Laissez-faire, Social Networks, and Race in a Pandemic

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Since the outbreak of the COVID-19 pandemic, mobility restricting policies have led to the cumulative lockdown of over half of the world's population. While this approach for mitigating the contagion has shown some positive results, the associated economic costs have been considerable. In the United States, the Bureau of Labor Statistics reported on May 8, 2020 that total non-farm payroll employment fell by 20.5 million in April 2020, and the unemployment rate rose. The high economic costs of lockdown measures forced state governments to consider easing quarantine measures, which was achieved at the expense of public health. The tendency to trade off population health for economic gains during the COVID-19 pandemic has been documented (see, e.g., Boucekkine et al. (2021), Cutler and Summers (2020), and Pongou, Tchuente and Tondji (2021)), but the distributional effects of tradeoff policies are understudied. Understanding these issues is vital to shedding light on how the welfare impacts of COVID-19 policies differ across racial subgroups within the United States.

We address these issues using a model that solves the problem of finding the optimal lockdown policy for a pandemic that spreads through networks of physical contacts. Using information on the COVID-19 pandemic and unique data on the social networks of nursing and long-term care homes in the United States (Chen, Chevalier and Long, 2021), Pongou, Tchuente and Tondji (2021) calibrate this model to estimate optimal tradeoffs between population health and short-term economic gains for 26 U.S. states. We exploit data on these estimated tradeoffs to analyze how laissez-faire policies–a preference for economic gains over population health–affect COVID-19 deaths in nursing homes, and how these effects vary by the racial composition and the network centrality of nursing homes. In line with Pongou and Serrano (2013), Debnam Guzman, Mabeu and Pongou (2021), Chang et al. (2021), and Fajgelbaum et al. (2021), we contribute to the growing literature investigating the importance of network structure in the distributional effects of virus spread.

I. Theory: Optimal Control Problem

Our framework follows the N-SIRD model introduced by Pongou, Tchuente and Tondji (2021) and includes both an individual-network-based probabilistic epidemiological model and a simple production environment. A community containing N individuals faces a virus that spreads through human contacts. At any continuous time t, individuals are subdivided into four health compartments: susceptible $S(t)$, infected $I(t)$, recovered $R(t)$, and deceased $D(t)$, so that $S(t)+I(t)+R(t)+D(t)=N$. For simplicity, we drop the time variable. At any time t, each individual i is in one of the following compartments S, I, R, and D, with respective probabilities s_i, x_i, r_i, and d_i, where $s_i+x_i+r_i+d_i=1$. A susceptible individual may become infected by coming into contact with an infected individual. We assume that physical contacts take place through an undirected weighted network, A, formalized by a symmetric adjacency matrix $(A_{i,j})$, where $A_{ij}=A_{ji}\in[0,\infty)$ is the connection intensity between individuals i and j, with $A_{ij}=0$ if $i=j$. Individuals move from susceptible to infected, and from infected to

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either recovered or deceased.

In order to contain the pandemic, a social planner enforces a lockdown policy that modifies the structure of the existing social network, A. Let L denote the lockdown compartment, and $l_i = P(i \in L)$ the probability that an individual i is sent into lockdown; $l_i = 1$ designates complete lockdown and $l_i = 0$ means no lockdown. Being in a complete lockdown disconnects an agent from all their neighbors, so that a susceptible agent will remain susceptible during the lockdown period. The infinitesimal change in the infection probability of agent i is $\dot{x_i} = \beta s_i(1 - l_i)\sum_{j \in N} A_{ij}(1-l_j)x_j - (\gamma+\kappa)x_i$, where β is the contact rate, γ is the recovery rate, and κ is the death rate. We denote i's health characteristics by $X_i = (x_i, s_i, r_i, d_i)^T$, where T is for the transpose. The laws of motion of agent i's recovery and death probabilities are $\dot{r_i} = \gamma x_i$ and $\dot{d_i} = \kappa x_i$, respectively. Since $s_i + x_i + r_i + d_i = 1$, the infinitesimal change in i's probability of being susceptible is: $\dot{s_i} = -\beta s_i(1-l_i)\sum_{j \in N}[A_{ij}(1-l_j)x_j]$. For each $i \in N$, the profile $\dot{X_i} = (\dot{x_i}, \dot{s_i}, \dot{r_i}, \dot{d_i})^T$ determines a nonlinear system of ordinary differential equations (ODE), and the combined ODEs of all individuals describe the disease dynamics. We assume that the initial value point $X_i(0)$ is such that $x_i(0) \geq 0$, $s_i(0) \geq 0$, $r_i(0) \geq 0$, $d_i(0) \geq 0$, and $x_i(0) + s_i(0) + r_i(0) + d_i(0) = 1$.

As in most SIR models, we assume that individuals in compartments S, I, and R are the only potential workers in the economy. At any given period t, each individual i possesses a capital level $k_i(t) = k_i$, and a labor supply $h_i = h_i(s_i, x_i, r_i, d_i, l_i)$ that depends on i's characteristics and the probability of being in lockdown; h_i is assumed to be continuous and differentiable in each of its input variables. Additionally, we assume that h_i is non-decreasing in the probabilities of being susceptible and recovered, and is non-increasing in the probabilities of being infected and deceased and in lockdown strictness. Capital combines with labor to generate output, y_i, based on a production function $y_i = y_i(k_i, h_i) = y_i(k_i, s_i, x_i, r_i, d_i, l_i)$, assumed to be continuous and differentiable and satisfying other standard assumptions. It follows that agent i's surplus function is $W_i = p_i y_i - w_i h_i$, where w_i represents the cost of one unit of labor, and p_i the unit price of output.

Lockdowns mitigate virus spread, but they also reduce economic activity, creating significant economic and social costs. Facing this tradeoff, the planner's goal is to choose a lockdown policy that will keep virus spread under a certain level at a minimum economic cost. We capture the planner's tradeoff by a tolerable infection incidence (defined as the relative number of new infections), $\lambda \in [0, 1]$. A wealth-leaning planner will choose a high value of λ, whereas a health-leaning planner will choose a low value of λ. The planner achieves their goal in two ordered steps. The first step consists of determining the set of lockdown policies, $l = (l_i)_{i \in N}$, that keep the virus incidence below λ: $\dot{x_i} \equiv \dot{x_i}(l) \leq \lambda$, for each $i \in N$. The second step consists of choosing among these contagion-minimizing policies the one which maximizes the discounted stream of economic surpluses; that is, the planner chooses the optimal admissible lockdown path, $l_i^*(t)$ for each agent $i \in N$, which along with the associated optimal admissible state path $X_i^*(t)$ in the ODE system, maximizes the present discounted value of aggregate surplus, $W(k, s, x, r, d, l) := \int_0^\infty e^{-\delta t}\left\{\sum_{i \in N} W_i(k_i, s_i, x_i, r_i, d_i, l_i)\right\} dt$, where δ is the planner's discount rate. Using optimal control theory, we can formalize the social planner's problem as: Maximize $W(k, s, x, r, d, l)$ such that for each $i \in N$, $X_i = (x_i, s_i, r_i, d_i)^T$ satisfies the ODE system, $\dot{x_i} \equiv \dot{x_i}(l) \leq \lambda$, and $l_i(t) \in [0, 1]$, for all t. Pongou, Tchuente and Tondji (2021) show that the planner's problem admits a unique optimal path $\{l^*(t)\}$ of the control variable and the states $\{x^*(t), r^*(t), d^*(t), s^*(t)\}$, given the initial conditions X_0 and the laws of motion of infection, susceptibility, recovery, and death.

II. Data and Calibration

Pongou, Tchuente and Tondji (2021) calibrate the model presented in Section I to estimate λ for 26 U.S. states using data on the epidemiological and economic variables and parameters of interest in the model from several sources. Data on the economic variables come from the Bureau of Labor Statistics and the Senior Living project.[1] Information on the epidemiological variables is obtained from Statista.[2]

To build the U.S. nursing home networks, we use data collected by the "Protect Nursing Homes" project on device-level geolocation information for smartphones present in at least one nursing home in the 11-week period following the nationwide restriction on nursing home visits on March 13, 2020. The intensity of connection between two nursing homes depends on the number of smartphones observed in both homes. To measure the centrality of a nursing home in the network, we use the *eigenvector centrality*, denoted ν_i; it measures the extent to which a nursing home i is connected to other highly connected nursing homes in a network A: $\nu_i = \frac{1}{e}\sum_{j=1}^{n} A_{ij}\nu_j$. To illustrate how network metrics vary across nursing homes, in Figure 1, we present network graphs for a subset of nursing homes in two U.S. states.

For our empirical analysis, we combine information on the estimated values of λ for the 26 U.S. states covered in Pongou, Tchuente and Tondji (2021) with data from the "Protect Nursing Homes" project in Chen, Chevalier and Long (2021). The descriptive statistics in Table 1 show that in an average nursing home, around 14% of residents are black. A majority of nursing homes work for a profit (73%). An average nursing home has a rating of 3.24 out of 5.

III. Laissez-faire, Race, and Death in Nursing Homes

We estimate the effect of laissez-faire policies on COVID-19 deaths in nursing homes and how this effect varies by the racial composition and the network centrality of nursing homes using the following equation:

$$\begin{aligned} covid\_death_{ijs} &= a_0\lambda_s + a_1 share\_black_{ijs} \\ &+ a_2 Eig\_Cent_{ijs} \times share\_black_{ijs} \\ &+ a_3\lambda_s \times Eig\_Cent_{ijs} \times share\_black_{ijs} \\ &+ a_4 Eig\_Cent_{ijs} + b_0 County\_ses_{js} \\ &+ b_1 D\_Profit_{ijs} + b_2\lambda_s \times Eig\_Cent_{ijs} \\ &+ b_3\lambda_s \times D\_Profit_{ijs} + b_4\lambda_s \times County\_ses_{js} \\ &+ X_{ijs}c + \theta_j + \varepsilon_{ijs}, \end{aligned}$$

where $covid\_death_{ijs}$ is a variable counting the total number of COVID-19 deaths in nursing home i located in county j and state s; $share\_black_{ijs}$ is the share of black residents in nursing home i; λ_s is tolerance to the virus in state s; Eig_Cent_{ijs} is the eigenvector centrality for nursing home i; $County\_ses_{js}$ is county j's average socioeconomic status; D_Profit_{ijs} is an indicator for whether a nursing home i is for profit or not; X_{ijs} represents other exogenous characteristics of the nursing home including the constant; and θ_j is the county fixed effect. The parameters of interest are a_0, a_1, a_2, a_3, and a_4. In particular, a_1, a_2, and a_3 estimate the effect of race and how it interacts with policy response and network centrality to affect COVID-19 death in nursing homes.

We report our main results in Table 2. In Column 1, we control for λ and the network centrality of a nursing home.[3] The coefficient on λ (the tolerable COVID-19 infection incidence) implies that increasing λ by 7.7 standard deviations increases the number of deaths in a not-for-profit nursing home by over 1.3 in low SES counties. We also find that nursing homes that occupy more central positions in networks experience more deaths. In Column 2, we control for the share of black seniors in a nursing home, finding a positive and statistically significant effect; a ten percentage point increase in the share of black residents in a nursing home is associated with an increase in the number of deaths of around 0.27. In Column 3, we control for the interaction term between λ and the share of black residents in a nursing home, finding a strong negative effect.

[1]Information from the Senior Living project was obtained on September 9, 2021 at https://www.seniorliving.org/nursing-homes/costs/.

[2]Statistica provides information on the reproduction number of COVID-19, and the rate of COVID-19 infection and death among nursing home residents in each U.S. state as of September 2020.

[3]In all columns of Table 2, additional controls, listed under the table, are included.

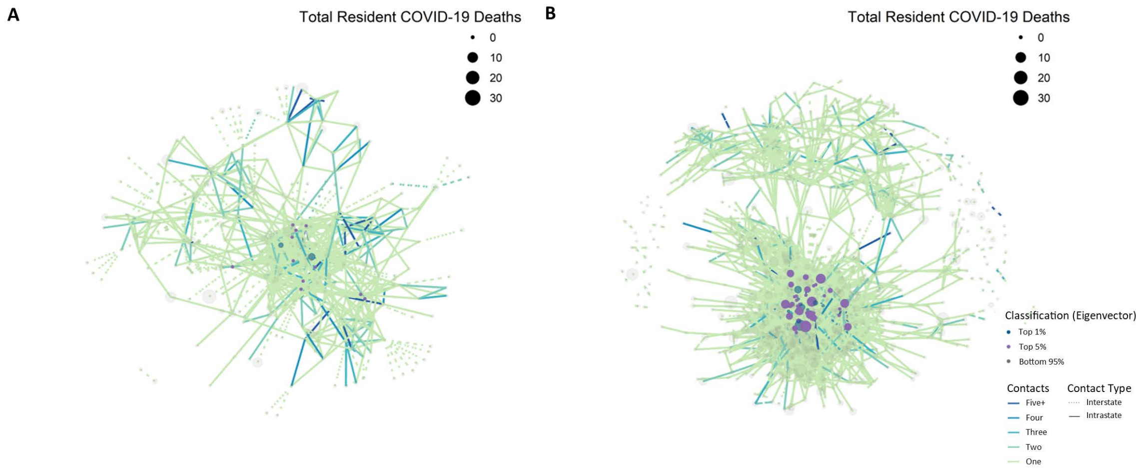

Figure 1. Network structure of two selected U.S. state nursing home facilities

Note: A: Alabama; B: California. In each network graph, node size varies with the number of COVID-19 deaths among residents reported to the U.S. Centers for Medicare & Medicaid Services as of May 31, 2020; edge colour differs with the number of contacts between nursing homes; a solid (resp. dotted) edge line corresponds to a connection between two nursing homes within the same U.S. state (resp. in two different states); and node colour differences are based on eigenvector ranking, with the dark blue colour, for example, highlighting the top 1% of facilities with high eigenvector centrality in the network.

Table 1—Descriptive Statistics of U.S. Nursing Homes.

Variable	Mean (standard deviation)
COVID-19 deaths	1.32 (4.60)
State's tolerance to the virus (λ)	0.12 (0.13)
Eigenvector centrality	.08 (0.18)
Share of Black	0.14 (0.20)
For profit	0.73
Overall rating (1-5)	3.24 (1.40)
County SES	355.70 (256.33)
Number of nursing homes	6,985

This finding implies that, although nursing homes with higher shares of black residents experience more deaths, such nursing homes are less negatively affected by laissez-faire policies.[4] We also control for an interaction term between centrality and the percentage of black residents in a nursing home, finding a negative effect. This means that, although network centrality increases mortality, its effect is lower for nursing homes with higher shares of black residents. Finally, in Column 4, we add a triple interaction term between λ, centrality, and the share of black residents in a nursing home, finding a positive effect, but statistically insignificant. This finding implies that laissez faire policies are more damaging to nursing homes that have a higher share of black residents and that occupy more central positions in the networks.

[4] Regression results splitting the sample between for-profit and not-for-profit nursing homes show that the reduced effect of laissez-faire policies on nursing homes with higher shares of black residents is driven by not-for-profit nursing homes.

IV. Conclusion

Our analysis highlights significant interactions between race, COVID-19 policies, and social network structure among U.S. seniors. Using a calibrated model of optimal lockdown policy which allows to estimate, for 26 U.S. states, tradeoffs between population health and short-term economic gains during the early COVID-19 pandemic, we find that laissez-faire policies significantly increase deaths in nursing homes. The harm-

TABLE 2—EFFECTS OF INFECTION TOLERANCE, EIGENVALUE CENTRALITY AND RACE ON COVID-19 DEATH IN NURSING HOMES.

	(1)	(2)	(3)	(4)
λ	1.307*	2.072**	2.249**	2.298**
	(1.78)	(2.18)	(2.39)	(2.45)
Eig_Cent	1.031***	0.993**	1.837***	1.911***
	(3.37)	(2.32)	(3.26)	(3.18)
Share of black		2.692***	3.908***	3.970***
		(4.73)	(4.67)	(4.49)
Eig_Cent × Share of black			-3.574**	-4.035
			(-2.06)	(-1.64)
λ× Eig_Cent			-1.961	-2.537
			(-0.90)	(-1.03)
λ× Share of black			-5.330**	-5.744**
			(-2.20)	(-2.08)
λ× Share of black × Eig_Cent				2.873
				(0.39)
Controls	Yes	Yes	Yes	Yes
Observations	6478	3549	3549	3549
R^2	0.073	0.105	0.106	0.106

Note: Controls are the overall rating of a nursing home, county SES, a dummy for whether a nursing home is for profit, λ interacted with county SES, λ interacted with a dummy for whether a nursing home is for profit, and the county fixed effect. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors are robust to heteroscedasticity of unknown form; t statistics in parentheses..

ful effect of laissez-faire policies is lower in nursing homes with a higher share of black residents. Interestingly, this finding implies that the health benefits of restrictive lockdown measures are smaller for nursing homes with higher shares of black residents. Finally, we find that laissez-faire policies tend to be more harmful to nursing homes with both central network positions and a high share of black residents.

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