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Daniel J. Hemel

Anup Malani

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# Immunity Passports and Moral Hazard

Daniel Hemel\* and Anup Malani\*\*

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## ABSTRACT

The idea of using “immunity passports” to restart the economy before the arrival of a SARS-CoV-2 vaccine has attracted increasing attention as the Covid-19 crisis has escalated. Under an “immunity passport” regime, individuals who test positive for SARS-CoV-2 antibodies would receive certificates allowing them to return to work and potentially to participate in a broader range of activities without social distancing. One concern raised by the “immunity passport” proposal is that not-yet-infected individuals would have an incentive to expose themselves to the virus intentionally so that they can develop antibodies and obtain passports. This paper evaluates the moral-hazard risk that an immunity passport regime would generate. We develop a rudimentary rational-actor model of self-infection decisions under an immunity passport regime and then parameterize the model using early data on SARS-CoV-2 infection outcomes. Our topline result is that strategic self-infection would be privately rational for younger adults under a wide range of plausible parameters. This result raises two significant concerns. First, in the process of infecting themselves, younger adults may expose others—including older and/or immunocompromised individuals—to SARS-CoV-2, generating significant negative externalities. Second, even if younger adults can self-infect without exposing others to risk, large numbers of self-infections over a short timeframe after introduction of the immunity passport regime may impose significant congestion externalities on health care infrastructure. We then evaluate several interventions that could mitigate moral hazard under an immunity passport regime, including the extension of unemployment benefits, staggered implementation of passports, and controlled exposure of individuals who seek to self-infect. Our results underscore the importance of careful planning around moral hazard as part of any widescale immunity passport regime.

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\* Assistant Professor and Ronald H. Coase Research Scholar, University of Chicago Law School; [dhemel@uchicago.edu](mailto:dhemel@uchicago.edu).

\*\* Lee and Brena Freeman Professor of Law, University of Chicago Law School; Professor, Pritzker School of Medicine; [amalani@uchicago.edu](mailto:amalani@uchicago.edu).

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## INTRODUCTION

In recent weeks, a number of policymakers, scholars, and commentators have begun to explore the idea of using “immunity certificates” or “immunity passports” to restart the economy before a vaccine for SARS-CoV-2, the virus that causes Covid-19, becomes available. Under an immunity passport regime, individuals who test positive for SARS-CoV-2 antibodies would be granted a certificate that allows them to return to work even while others remain sheltered in place. Chile’s health ministry has announced plans to implement an immunity passport regime.<sup>1</sup> US Senator Bill Cassidy of Louisiana, one of the three physicians in Congress’s upper chamber, has voiced his support for immunity passports,<sup>2</sup> and Dr. Anthony Fauci, director of the U.S. National Institute of Allergy and Infectious Diseases, has said that Trump administration officials are considering the idea.<sup>3</sup> The UK health secretary, the president of the Italian region of Veneto, and the CEO of Delta Air Lines all have expressed interest,<sup>4</sup> and the famed epidemiologist Larry Brilliant has backed the idea.<sup>5</sup> A San Francisco-based startup has raised \$100 million to develop a smartphone-based immunity-passport system in conjunction with an (unnamed) European government,<sup>6</sup> and researchers in Germany are reportedly investigating the idea’s feasibility.<sup>7</sup>

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<sup>1</sup> See John Bartlett, Chile’s ‘Immunity Passport’ Will Allow Recovered Coronavirus Patients to Break Free from Lockdown, Get Back to Work, Wash. Post (Apr. 20, 2020), [https://www.washingtonpost.com/world/the\\_americas/chile-coronavirus-immunity-passport-antibody-testing-card/2020/04/20/8daef326-826d-11ea-81a3-9690c9881111\\_story.html](https://www.washingtonpost.com/world/the_americas/chile-coronavirus-immunity-passport-antibody-testing-card/2020/04/20/8daef326-826d-11ea-81a3-9690c9881111_story.html).

<sup>2</sup> See Press Release, Bill Cassidy, M.D., U.S. Senator for Louisiana, Cassidy Joins CNN To Promote Establishing a Coronavirus Immunity Registry (Apr. 6, 2020), <https://www.cassidy.senate.gov/newsroom/video/cassidy-joins-cnn-to-promote-establishing-a-coronavirus-immunity-registry>.

<sup>3</sup> See Adrianna Rodriguez, Dr. Fauci Says Immunity Certificates ‘Possible’ After Coronavirus Pandemic. Here’s What That Means, USA Today (Apr. 16, 2020), <https://www.usatoday.com/story/news/health/2020/04/16/covid-19-fauci-says-immunity-certificates-possible-what-they/2987765001>.

<sup>4</sup> See Amy Jones, Government Is ‘Looking at’ Introducing Immunity Passports, Matt Hancock Confirms, Telegraph (London) (Apr. 2, 2020), <https://www.telegraph.co.uk/politics/2020/04/02/government-looking-introducing-immunity-passports-matt-hancock>; Jason Horowitz, In Italy, Going Back to Work May Depend on Having the Right Antibodies, N.Y. Times (Apr. 4, 2020), <https://www.nytimes.com/2020/04/04/world/europe/italy-coronavirus-antibodies.html>.

<sup>5</sup> See Steven Levy, The Doctor Who Helped Defeat Smallpox Explains What’s Coming, Wired (Mar. 19, 2020), <https://www.wired.com/story/coronavirus-interview-larry-brilliant-smallpox-epidemiologist>.

<sup>6</sup> See Dan Primack, Company Working to Develop “Immunity Passports” Raises \$100 Million, Axios (Apr. 15, 2020), <https://www.axios.com/identity-passports-coronavirus-onfido-ce569830-85a3-4b1e-b8ad-7e61b52aa817.html>.

<sup>7</sup> Kate Proctor, Ian Sample & Philip Oltermann, ‘Immunity Passports’ Could Speed Up Return to Work After Covid-19, Guardian (London) (Mar. 30, 2020), <https://www.theguardian.com/world/2020/mar/30/immunity-passports-could-speed-up-return-to-work-after-covid-19>.

Unless a vaccine suddenly and unexpectedly emerges, we can expect the idea to garner increasing attention as the economic recession caused by Covid-19 deepens.

The immunity-passport proposal rests on a plausible—though as yet unproven—epidemiological premise: that individuals who are infected with SARS-CoV-2 and who produce antibodies to the virus will then be immune to reinfection (at least for some nontrivial length of time). The proposal also raises a number of practical and programmatic questions: Who should have authority to issue these certificates? Can the requisite serology tests be conducted quickly and accurately? Will a black market in fraudulent passports emerge? What entitlements (other than the ability to return to work) will a passport entail?<sup>8</sup> The proposal further implicates legal and ethical concerns about health-status discrimination and patient privacy that any fleshed-out passport program would need to confront.<sup>9</sup>

For present purposes, we set aside all of those issues and focus on another aspect of the immunity passport proposal that requires careful attention but so far has received too little<sup>10</sup>: the incentives for self-infection that such a program potentially would generate. To elaborate: The existence of immunity passports may induce healthy individuals to expose themselves to SARS-CoV-2 so that they can develop antibodies, obtain certification, and return to paying work. This possibility is especially worrisome because “strategic self-infection” could—in certain circumstances—be privately rational and socially quite harmful. Any immunity passport proposal will need to grapple with the moral hazard issue or else could lead to disastrous consequences.

To better understand the moral hazard issue, we present a rudimentary model of self-infection incentives under an immunity passport regime. We populate our model with agents who

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<sup>8</sup> For explorations of these and related issues, see Henry T. Greely, Covid-19 ‘Immunity Certificates’: Practical and Ethical Conundrums, *STAT* (Apr. 10, 2020), <https://www.statnews.com/2020/04/10/immunity-certificates-covid-19-practical-ethical-conundrums>; Mark A. Hall & David M. Studdert, Privileges and Immunity Certification During the COVID-19 Pandemic, *JAMA* (May 6, 2020) (online), doi:10.1001/jama.2020.7712; Govind Persad & Ezekiel J. Emanuel, The Ethics of COVID-19 Immunity-Based Licenses (“Immunity Passports”), *JAMA* (May 6, 2020) (online), doi:10.1001/jama.2020.8102.

<sup>9</sup> See Alexandra Phelan, COVID-19 Immunity Passports and Vaccination Certificates: Scientific, Equitable, and Legal Challenges, *Lancet* (May 4, 2020) (online), [https://doi.org/10.1016/S0140-6736\(20\)31034-5](https://doi.org/10.1016/S0140-6736(20)31034-5).

<sup>10</sup> Too little, but not none. See, e.g., Stephanie Baker & Erik Larson, The Problem With Immunity Certificates, *Bloomberg Businessweek* (Apr. 9, 2020), <https://www.bloomberg.com/news/articles/2020-04-09/there-s-a-big-problem-with-coronavirus-immunity-certificates> (quoting Professor I. Glenn Cohen of Harvard Law School, who emphasizes the moral hazard concern: “Like the ‘chickenpox parties’ of old, some workers will want to get infected . . . . That sounds crazy, but if having the antibodies becomes the cost of entering the job market and thus feeding your family, there may be workers who feel pressured into it”). Hall & Studdert, *supra* note 8, and Persad & Emanuel, *supra* note 8, also discuss moral hazard concerns, though we are—to our knowledge—the first to investigate strategic self-infection through a parameterized model.

vary by age. We show how strategic self-infection would be privately optimal for younger individuals given plausible parameters. We also identify conditions under which self-infection—though in the self-interest of many younger individuals—would generate social costs that swamp private benefits. We then consider possible mechanisms to align individual incentives with social objectives. We find that substantial weekly unemployment benefits—on the order of the \$600 minimum benefit provided by Congress in March 2020 legislation—can ameliorate the moral hazard problem significantly. We also assess a number of other strategies to mitigate moral hazard and/or ease congestion externalities that may arise from sudden self-infection by large numbers of individuals.

One key insight is that the viability of an immunity passport regime depends upon—among other factors—the strength of the safety net. Safety-net programs have two cross-cutting effects on moral hazard: government-provided health insurance reduces the private cost of self-infection (exacerbating moral hazard), but unemployment benefits reduce the marginal private gain from obtaining a passport (mitigating moral hazard). Our study provides a first-cut analysis of the relative magnitudes of these two effects. We find that for almost all plausible parameters, the moral hazard-mitigating effect of unemployment benefits swamps the moral hazard-exacerbating effect of health insurance.

Our analysis does not support the overall wisdom of the immunity passport proposal, which depends upon a variety of considerations that we have bracketed here. What our analysis does indicate is that an immunity passport regime—if adopted—should be packaged with other interventions that manage the moral hazard risk accompanying such a system. We consider a number of possible interventions in this paper, but our analysis is not exhaustive. Most importantly, our analysis underscores the importance of further attention to moral hazard in the development of immunity passport proposals.

## **FRAMEWORK AND ANALYSIS**

### **Approach**

Before delving into the details of our model, we briefly explain the rationale for our approach and address potential objections.

Our approach is rooted in rational choice theory and proceeds from the premise that individuals will act to maximize their own utility subject to constraints. As a first cut, we assume

risk neutrality and full information. We later discuss how adjustments to these assumptions may affect our results.

Our claim is not that all individuals will act according to these rational-choice assumptions. Individuals will make all sorts of miscalculations: some will overestimate the risks associated with Covid-19; some will underestimate the risks; some will make decisions divorced from any rational risk calculus. Our model also does not account for substantial heterogeneity within age groups. Thus, when we say that a 20-year-old would have an incentive to self-infect, we do not mean that *all* 20-year-olds would have incentives to do so—an immunocompromised 20-year-old or a 20-year-old who is happily taking classes full-time via Zoom might not. Moreover, and fortunately, not all individuals act out of pure self-interest. Some may act (or refrain from acting) for altruistic or solidaristic reasons. As a result, our model will not perfectly predict human behavior.

Our ambition is more modest. We seek to understand whether an immunity passport regime incentivizes individuals, on the whole, to act consistent with social objectives. If a substantial segment of the population would have private incentives to engage in socially destructive behavior, then we consider that to be a serious problem, and we think it is worth looking for ways to address that problem. It is, to be sure, possible that altruism or social solidarity will significantly mitigate moral hazard. But if proponents of immunity passports are banking on widespread altruism and solidarity, that assumption should be stated explicitly and interrogated accordingly. This is especially true if—as our analysis indicates—many individuals would have very powerful private incentives to self-infect under an immunity passport regime. For the regime *not* to lead to strategic self-infection, then we must assume that individuals will be *very* altruistic—forgoing thousands of dollars of gains for the greater good.

Before proceeding further, an additional note is in order: The numerical estimates here are not intended to serve as precise quantifications of the conditions under which individuals will self-infect under an immunity passport regime. Our model (like all models) is a simplification of reality, and—in particular—it is a simplified version of a regime that does not yet exist. Much will depend upon the details of any immunity passport regime as well as any changes over time in parameters such as the infection fatality rate for Covid-19. Our goal is to illustrate how an immunity passport might shape self-infection incentives given a simplified model and plausible parameters. We offer these results as a quantitative illustration of a qualitative phenomenon, not as point estimates of actual behavior under an as-yet-ill-defined policy.

## Benchmark Model

Our benchmark model involves a rational, risk-neutral agent seeking to maximize her own utility. We will assume that the agent is currently subject to a shelter-in-place order that prevents her from working. The order will last for  $N$  periods until a SARS-CoV-2 vaccine reaches market.

The agent's utility for any period is a function of her consumption and her health state. We model consumption as after-tax income ( $y$ ) less out-of-pocket medical expenses ( $e$ ), and the variable  $h$  denotes health state. The agent's total utility for the remainder of the pandemic ( $U$ ) =  $\sum_{t=0}^N u(y_t, -e_t, h_t)$ . After-tax income is  $y_p$  in periods in which the agent has permission to work outside the home and  $y_o$  when she does not ( $y_p \geq y_o$ ). The agent's health state is  $h_i$  when she is infected with SARS-CoV-2 and  $h_o$  when not ( $u(h_o) \geq u(h_i)$ ). Let  $p_{i,s}$  be the probability that the agent is infected at some point during the pandemic conditional upon sheltering;  $Q$  is the duration of infection, and  $r$  is the probability conditional upon infection that the agent recovers in time to return to work before the pandemic's end. We assume that all infected agents recover post-infection unless they die. Post-pandemic utility is represented by  $\sum_{t=N}^T u(y_p, h_o)$ . That is, after the pandemic, agents have permission to work and are not infected with SARS-CoV-2. Agents who survive the pandemic live a total of  $T$  periods. Agents who do not recover lose out on post-pandemic utility.

In the benchmark case, the agent has the opportunity to self-infect, after which she can obtain an immunity passport. As an initial exercise, we set  $p_s = 0$ , such that the agent can avoid infection with certainty by remaining sheltered. For arithmetic ease, we will assume that the relationship between utility and consumption is linear over the relevant range and that the utility of consumption and health are independent. Thus:

$$U_{self-infect} = \sum_{t=0}^Q u(y_o, h_i) - e_i + r(\sum_{t=Q}^T u(y_p, h_o))$$

$$U_{shelter} = \sum_{t=0}^N u(y_o, h_o) + \sum_{t=N}^T u(y_p, h_o)$$

The agent self-infects if:

$$U_{self-infect} - U_{shelter} > 0$$

$$\sum_{t=0}^Q u(y_o, h_i) - e_i + r(\sum_{t=Q}^T u(y_p, h_o)) - \sum_{t=0}^N u(y_o, h_o) - \sum_{t=N}^T u(y_p, h_o) > 0$$

$$\begin{aligned}
Qy_o + Qu(h_i) - e_i + r(T-Q)y_p + r(T-Q)u(h_o) - Ny_o - (T-N)y_p - Tu(h_o) &> 0 \\
Q(u(h_i) - u(h_o)) - e_i + r(N-Q)(y_p - y_o) - (1-r)((T-Q)(u(h_o))) + (N-Q)y_o + (T-N)y_p &> 0 \quad (1)
\end{aligned}$$

We define  $V_Q^T$  as the agent's value of life from  $t = Q$  until  $t = T$  conditional upon non-infection:

$$\begin{aligned}
V_Q^T &= \sum_{t=Q}^N u(y_o, h_o) + \sum_{t=N}^T u(y_p, h_o) \\
V_Q^T &= (T-Q)(u(h_o)) + (N-Q)y_o + (T-N)y_p
\end{aligned}$$

That is,  $V_Q^T$  denotes the expected utility from living  $T-Q$  additional periods in health state  $h_o$  (no infection) and earning  $y_o$  for the remaining  $N-Q$  periods of the pandemic plus  $y_p$  for the  $T-N$  periods afterwards.

Substituting  $V_Q^T$  into inequality 1, we arrive at:

$$Q(u(h_i) - u(h_o)) - e_i + r(N-Q)(y_p - y_o) - (1-r)V_Q^T > 0 \quad (2)$$

Expressed verbally, inequality 2 states that the agent will self-infect if the utility she will derive from extra after-tax income with an immunity passport, less the health disutility of infection, associated medical expenses, and the probability-weighted mortality cost, exceeds zero.

Note that the net benefits of a passport may turn out to be greater than or less than the benchmark model envisions. The benchmark model does not account for the possibility that passports could confer privileges other than permission to work (e.g., permission to attend large gatherings or enter restaurants and other crowded spaces). Weighing in the opposite direction, the benchmark model does not account for the opportunity cost of labor (i.e., the nonmarket benefits of sheltering in place). For example, an individual may assign positive value to the extra time she has to watch movies on Netflix, bake sourdough bread, or—less frivolously—care for young, old,



or disabled family members.<sup>11</sup> For all these reasons, and as emphasized above, the benchmark model should be understood as illustrative rather than comprehensive.

### Plausible Parameters

To parameterize the benchmark model, we use data from the Bureau of Labor Statistics reporting median weekly earnings for full-time wage and salary workers by age in the first quarter of 2020.<sup>12</sup> We calculate age-specific effective tax rates for a single person earning the median age-specific wage over a 52-week year, taking into account the employee portion of Social Security and Medicare taxes. We use a value for  $Q$  of 21 days, reflecting the World Health Organization's recommended 14-day quarantine post-exposure<sup>13</sup> plus an additional 7 days to allow for serology testing and passport processing.

We estimate the utility loss from infection using the construct of “quality-adjusted life days,” with 365 quality-adjusted life days per quality-adjusted life year (QALY). This allows us to import estimates of the value of a QALY from healthcare decisionmaking settings.<sup>14</sup> We assume that asymptomatic infections yield no utility loss; that non-hospitalized symptomatic individuals experience a utility loss of 0.5 QALDs per day of infection; and that hospitalized patients experience a utility loss of 1.0 QALDs per day of hospitalization. Based on case reports from China, we assume mean symptom duration of 8 days for nonhospitalized patients.<sup>15</sup> For more severe cases, we use data from Kaiser Permanente patients in California and Washington state, for whom the mean duration of hospital stays was 11.3 days for patients not admitted to intensive care

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<sup>11</sup> The opportunity cost of labor also may be negative for an individual with “cabin fever,” who may prefer work over sheltering in place even if work is unpaid.

<sup>12</sup> See U.S. Dep’t of Labor, Bureau of Labor Statistics, Economic News Release, Table 3. Median Usual Weekly Earnings of Full-Time Wage and Salary Workers By Age, Race, Hispanic or Latino Ethnicity, and Sex, First Quarter 2020 Averages, Not Seasonally Adjusted (Apr. 15, 2020), <https://www.bls.gov/news.release/wkyeng.t03.htm>.

<sup>13</sup> See World Health Org., Considerations for Quarantine of Individuals in the Context of Containment for Coronavirus Disease (COVID-2019)—Interim Guidance (Mar. 19, 2020), <https://apps.who.int/iris/rest/bitstreams/1272428/retrieve>.

<sup>14</sup> See Peter J. Neumann, Joshua T. Cohen & Milton C. Weinstein, Updating Cost-Effectiveness — The Curious Resilience of the \$50,000-per-QALY Threshold, 371 *New Eng. J. Med.* 796 (2014). We follow Neumann et al.’s \$200,000-per-QALY suggestion.

<sup>15</sup> See De Chang, Time Kinetics of Viral Clearance and Resolution of Symptoms in Novel Coronavirus Infection, *Am. J. Respiratory & Critical Care Med.* (Mar. 23, 2020) (in press).

and 19.4 days for ICU patients.<sup>16</sup> Note that in the benchmark model, the overwhelming majority of private and social costs are mortality costs, so even quite significant changes in estimates of non-mortality utility losses will have a limited effect on the main results.

We assume that 50 percent of infections are asymptomatic, based on data from Iceland's widespread testing effort.<sup>17</sup> (Note that we vary this figure and all other health parameters in our robustness checks.) We use age-stratified estimates of hospitalization rates and infection fatality rates from researchers at Imperial College London, based on cases reported in mainland China as well as international travelers repatriated after the outbreak.<sup>18</sup> We use age-stratified estimates of ICU admission conditional upon hospitalization from the Centers for Disease Control and Prevention.<sup>19</sup>

For medical expenses, we use cost data from the Kaiser Family Foundation, which estimates a cost of approximately \$2500 per inpatient day in the United States.<sup>20</sup> We follow the rough rule of thumb that the cost per day in an ICU is three times average cost.<sup>21</sup> In our benchmark model, we include results for agents who are fully insured (i.e., all hospitalization costs are social costs) and for patients without insurance (i.e., all hospitalization costs are borne by the agent). Health and Human Services Secretary Alex Azar has said that the Trump administration will use a portion of CARES Act funding to reimburse hospitals at Medicare rates for treating uninsured individuals with Covid-19 on the condition that the hospital not bill patients any balance,<sup>22</sup> so we expect that most individuals will fall into the insured category.

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<sup>16</sup> Joseph A. Lewnard et al., Incidence, Clinical Outcomes, and Transmission Dynamics of Hospitalized 2019 Coronavirus Disease Among 9,596,321 Individuals Residing in California and Washington, United States: A Prospective Cohort Study (Apr. 16, 2020), <https://www.medrxiv.org/content/10.1101/2020.04.12.20062943v1>.

<sup>17</sup> Jason Gale, Coronavirus Cases Without Symptoms Spur Call for Wider Tests, Bloomberg (Mar. 22, 2020), <https://www.bloomberg.com/news/articles/2020-03-22/one-third-of-coronavirus-cases-may-show-no-symptom-scmp-reports>.

<sup>18</sup> Robert Verity et al., Estimates of the Severity of COVID-19 Disease (Imperial Coll. London, Mar. 13, 2020), <https://www.medrxiv.org/content/10.1101/2020.03.09.20033357v1>.

<sup>19</sup> CDC COVID-19 Response Team, Severe Outcomes Among Patients with Coronavirus Disease 2019 (COVID-19) — United States, February 12–March 16, 2020, 69 *Morbidity & Mortality Wkly. Rpt.* 343, 345 tbl. (Mar. 27, 2020).

<sup>20</sup> Kaiser Family Found., Hospital Adjusted Expenses per Inpatient Day, <https://www.kff.org/health-costs/state-indicator/expenses-per-inpatient-day> (last visited Apr. 15, 2020) (2018 data).

<sup>21</sup> See, e.g., M. Elizabeth Wilcox & Gordon D. Rubinfeld, Is Critical Care Ready for an Economic Surrogate Endpoint?, 19 *Critical Care* no. 248 (2015).

<sup>22</sup> See Christen Linke Young et al., Responding To COVID-19: Using The CARES Act's Hospital Fund To Help The Uninsured, Achieve Other Goals, *Health Affairs* (Apr. 11, 2020), <https://www.healthaffairs.org/doi/10.1377/hblog20200409.207680/full>.

We use age-adjusted estimates of the private value of a statistical life from University of Chicago economists Kevin Murphy and Robert Topel.<sup>23</sup> These estimates are based on wage-risk tradeoffs—instances in which individuals accept jobs with higher mortality risks in exchange for more money. The use of wage-risk tradeoffs to calculate the private value of a statistical life is appropriate where, as here, what we are modeling is whether and when individuals would be willing to put their own health and lives at risk for additional income.

The key missing input of our model is the length of the shelter-in-place period. Rather than impose our own estimates ( $N$ ), we report the number of weeks that the period would need to last in order for infection to be privately optimal.

## Outputs

[INSERT TABLE 1 HERE]

Table 1 reports the outputs of our model. Two key insights emerge. The first is that at all ages, and especially at older ages, mortality costs represent the bulk of the private costs of self-infection. This is true for fully insured and for uninsured agents—health insurance, it turns out, has a muted impact on self-infection incentives. This observation also highlights the fact that the robustness of our cost estimates will depend largely on the accuracy of our mortality cost estimates. Even a very substantial overestimate or underestimate of health utility and health care costs is not likely to change the topline result dramatically.

The second insight is that under an immunity passport regime, self-infection would be privately optimal for younger workers at relatively low values of  $N$ . For a fully insured 20-year-old, for example, self-infection is privately optimal if the 20-year-old expects the shelter-in-place period to last an additional 10.9 weeks (i.e., if an immunity passport would enable the 20-year-old to work an additional 7.9 weeks at the median age-specific wage, conditional upon recovery). When we run the model for every age (rather than in 10-year increments), we find that self-infection is privately optimal for all individuals through age 49 if they expect the shelter-in-place period to last less than half a year.

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<sup>23</sup> See Kevin M. Murphy & Robert H. Topel, *The Value of Health and Longevity*, 114 *J. Pol. Econ.* 871 (2006).

## Social Cost

Estimating the social cost of self-infection requires us to know how many additional infections will be generated per self-infection and what the ages of the additionally infected might be. To calculate additional self-infections, we follow the standard assumption that each infection leads to  $R$  additional infections, where  $R$  is the effective reproduction number. Thus where  $R < 1$ , a single self-infection leads to  $\frac{1}{1-R} - 1$  additional infections. (As long as  $R > 1$ , the virus grows without end.)

Estimating the value of  $R$  when the primary case is contracted intentionally presents a problem of out-of-sample forecasting, because we lack evidence from any large-scale self-infection effort involving SARS-CoV-2. One possibility is that individuals who intentionally self-infect will take unusually strong precautions afterwards to avoid spread. Whether this occurs will depend upon altruism, living arrangements, and—perhaps most importantly—the mechanism by which self-infection occurs. If individuals can self-infect by receiving targeted viral doses, then it is plausible that they will self-quarantine immediately, and  $R$  may be very low. If individuals who wish to self-infect have no other option but to behave “carelessly” in dense settings until symptoms emerge, then  $R$  may be much higher (and potentially much higher than 1). Self-infecting individuals may even be “super-spreaders” until symptoms emerge (or, in asymptomatic cases, until they no longer are infectious).

We parameterize our social cost model based on four different estimates of  $R$ ;  $R = 0.2$ ;  $R = 0.4$ ;  $R = 0.6$ ; and  $R = 0.8$ . Data from Singapore—which has adopted aggressive case monitoring, contract tracing, and enforced quarantine measures<sup>24</sup>—suggests that these measures have achieved an  $R = 0.6$ , with  $R = 0.4$  as the lower bound of the 95 percent confidence interval.<sup>25</sup> Note that  $R = 0.8$  should not be interpreted as an upper bound because—as emphasized above— $R$  could exceed 1 depending on the self-infection mechanism.<sup>26</sup>

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<sup>24</sup> See Pushan Dutt, Singapore’s Spike in Coronavirus Cases Shows the Road to Recovery Will Be a Bumpy Ride, *The Conversation* (Apr. 23, 2020), <https://theconversation.com/singapores-spike-in-coronavirus-cases-shows-the-road-to-recovery-will-be-a-bumpy-ride-136994> (describing Singapore’s measures).

<sup>25</sup> Anna Tariq et al., Real-Time Monitoring the Transmission Potential of COVID-19 in Singapore, *March 2020* (Apr. 17, 2020), <https://doi.org/10.1101/2020.02.21.20026435>.

<sup>26</sup> One way of potentially motivating our reported lower bound of  $R = 0.2$  is as follows: If half of follow-on cases are among people who wish to be infected, then that half of cases should not be included in social costs. Thus,  $R = 0.2$  could be representative of an effective reproduction number of 0.4 and a 50 percent desired self-infection rate.

We also consider two potential age profiles for secondary cases. One possibility is that all secondary infections remain within the age group of the primary case (i.e., 20-year-olds infect other 20-year-olds; 30-year-olds infect other 30-year-olds, and so on). Another possibility is that ages of secondary cases are a random draw from the age distribution (i.e., if 14 percent of the population is in the 20- to 29-year-old age group, then 14 percent of secondary cases will be in that age group regardless of the age of the primary case). In all likelihood, reality will lie somewhere in between these two extremes. Containing secondary infections within age groups is unlikely—even if self-infected individuals isolate themselves immediately upon experiencing symptoms—for two reasons. First, many individuals live in multigenerational households where they could expose older or younger members even if they take all appropriate precautions.<sup>27</sup> Second, as noted above, self-infected individuals may come into contact with a wide age range of others before they become symptomatic. At the same time, we doubt that secondary infections will be a totally random draw, assuming that older individuals are careful about social distancing and that self-infected individuals are responsible about self-isolation.

[INSERT TABLE 2 HERE]

Table 2 reports the outputs of our social-cost model. We follow the standard definition of social costs as the sum of private costs and external costs. In determining the values of  $N$  for which self-infection is socially optimal, we continue to assume a three-week lag between self-infection and the start of work (conditional upon recovery), and we use pre-tax rather than after-tax income to calculate social benefits.

Table 2, when juxtaposed against Table 1, illustrates the significance of the potential moral hazard risk. For most age groups under most specifications, there exists a range of values for  $N$  (and sometimes quite a wide range) over which self-infection yields net private benefits and net social costs.<sup>28</sup> For example, if the shelter-in-place period is half a year (26 weeks), then self-

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<sup>27</sup> Overall, 20 percent of U.S. adults live in multigenerational households (i.e., households with adults from multiple generations). Adults in their late 20s (among the most likely to self-infect) and adults over the age of 85 (the most vulnerable to Covid-19) are the most likely to live in multigenerational settings. D’Vera Cohen & Jeffrey S. Passel, A Record 64 Million Americans Live in Multigenerational Households, Pew Research Ctr.: FactTank (Apr. 5, 2018), <https://www.pewresearch.org/fact-tank/2018/04/05/a-record-64-million-americans-live-in-multigenerational-households>.

<sup>28</sup> The only exceptions are 60- and 70-year-olds when  $R = 0.4$  and secondary infections are a random draw from the age distribution. Under these circumstances, the negative externality of self-infection is smaller than the positive fiscal externality from additional taxes paid.

infection is privately optimal for individuals under 50 and will be socially suboptimal regardless of the age of the self-infecting agent if  $R \geq 0.4$  and secondary infections cannot be contained within age groups (or at higher levels of  $R$  even if secondary infections can be contained within age groups).

Moreover, the degree of altruism necessary to align individual behavior with the social objective is potentially quite significant for younger individuals. If the shelter-in-place period lasts an additional half-year, then a 20-year-old—by choosing not to self-infect—is effectively forgoing the equivalent of 14 to 15 weeks of wages (23 weeks of actual wages, minus 8 to 9 weeks to recoup pecuniary and nonpecuniary infection costs). For a 30-year-old, the sacrifice is approximately 9 to 10 weeks of wages; for a 40-year-old, 4 to 5 weeks of wages. Again, it is possible that individuals would be willing to make these sacrifices for the greater good. But note that the very idea of immunity passports—which assumes a need to verify that individuals accurately represent their immunity status—is predicated on a model of human behavior that rejects the premise of perfect altruism.

### **Congestion Externalities**

One limitation of the social-cost model above is that it fails to account for congestion externalities arising from a large number of younger adults self-infecting simultaneously (and a small percentage—though still potentially a large number—of those adults falling ill and needed to be hospitalized). To arrive at a sense of what the consequences of simultaneous self-infection might be, we estimate the number of individuals in each age group who would need to be admitted to intensive care if a given percentage of age-group members self-infected simultaneously.

[INSERT TABLE 3 HERE]

As Table 3 illustrates, simultaneous self-infection by 5 percent of individuals in their 20s, 30s, and 40s (i.e., the age groups for whom self-infection is privately optimal given a shelter-in-place period of half a year) would result in 4,419 individuals in their 20s, 12,974 individuals in their 30s, and 21,854 individuals in their 40s requiring admission to the ICU, consuming 70.5 percent of all U.S. medical-surgical ICU beds.<sup>29</sup> If an additional 5 percent of individuals in each

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<sup>29</sup> The American Hospital Association estimates that there were 55,663 medical-surgical intensive care beds in U.S. community hospitals in fiscal year 2018. See Am. Hosp. Ass'n, Fast Facts on U.S. Hospitals, 2020 (Mar. 2020), <https://www.aha.org/statistics/fast-facts-us-hospitals>.

age group self-infected simultaneously, then ICU admissions would exceed nationwide capacity by an estimated 41 percent. And note that many of those beds still would be needed by individuals who contracted Covid-19 through means other than self-infection, along with all of the patients in the ICU for non-Covid-19 reasons.

## Robustness

Three important assumptions undergird our analysis above: first, that the probability of infection conditional on sheltering ( $p_s$ ) is zero; second, that the severity of Covid-19 across the age distribution is roughly in line with the evidence from China; and third, that the value of a statistical life for purposes of wage-risk tradeoffs is consistent with the Murphy-Topel estimates.<sup>30</sup> We evaluate each in turn.

### *“Organic” Infections*

An important simplifying assumption that we make in our benchmark model is that the probability of infection conditional on sheltering ( $p_s$ ) is zero, such that all self-infesting individuals will not be infected *but for* their own volition, and all secondary cases involve people who would not be infected *but for* the primary case of self-infection. This assumption is almost certainly counterfactual. We consider whether our results are robust to changes in the value of  $p_s$ .

As a robustness evaluation exercise, we recalculate our main results with  $p_s$  set to 0.5 over the course of the shelter-in-place period. We set  $N$  equal to 26 weeks and assume that the weekly probability of infection conditional upon sheltering is constant ( $0.5/26 \approx 0.019$ ). For arithmetic ease (and given the relatively short duration of the period in question), we assume a discount rate of zero. Table 4 reports the private cost of self-infection, the additional after-tax wages resulting from self-infection, and the net private benefit (cost) of self-infection when  $p_s = 0$  and again when  $p_s = 0.5$ .

[INSERT TABLE 4 HERE]

Setting  $p_s$  to 0.5 mechanically reduces the private cost of self-infection by 50 percent relative to the benchmark case, because 50 percent of self-infesting individuals would have

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<sup>30</sup> As noted, other assumptions—such as the quality adjusted life day losses for various disease outcomes and the length and cost of hospital stays—are less likely to affect our main results, given that the primary costs of self-infection appear to be mortality costs.

become infected regardless of their volitional acts. The marginal benefit of self-infection also declines (although by less), because some individuals who self-infect and become passport-eligible still would have become passport-eligible (though likely at a later date) under the counterfactual in which they do not self-infect. The fundamental result does not change: individuals in their 20s, 30s, and 40s still have a private incentive to self-infect if the shelter-in-place period is expected to last at least half a year, while older individuals do not. Concerns about health infrastructure congestion become, if anything, more acute, because the flood of self-infecting patients into emergency rooms and intensive care units will be supplemented by a steadier stream of organically infected patients.

### ***Disease Severity***

Next, we vary our assumptions about disease severity. In Tables 5.A and 5.B, we re-estimate our main results on the assumption that the percentage of infected individuals who are symptomatic, the hospitalization rate, and the infection fatality rate are all half of what we believed. Predictably, this change makes self-infection more likely but less socially cost. Fully insured 20-year-olds now have an incentive to self-infect if  $N$  is approximately 7 weeks (10 weeks for 30-year-olds, 12 weeks for 40-year-olds, and 28 weeks for 50-year-olds). Because disease severity is lower, self-infection is socially optimal under a wider range of conditions (setting aside congestion externalities).

[INSERT TABLES 5.A and 5.B HERE]

Congestion externalities complicate the analysis. A less severe disease would mean a lower probability that self-infected individuals show up in emergency rooms and intensive care units, but individuals would have stronger incentives to self-infect. For example, if 10 percent of individuals in the 20-to-49 age demographic chose to self-infect and ICU admission rates were half of what we have estimated, then this still would result in nearly 40,000 ICU admissions, filling more than 70 percent of medical-surgical ICU beds. For this reason, we believe that the moral hazard generated by immunity passports would likely remain acute even if the medical hazard generated by self-infection is significantly less than early data suggests.

In estimating plausible lower bounds on disease severity, note that the mortality assumptions in our benchmark model translate to a population-wide infection fatality rate of 0.914 percent, and the mortality assumptions in our robustness check translate to an infection fatality



rate of 0.457 percent. Already as of May 3, 2020, the number of confirmed and probable Covid-19 deaths reported by the New York City Health Department was 0.223 percent of the city's total population.<sup>31</sup> At the beginning of May, Governor Andrew Cuomo released data from antibody testing in New York City suggested that 19.9 percent the city's population had developed Covid-19 antibodies.<sup>32</sup> If these figures are accurate, they would suggest an infection fatality rate slightly higher than what our benchmark model assumes (in a city with a smaller share of its population over 65 than the nation as a whole<sup>33</sup>). While it is possible that therapeutics such as the antiviral drug remdesivir and the anti-inflammatory treatment tocilizumab will reduce the severity of disease outcomes,<sup>34</sup> we stress again that changes in disease severity have cross-cutting effects on congestion externalities.

### *Alternative Statistical-Life Values*

Finally, we re-estimate our main results using a different source of data on the value of a statistical life. We replace with the Murphy-Topel figures with age-adjusted estimates of the private value of a statistical life from economists Joseph Aldy of the Harvard Kennedy School and W. Kip Viscusi of Vanderbilt University.<sup>35</sup> Aldy and Viscusi, like Murphy and Topel, use wage-risk tradeoffs within and across industry to derive their estimates, though the Aldy-Viscusi estimates are entirely reliant on observational data whereas the Murphy-Topel estimates are fitted to a specific utility model.

[INSERT TABLES 6.A AND 6.B HERE]

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<sup>31</sup> See N.Y. City Health Dep't, Covid-19: Data, <https://www1.nyc.gov/site/doh/covid/covid-19-data.page> (last visited May 3, 2020). The U.S. Census Bureau's most recent estimate of the city's population is 8,398,748. See U.S. Census Bureau, Quick Facts: New York City, New York, <https://www.census.gov/quickfacts/newyorkcitynewyork> (last visited May 3, 2020) (estimates as of July 1, 2018).

<sup>32</sup> Gov'r Andrew M. Cuomo (N.Y.), Press Release, Amid Ongoing COVID-19 Pandemic, Governor Cuomo Announces Results of Completed Antibody Testing Study of 15,000 People Showing 12.3 Percent of Population Has COVID-19 Antibodies (May 2, 2020), <https://www.governor.ny.gov/news/amid-ongoing-covid-19-pandemic-governor-cuomo-announces-results-completed-antibody-testing>.

<sup>33</sup> The over-65 demographic accounts for 14.1 percent of the New York City population and 16.0 percent of the U.S. population. See U.S. Census Bureau, Quick Facts: United States, <https://www.census.gov/quickfacts/fact/table/US/PST045219> (last visited May 3, 2020).

<sup>34</sup> See Two Potential Therapies for Covid-19 Have Some Effect, *Economist* (May 9, 2020), <https://www.economist.com/science-and-technology/2020/05/09/two-potential-therapies-for-covid-19-have-some-effect>.

<sup>35</sup> Joseph E. Aldy & W. Kip Viscusi, Adjusting the Value of a Statistical Life for Age and Cohort Effects, 3 *Rev. Econ. & Stats.* 573 (2008). For demographic groups not represented in wage-risk data (i.e., the very young and the very old), we use the closest reported age band.

Our results using the Aldy-Viscusi VSL estimates are broadly consistent with the benchmark model, though the gap between the private and social breakeven values of  $N$  is now even larger. These results lead us to believe that our results are not an artifact of the particular set of VSL estimates we have chosen for the main analysis.

## DISCUSSION

The key takeaway from the analysis above is that moral hazard is a real risk under an immunity passport regime. The risk arises partly because self-infecting individuals potentially expose other (possibly more vulnerable) individuals to SARS-CoV-2 and partly because simultaneously self-infecting individuals themselves may cause congestion of emergency rooms and intensive care units, even if those individuals are primarily young and healthy. In this section, we consider strategies to mitigate moral hazard in the immunity passport context.

### Unemployment Benefits

One way to mitigate moral hazard under an immunity passport regime is to raise the utility of individuals sheltering in place (thereby narrowing the gap in utility with and without a passport). The CARES Act passed by Congress in March 2020 effectively does this by providing millions of unemployed workers with a federally financed benefit of \$600 per week.<sup>36</sup> Table 7 illustrates the effect of a \$600 (taxable) benefit on the strategic self-infection thresholds of the benchmark model.<sup>37</sup> We assume an effective tax rate on unemployment benefits of 6.69 percent, which is the effective federal income tax rate for an individual receiving \$600 per week throughout the year.<sup>38</sup>

[INSERT TABLE 7 HERE]

The effect of unemployment insurance on self-infection incentives is dramatic. With unemployment benefits of \$600 per week, self-infection is never privately optimal for 20-year-olds earning the age-specific median weekly wage for the straightforward reason that the after-tax

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<sup>36</sup> Coronavirus Aid, Relief, and Economic Security Act (CARES Act), H.R. 748, § 2104 (2020).

<sup>37</sup> We assume that benefits will continue throughout the shelter-in-place period. Current law limits benefits to 26 weeks in most states (and less than 26 weeks in seven states). The CARES Act provides states with funding to extend benefits to 39 weeks. See Ctr. on Budget & Policy Priorities, Policy Basics: How Many Weeks of Unemployment Compensation Are Available? (Apr. 13, 2020), <https://www.cbpp.org/research/economy/policy-basics-how-many-weeks-of-unemployment-compensation-are-available>.

<sup>38</sup> The unrounded figure is 11.27%. Note that unemployment benefits are exempt from FICA taxes. See *United States v. Quality Stores, Inc.*, 572 U.S. 141, 155 (2014).

wage (\$518) is less than the after-tax value of unemployment benefits. (The age-specific pre-tax median wage—\$605—is slightly higher than the pre-tax value of unemployment benefits, but wages are subject to Federal Insurance Contribution Act taxes whereas unemployment benefits are not.) For older workers, self-infection does not become optimal until the shelter-in-place period approaches a full year or more.

Importantly, this does not mean that moral hazard is an insignificant issue now that the CARES Act has become law. The duration of benefits varies across states. Florida and North Carolina—the states with the least generous unemployment insurance programs—allow only 12 weeks of benefits.<sup>39</sup> The introduction of immunity passports would generate a particularly acute moral hazard in these states—especially if a significant share of unemployed workers have exhausted some or all of their 12 weeks of benefits by the time that the program is implemented. The CARES Act provides federal funding for states to extend their benefits by 13 weeks (which would lead to 39 weeks total of coverage in most states). Depending on when in the crisis an immunity passport regime is implemented and how long the shelter-in-place period is expected to last, that 39-week span may need to be extended in order to mitigate moral hazard concerns. Note as well that not all unemployed workers are eligible for unemployment benefits. For example, students graduating from high school or college this spring generally will not be benefit-eligible because they were not previously employed. For these recent graduates—who are generally young and healthy—self-infection incentives under an immunity passport regime would be especially powerful.

### **Staggered Implementation**

Another potential way to avoid some of the negative externalities anticipated under an immunity passport regime is to implement the program in a staggered fashion. For example, in the first month, individuals born in January through April would be eligible for passports; in the second month, individuals born in May through August; in the third month, September through December. This approach would not substantially reduce self-infection incentives (except insofar

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<sup>39</sup> See Ctr. for Budget & Policy Priorities, Policy Basics: How Many Weeks of Unemployment Compensation Are Available? (Apr. 13, 2020), <https://www.cbpp.org/research/economy/policy-basics-how-many-weeks-of-unemployment-compensation-are-available>.

as it reduces  $N$  for later tranches). It would, importantly, alleviate congestion externalities because individuals with later-in-the-year birth months would presumably delay self-infection.

Staggered implementation (whether by birth month, last name, random lot, or any other distinction) would raise inevitable objections of arbitrariness. And staggered implementation is not a solution to the concerns about secondary infections emphasized above. It may, though, prove preferable to the alternative of implementing the immunity passport regime for the entire population in one fell swoop and setting off a wave of self-infections and hospitalizations.

### **Controlled Infection**

A more controversial approach than the above-listed options would be to provide individuals with the option of self-infecting in a controlled setting. Individuals who choose this option would commit to self-quarantining immediately, thereby limiting the likelihood of secondary infections and reducing social costs. (The government potentially could provide isolated living facilities where self-infected individuals could remain until no longer contagious.) The analogy would be to methadone clinics where individuals addicted to heroin can obtain an alternative opioid. Methadone injection is, of course, not a practice that society wants to encourage (except for rare pain management purposes). The policy rationale for methadone clinics is that if individuals *do* use opioids, it is better that they do so in a safer setting where they expose themselves and others to fewer risks.

We emphatically do not endorse this option. Compared to an alternative in which individuals self-infect by behaving carelessly in large-group settings for several days until they begin to experience symptoms, however, controlled infection may be a less socially costly way of implementing an immunity passport regime. And for those uncomfortable with the idea of infecting individuals with SARS-CoV-2 in a controlled setting, we suggest that they should be even more uncomfortable with an immunity passport regime that generates incentives for widespread and uncontrolled self-infection.

### **Other Approaches**

Aside from unemployment benefits, staggered implementation, and controlled infection, several other adjustments to the immunity passport proposal potentially could reduce moral hazard, though none are terribly promising.

For example, passports could be explicitly time-limited. The incentive to self-infect will be weaker if, for example, the passport is valid for only four weeks. However, the viability of this strategy depends upon the credibility of the government's commitment not to renew the passports. If passports succeed in facilitating the reopening of the economy, then political pressure to renew will be strong.

Another option is to restrict passports by age. Perhaps counterintuitively, our analysis suggests that if age limitations are imposed, they should be age floors—not age ceilings. The reason is that younger individuals have stronger incentives to self-infect strategically. For older workers who face higher private costs of infection, passports will be attractive only to individuals who organically develop natural immunity. Note, though, that this moral-hazard argument for age floors may be outweighed by epidemiological considerations cutting in the opposite direction. For example, if natural immunity is more robust and durable among younger individuals than older individuals, then the argument for age floors becomes substantially weaker.

Another approach is to try to distinguish directly between individuals who develop natural immunity organically and individuals who self-infect strategically. One way to do this would be to allow only a brief window during which individuals can demonstrate antibodies and obtain passports. IgM antibodies typically appear several days after infection, whereas IgG antibodies emerge later (7 to 10 days after infection, according to the FDA<sup>40</sup>). One can imagine an immunity passport regime that provides passports to individuals who establish immunity via an IgG antibody test in the first week after the program is implemented—and then closes off to new applications.

This approach carries serious shortcomings. The introduction of an immunity passport regime almost certainly would be preceded by public debate. If implementation becomes likely, individuals may have an incentive to self-infect strategically in the period prior to implementation so that they can obtain passports during the five-day window. A surge in strategic self-infection could overwhelm health care infrastructure even before the immunity passport regime goes live. Moreover, scaling up antibody testing so that all already-infected individuals can establish immunity within a five-day window would be a daunting logistical challenge. And the viability of this approach hinges upon the credibility of the government's commitment not to reopen the

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<sup>40</sup> U.S. Food & Drug Admin, Fact Sheet for Healthcare Providers, qSARS-CoV-2 IgG/IgM Rapid Test—Cellex Inc. (Apr. 1, 2020), <https://www.fda.gov/media/136623/download>.

program. Once a substantial minority of the population resumes work and other activities, the pressure on the government to allow others into the regime will rise.

## CONCLUSION

Our analysis offers a first look at the moral hazard generated by proposed immunity passport regimes. Although subject to all the limits of rational-actor models, the conclusions nonetheless merit attention: An immunity passport regime could lead to widespread strategic self-infection—and a potential public health disaster—unless policymakers take action aimed at aligning private incentives with the social objective.

The immediate focus of our analysis is the immunity passport proposal in the context of Covid-19, but our analysis also contributes to broader understandings of policy in a pandemic. It is well understood that—outside the pandemic context—unemployment insurance is a potential source of moral hazard because it reduces the incentive to search for new work.<sup>41</sup> Yet the same policies that create moral hazard outside a pandemic can mitigate moral hazard during one. This is true both in the mitigation and suppression phase, when the availability of paid leave may affect viral spread,<sup>42</sup> and in the recovery phase, when the magnitude and duration of unemployment benefits may affect the incentive compatibility of programs to restart the economy. Analysis of the immunity passport proposal highlights the importance of considering interactions between the social safety net and public health when evaluating pandemic and post-pandemic policy.

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<sup>41</sup> See, e.g., Raj Chetty, Moral Hazard versus Liquidity and Optimal Unemployment Insurance, 116 *J. Pol. Econ.* 173 (2008); Gary D. Hansen & Ayşe Imrohoroğlu, The Role of Unemployment Insurance in an Economy with Liquidity Constraints and Moral Hazard, 100 *J. Pol. Econ.* 118 (1992).

<sup>42</sup> See Usha Ranji, Michelle Long & Alina Salganicoff, Coronavirus Puts a Spotlight on Paid Leave Policies, Kaiser Family Found.: Women's Health Policy (Mar. 30, 2020), <https://www.kff.org/womens-health-policy/issue-brief/coronavirus-puts-a-spotlight-on-paid-leave-policies>.

**Table 1. Private Cost of Self-Infection and Breakeven Values of  $N$**

Age	Health Utility Cost	Mortality Cost	Healthcare Cost	Private Cost (fully insured)	Private Cost (uninsured)	Breakeven Value of $N$ (fully insured) (weeks)	Breakeven Value of $N$ (uninsured) (weeks)
20	\$1,156	\$2,946	\$593	\$4,102	\$4,695	10.9	12.1
30	\$1,282	\$8,192	\$1,833	\$9,474	\$11,307	15.9	18.4
40	\$1,332	\$14,431	\$2,318	\$15,762	\$18,080	20.7	23.3
50	\$1,644	\$43,583	\$6,117	\$45,226	\$51,344	53.2	59.8
60	\$1,879	\$93,900	\$8,718	\$95,780	\$104,498	112.4	120.8
70	\$2,280	\$121,886	\$13,683	\$124,166	\$137,850	168.2	181.9

**Table 2. Social Cost of Self-Infection and Breakeven Values of  $N$**

Age	$R = 0.2$ <i>age-contained</i>		$R = 0.2$ <i>random draw</i>		$R = 0.4$ <i>age-contained</i>		$R = 0.4$ <i>random draw</i>	
	Social cost	Breakeven Value of $N$ (weeks)	Social cost	Breakeven Value of $N$ (weeks)	Social cost	Breakeven Value of $N$ (weeks)	Social Cost	Breakeven Value of $N$ (weeks)
20	\$5,869	12.7	\$12,642	23.9	\$7,825	15.9	\$25,886	45.8
30	\$14,133	19.2	\$19,253	25.1	\$18,845	24.6	\$32,498	40.3
40	\$22,600	24.0	\$26,027	27.1	\$30,134	30.9	\$39,272	39.4
50	\$64,180	61.6	\$59,291	57.2	\$85,573	81.2	\$72,535	69.3
60	\$130,622	126.1	\$112,444	108.9	\$174,163	167.1	\$125,689	121.4
70	\$172,312	195.0	\$145,797	165.4	\$229,750	258.9	\$159,041	180.2

Age	$R = 0.6$ <i>age-contained</i>		$R = 0.6$ <i>random draw</i>		$R = 0.8$ <i>age-contained</i>		$R = 0.8$ <i>random draw</i>	
	Social cost	Breakeven Value of $N$ (weeks)	Social cost	Breakeven Value of $N$ (weeks)	Social cost	Breakeven Value of $N$ (weeks)	Social Cost	Breakeven Value of $N$ (weeks)
20	\$11,737	22.4	\$55,505	94.8	\$39,124	67.7	\$134,973	226.2
30	\$28,267	35.4	\$66,525	79.4	\$94,223	111.1	\$145,993	170.6
40	\$45,200	44.9	\$77,814	75.2	\$150,668	142.7	\$157,282	148.9
50	\$128,360	120.3	\$133,254	124.8	\$427,865	394.0	\$212,721	197.4
60	\$261,244	249.1	\$221,843	212.0	\$870,813	823.4	\$301,311	286.9
70	\$344,624	386.9	\$277,430	312.1	\$1,148,748	1,282.7	\$356,898	400.6

**Table 3. ICU Beds Needed vs. ICU Capacity for Various Self-Infection Rates**

Age	ICU Beds if 5% Self-Infect	ICU Beds if 10% Self-Infect
20-29	4,419	8,839
30-39	12,974	25,947
40-49	21,854	43,707
<b>Total ICU Beds Needed</b>	<b>39,246</b>	<b>78,493</b>
<b>Percent of ICU Capacity</b>	<b>70.5%</b>	<b>141.0%</b>

**Table 4. Private Cost of Self-Infection, Additional After-Tax Wages, and Net Private Benefit, Without and With Organic Infection ( $N = 26$  weeks)**

Age	$p_s = 0$			$p_s = 0.5$		
	Private Cost	Additional After-Tax Wages	Net Private Benefit	Private Cost	Additional After-Tax Wages	Net Private Benefit
20	\$4,102	\$11,910	\$7,808	\$2,051	\$6,413	\$4,362
30	\$9,474	\$16,834	\$7,360	\$4,737	\$9,065	\$4,328
40	\$15,762	\$20,461	\$4,699	\$7,881	\$11,018	\$3,136
50	\$45,226	\$20,709	-\$24,518	\$22,613	\$11,151	-\$11,462
60	\$95,780	\$20,136	-\$75,643	\$47,890	\$10,843	-\$37,047
70	\$124,166	\$17,291	-\$106,875	\$62,083	\$9,311	-\$52,773



**Table 5a. Private Cost of Self-Infection and Breakeven Values of  $N$  When Disease Severity Is Reduced by 50%**

Age	Health Utility Cost	Mortality Cost	Healthcare Cost	Private Cost (fully insured)	Private Cost (uninsured)	Breakeven Value of $N$ (fully insured) (weeks)	Breakeven Value of $N$ (uninsured) (weeks)
20	\$578	\$1,473	\$296	\$2,051	\$2,347	7.0	7.5
30	\$641	\$4,096	\$916	\$4,737	\$5,653	9.5	10.7
40	\$666	\$7,215	\$1,159	\$7,881	\$9,040	11.9	13.1
50	\$822	\$21,791	\$3,059	\$22,613	\$25,672	28.0	31.4
60	\$940	\$46,950	\$4,359	\$47,890	\$52,249	57.2	61.7
70	\$1,140	\$60,943	\$6,842	\$62,083	\$68,925	83.8	91.6

**Table 5b. Social Cost of Self-Infection and Breakeven Values of  $N$  When Disease Severity Is Reduced by 50%**

Age	$R = 0.2$ <i>age-contained</i>		$R = 0.2$ <i>random draw</i>		$R = 0.4$ <i>age-contained</i>		$R = 0.4$ <i>random draw</i>	
	Social cost	Breakeven Value of $N$ (weeks)	Social cost	Breakeven Value of $N$ (weeks)	Social cost	Breakeven Value of $N$ (weeks)	Social Cost	Breakeven Value of $N$ (weeks)
20	\$2,934	7.9	\$6,321	13.5	\$3,912	9.5	\$12,943	24.4
30	\$7,067	11.1	\$9,627	14.0	\$9,422	13.8	\$16,249	21.6
40	\$11,300	13.5	\$13,013	15.1	\$15,067	17.0	\$19,636	21.2
50	\$32,090	32.3	\$29,645	30.1	\$42,787	42.1	\$36,268	36.1
60	\$65,311	64.5	\$56,222	56.0	\$87,081	85.0	\$62,844	62.2
70	\$86,156	99.0	\$72,898	84.2	\$114,875	131.0	\$79,521	91.6

Age	$R = 0.6$ <i>age-contained</i>		$R = 0.6$ <i>random draw</i>		$R = 0.8$ <i>age-contained</i>		$R = 0.8$ <i>random draw</i>	
	Social cost	Breakeven Value of $N$ (weeks)	Social cost	Breakeven Value of $N$ (weeks)	Social cost	Breakeven Value of $N$ (weeks)	Social Cost	Breakeven Value of $N$ (weeks)
20	\$5,869	12.7	\$27,753	48.9	\$19,562	35.3	\$67,486	114.6
30	\$14,133	19.2	\$33,263	41.2	\$47,111	57.1	\$72,996	86.8
40	\$22,600	24.0	\$38,907	39.1	\$75,334	72.9	\$78,641	75.9
50	\$64,180	61.6	\$66,627	63.9	\$213,933	198.5	\$106,361	100.2
60	\$130,622	126.1	\$110,922	107.5	\$435,407	413.2	\$150,655	144.9
70	\$172,312	195.0	\$138,715	157.5	\$574,374	642.9	\$178,449	201.8

**Table 6a. Private Cost of Self-Infection and Breakeven Values of  $N$  With Aldy-Viscusi VSL Estimates**

Age	Health Utility Cost	Mortality Cost	Healthcare Cost	Private Cost (fully insured)	Private Cost (uninsured)	Breakeven Value of $N$ (fully insured) (weeks)	Breakeven Value of $N$ (uninsured) (weeks)
20	\$1,156	\$2,027	\$593	\$3,183	\$3,776	9.1	10.3
30	\$1,282	\$5,665	\$1,833	\$6,948	\$8,780	12.5	15.0
40	\$1,332	\$9,773	\$2,318	\$11,104	\$13,422	15.5	18.1
50	\$1,644	\$37,167	\$6,117	\$38,811	\$44,928	46.1	52.7
60	\$1,879	\$123,473	\$8,718	\$125,352	\$134,070	146.2	154.1
70	\$2,280	\$218,601	\$13,683	\$220,881	\$234,564	296.8	307.4

**Table 6b. Social Cost of Self-Infection and Breakeven Values of  $N$  With Aldy-Viscusi VSL Estimates**

Age	$R = 0.2$ <i>age-contained</i>		$R = 0.2$ <i>random draw</i>		$R = 0.4$ <i>age-contained</i>		$R = 0.4$ <i>random draw</i>	
	Social cost	Breakeven Value of $N$ (weeks)	Social cost	Breakeven Value of $N$ (weeks)	Social cost	Breakeven Value of $N$ (weeks)	Social Cost	Breakeven Value of $N$ (weeks)
20	\$4,720	10.8	\$17,106	31.3	\$6,294	13.4	\$39,323	68.0
30	\$10,975	15.6	\$22,110	28.4	\$14,634	19.8	\$44,327	53.9
40	\$16,778	18.6	\$26,752	27.8	\$22,370	23.7	\$48,968	48.4
50	\$56,160	54.3	\$58,258	56.2	\$74,880	71.4	\$80,474	76.5
60	\$167,587	160.9	\$147,400	141.9	\$223,450	213.5	\$169,616	162.8
70	\$293,205	329.6	\$247,894	279.2	\$390,940	438.5	\$270,111	303.9

Age	$R = 0.6$ <i>age-contained</i>		$R = 0.6$ <i>random draw</i>		$R = 0.8$ <i>age-contained</i>		$R = 0.8$ <i>random draw</i>	
	Social cost	Breakeven Value of $N$ (weeks)	Social cost	Breakeven Value of $N$ (weeks)	Social cost	Breakeven Value of $N$ (weeks)	Social Cost	Breakeven Value of $N$ (weeks)
20	\$9,441	18.6	\$83,756	141.5	\$18,882	34.2	\$217,054	361.9
30	\$21,950	28.2	\$88,759	104.9	\$43,901	53.4	\$222,058	257.9
40	\$33,555	34.1	\$93,401	89.6	\$67,110	65.2	\$226,700	213.2
50	\$112,320	105.6	\$124,907	117.1	\$224,641	208.3	\$258,206	238.9
60	\$335,175	318.8	\$214,049	204.7	\$670,349	634.5	\$347,348	330.2
70	\$586,410	656.3	\$314,543	353.4	\$1,172,821	1,309.5	\$447,842	501.9

**Table 7. Breakeven Values of  $N$  With Weekly Unemployment Benefit of \$600**

<b>Age</b>	<b>Breakeven Value of <math>N</math> (fully insured) (weeks)</b>	<b>Breakeven Value of <math>N</math> (uninsured) (weeks)</b>
20	—	—
30	57.9	68.5
40	50.7	57.7
50	134.5	152.3
60	296.6	323.3
70	577.8	641.2