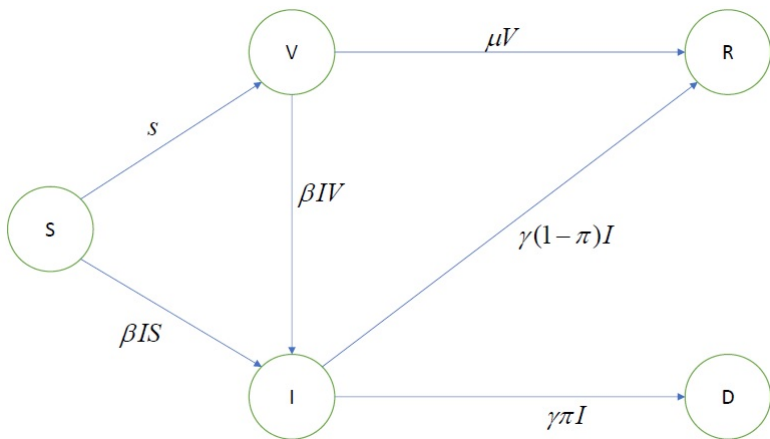
Age Class	Prob[ICU if infected]	Prob[deceased if infected]
0-18	0.01%	0.001%
19-64	0.48%	0.18%
65+	1.75%	4.75%

**Table:** Estimation of the hospitalization rate and of the infection-fatality proportion by age class in France. Source: Saltje et al. (2020) for the ICU rate and Lapidus et al. (2021) for the IFP.

# Description of the model

- Three age classes  $i \in (0-18, 19-64, 65+)$  with  $N_i$  individuals in class  $i$ ;
- Five health states (S, V, I, R, D).
- The SIR model describes the dynamic of the pandemic through social interactions.
- Two age-specific policy instruments: **vaccination** and **Social Distance (SD)**.
- Two evaluation criteria: Death toll per age class, and wealth lost. Valuing lives lost allows for going to a single criterion.
  - The economic loss (quarantine, confinement, cost of vaccine);
  - The value of lives lost.

# Description of the model



# Vaccination campaign

- We assume that at date 0, a flow of vaccines becomes available.
  - Once vaccinated, the person remains susceptible for some time. A fraction  $\mu$  of vaccinated people becomes immunized in each period;
- Efficient sequence of vaccination: (1) senior, (2) middle-aged, and (3) junior.
  - $s_{it}$  denotes the number of individuals of age  $i$  that are vaccinated at date  $t$ .
- We assume an exogenous vaccination capacity  $s$  per day.
- A proportion  $a$  of the population is antivax.

# ICU capacity and covid mortality

- The SD policy is aimed at making sure that the national ICU capacity is never overwhelmed.
- At the end of the infection period, a fraction  $h_i$  of infected people needs an ICU for a duration of  $T_{ICU}$ .

$$newICU_{i,t} = h_i \gamma_i I_{i,t}$$

- The number of people in ICU at date  $t$  is denoted  $ICU_t$ .

$$ICU_{i,t} = \sum_{\tau=1}^{T_{ICU}} newICU_{i,\tau}$$

- The national ICU capacity is denoted  $\overline{ICU}$ .



# MR-SIR model with vaccination

$$S_{i,t+1} - S_{i,t} = - \left( \sum_{j=1}^J \beta_{ijt} I_{j,t} \right) S_{i,t} - s_{it}$$

$$V_{i,t+1} - V_{i,t} = s_{it} - \left( \sum_{j=1}^J \beta_{ijt} I_{j,t} \right) V_{i,t} - \mu V_{it}$$

$$I_{i,t+1} - I_{i,t} = \left( \sum_{j=1}^J \beta_{ijt} I_{j,t} \right) (S_{i,t} + V_{i,t}) - \gamma_i I_{i,t}$$

$$R_{i,t+1} - R_{i,t} = \gamma_i (1 - \pi_i) I_{i,t} + \mu V_{i,t}$$

$$D_{i,t+1} - D_{i,t} = \gamma_i \pi_i I_{i,t}$$

$$\beta_{ijt} = \alpha_{ij} \left( \beta_q(1 - \kappa) + (\underline{\beta}b_{jt} + \overline{\beta}(1 - b_{jt}))\kappa \right) (1 - b_{it})$$

- $\alpha_{ij}$  measures the BAU intensity of social interactions between age classes  $i$  and  $j$ .
- The relative contagion of an infected person depends upon whether he is quarantined, confined, or free, with  $\beta_q < \underline{\beta} < \overline{\beta}$ .
- Rate of asymptomatic if infected:  $\kappa$ .
- Among infected persons of age class  $j$ , a fraction
  - $1 - \kappa$  is symptomatic quarantined ( $\beta = \beta_q$ );
  - $\kappa b_{jt}$  is confined ( $\beta = \underline{\beta}$ );
  - $\kappa(1 - b_{jt})$  is freed ( $\beta = \overline{\beta}$ ).

- Telework for fraction  $\xi_j$  of confined people.
- Cost of lockdown/quarantine per unit of time:  $w_j$ .
- Value of a life lost:  $\ell_j$ .
- Unit cost of vaccines:  $p$ .
- I assume the prohibition of the "immunity passport".
- End date  $T$ : When total infection  $I_t$  is smaller than  $I_{min}$ .
- Economic loss incurred by age class  $j$ :

$$W_j = p v_{jT} + w_j \sum_{t=0}^T \left( (1 - \xi_j) b_{jt} (S_{j,t} + \kappa I_{j,t} + (1 - \omega) R_{j,t}) + (1 - \kappa) I_{j,t} + D_{j,t} \right)$$

- Total welfare cost:

$$L = \sum_{j \in \{y, m, s\}} \left( \ell_j D_{j,T} + W_j \right).$$

# Health policy: Stop-and-go

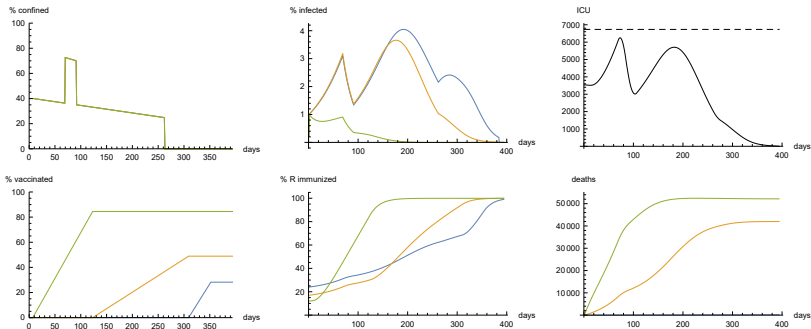
- I take the speed  $s$  of vaccination as given.
- The SD policy is assumed to be non-discriminatory ( $b_{it} = b_t \forall i$ ).
- I consider the typical stop-and-go strategy to "flatten the curve" and to protect the ICU capacity, as it has been widely used since the beginning of the pandemic.
  - Three possible intensities of confinement:  $b_l < b_m < b_h$ .
  - Three ICU thresholds:  $r_l < r_m < r_h$ .
- The effective  $b$  is linearly decreasing with the fraction of vaccinated people:  $b \rightarrow b(1 - v_t)$ .

	$l$	$m$	$h$
$b$	0%	40%	80%
$r$	30%	60%	90%

# Calibration of the model (France, Pop=67 millions)

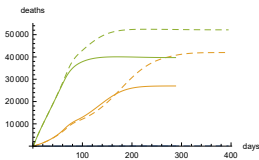
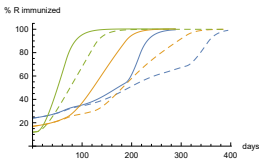
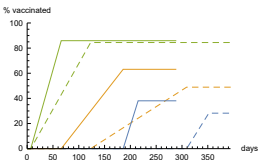
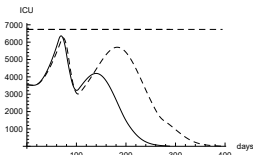
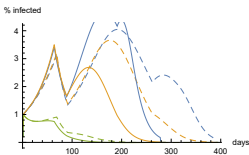
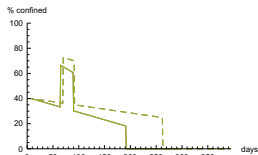
	Value	Description
$\gamma$	1/18	Daily recovery rate
$\mu$	1/20	Daily immunization rate among newly vaccinated
$\beta_q$	0	Daily contagion rate of quarantined persons
$\underline{\beta}$	0.15	Daily contagion rate of confined persons
$\overline{\beta}$	0.9	Daily contagion rate of working persons
$\kappa$	35	Proportion of asymptomatic positives (in %)
$\omega$	0	Proportion of immunized people with an immunity passport
$\xi$	0.5	Proportion of telework
$I_{min}$	30000	Extinction threshold of the pandemic
$\overline{ICU}$	6733	ICU capacity
$(b^l, b^m, b^h)$	(0,40,80)	Intensities of lockdown (in%)
$(r_l, r_m, r_h)/\overline{ICU}$	(30,60,90)	Policy limits in ICU capacity (in%)
$N$	(22.7, 56.8, 20.5)	Age-distribution of population (in %)
$\pi$	(0.002, 0.30, 7.79)	Infection-fatality proportion (in %)
$h$	(0.01, 0.48, 1.75)	Prob. of ICU if infected (in %)
$R_0/N$	(24,17,12)	Fraction of initially immunized people (in %)
$\alpha_1.$	(2, 0.5, 0.25)	Intensity of transmission from young
$\alpha_2.$	(0.5, 1, 0.25)	Intensity of transmission from adult
$\alpha_3.$	(0.25, 0.25, 0.5)	Intensity of transmission from senior
$T_{ICU}$	15	Days in ICU
$w$	(0, 176, 0)	Economic loss of confinement (in % of GDP/cap)
$\ell$	(100,100,100)	Value of life lost (in years of GDP/cap)
$p$	0.1	Cost of vaccine for the entire population (in % of GDP)

# Benchmark: Vaccinating 100.000 persons/day



vaccine speed	lives lost			loss	
	19-64	65+	total	wealth %GDP	total %GDP
$10^6/day$					
0.10	41641	50026	91817	13.82	27.53

# Speeding the campaign: Vaccinating 200,000 persons/day



vaccine speed	lives lost			loss	
	19-64	65+	total	wealth %GDP	total %GDP
$10^6/day$					
0.20	26159	37166	63450	9.31	18.78

# Results for various vaccination speeds

vaccine speed	lives lost			loss	
	19-64	65+	total	wealth	total
$10^6/day$				%GDP	%GDP
0.00	72705	396464	469351	34.71	104.80
0.05	55387	78780	134337	18.45	38.50
0.10	41641	50026	91817	13.82	27.53
0.15	32857	41609	74605	11.13	22.26
0.20	26159	37166	63450	9.31	18.78
0.25	22642	32883	55638	8.04	16.34
0.50	16245	29151	45470	5.06	11.84

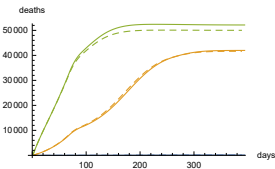
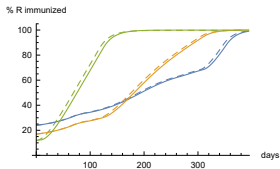
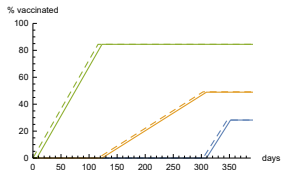
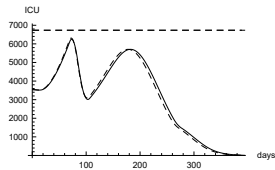
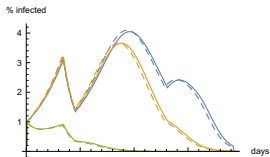
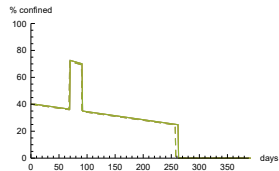


# Net benefits of speeding vaccination

- Large benefit of a vaccination even at the low speed of 100k doses/day:
  - Lives saved: 375k, or 80% of the death toll without a vaccine.
  - Reduction in economic loss: more than 20% of annual GDP (to be compared to the cost of vaccination: 0.1%).
- Marginal benefit of vaccination speed is rapidly decreasing.
  - This is due to large differences in ICU and mortality rates across ages.
  - Good news for countries with a less intense vaccination campaign.
- Most of the benefit comes from the senior lives saved.

- Without a vaccine, the situation would be catastrophic.
- I explained in JPET-2020 that a weak uniform lockdown is far from efficient.
  - One should consider the zero-covid policy. But can we eradicate the virus at the end of the intense lockdown?
  - Differentiating the intensity of the lockdown on the basis of a vulnerability index would divide the number of deaths and economic loss by 2.
- Discriminating the allocation of the vaccine is acceptable, but discriminating the intensity of the lockdown is not.

# One week delay of the vaccination (100,000 doses/day)



## Welfare loss of a one week delay of the vaccination (100,000 doses/day)

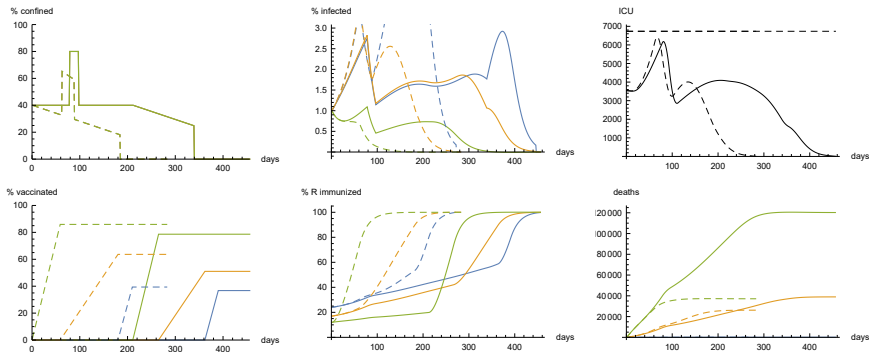
	lives lost			loss	
	19-64	65+	total	wealth	total
0 day	41641	50026	91817	13.82	27.53
7 days	41980	52168	94298	14.16	28.23

- A one-week delay to launch the campaign increases the death toll by 2,481.
- It reduces GDP by 0.34%.

# Welfare loss of vaccine nationalism: Model

- Consider two countries, each in the same initial condition of France at the beginning of its vaccination campaign.
- The vaccine production capacity of the pair equals 200,000 doses per day.
- I compare two vaccination strategies:
  - Efficient: Each country receives 100,000 doses/day;
  - Nationalist: The producing country receives 200,000 doses/day until its whole population is vaccinated, and then exports 200,000 doses/day to the importing country.
- It takes 211 days to fully vaccinate the producing country.

# Welfare loss of vaccine nationalism: Dynamics



**Figure:** Dynamics of the pandemic in the thought experiment of vaccine nationalism. The importing country (plain curves) starts its vaccination campaign on day 211 after the producing country (dashed curve) has fully vaccinated its population.

# Welfare loss of vaccine nationalism: Results

	lives lost			loss	
	19-64	65+	total	wealth	total
Efficient					
Mean	41641	50026	91817	13.82	27.53
Nationalism					
Mean	32560	78708	111398	14.42	31.04
Producer	26159	37166	63450	9.31	18.78
Importer	38969	120250	159347	19.53	43.31

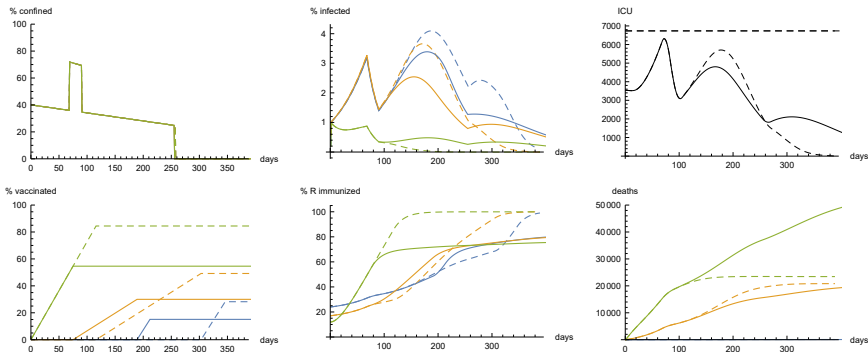
- Vaccinating the juniors in the producing country before vaccinating the seniors in the importing country is inefficient.
- The vaccine nationalism is responsible for 39k additional deaths. This is a 20% increase in the global death toll.
- The mean GDP loss is increased by 0.60%.
- Global welfare of the pandemic is made 13% worse by the vaccine nationalism.
- The large differentials in impacts make the first-bet solution an illusion.



# Welfare loss of antivax: Model

- Suppose that 30% of the population refuse to be vaccinated.
- I compare two vaccination strategies, based on the benchmark calibration of 100,000 doses/day:
  - Efficient: 100% of the population get the vaccine, starting with the seniors;
  - Antivax: 70% of the population get the vaccine, starting with the seniors.

# Welfare loss of antivax: Dynamics and results



- Externality of anti-vaxxers on pro-vaxxers:
  - 5,100 more deaths among old pro-vaxxers;
  - 4,700 less deaths among middle-aged pro-vaxxers.
- Externality of pro-vaxxers on anti-vaxxers:
  - 60,000 less deaths among anti-vaxxers.
- No sizeable economic effect.

## Concluding remarks

- The emergence of the B117 variant raises a new challenge.
- The marginal social benefit of the speed of vaccination is strongly decreasing in this speed.
- Basic results:
  - A one-week delay in the vaccination campaign increases the death toll by 2,500 and destroys 8bn euros of wealth.
  - Vaccine nationalism increases the global death toll by 20% in 2021.
- The presence of 30% antivax in the French population
  - increases the death toll by 60k;
  - has a negative externality on senior pro-vaxxers, and a positive externality on middle-aged pro-vaxxers. Net neutral.