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ARTICLE

Aggregate health shock and retirement decision†

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Abstract

The retirement of old workers increased during the COVID-19 pandemic, and health concerns are considered to be a critical factor. To understand the effect of pure health concerns during the pandemic, we analyze the impact of the aggregate health shock on retirement decisions using a life cycle model. The aggregate health shock changes the economy from the normal state to the pandemic state, where the probability of adverse idiosyncratic health shock increases, especially if agents are working. Simulation results suggest that the shock accelerates the retirement of agents aged over 60. The increase in retirement is significant even though the shock is expected to be temporary. Also, the effect hinges on the assumption that working poses a greater risk of receiving a negative health shock than retiring. Even accounting for the large income and wealth changes that US households experienced in 2020, a counterfactual experiment suggests that the aggregate health shock plays a prominent role in increasing retirement.

Keywords: Retirement; health shock; COVID-19; life cycle model

JEL Classification: J26; I18; E24

1. Introduction

The COVID-19 pandemic accompanied many adverse economic outcomes. One among them is the contraction of the labor supply, especially that of older households. According to US Current Population Survey, while the labor force participation rate of all ages dropped from 63.1 percent in 2019 to 61.7 percent in 2021, the rate for ages 55 and over declined more distinctively, from 40.2 percent in 2019 to 38.4 percent in 2021.

Recent research suggests that an increase in retirement is an essential factor in older households' labor supply contraction during the pandemic. Nie and Yang (2021) indicate that the share of retirees in the US population increased sharply during the pandemic, as is shown in Figure 1(a). This pattern contrasts with the Great Recession, when the share remains relatively stable. According to Davis (2021a), this increase in retirement is mainly driven by the higher transition from employment and unemployment to retirement and the lower transition from retirement to employment (Figure 1(b)).

This surge in retirement has several economic implications, and some of them may have lingering effects on the economy even after the pandemic. Because retired households are less likely to return to work than those in the labor force, it may delay the recovery of the labor supply in the future. A higher retirement rate will likely induce a financial burden for social security and pension funds because of reduced contributions and a higher expected number of beneficiaries. Also, it may have welfare implications considering a significant portion of those retirements are

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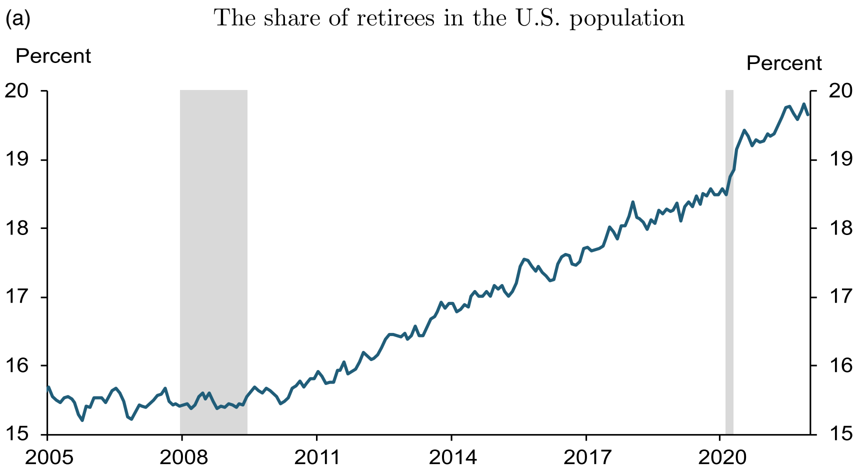
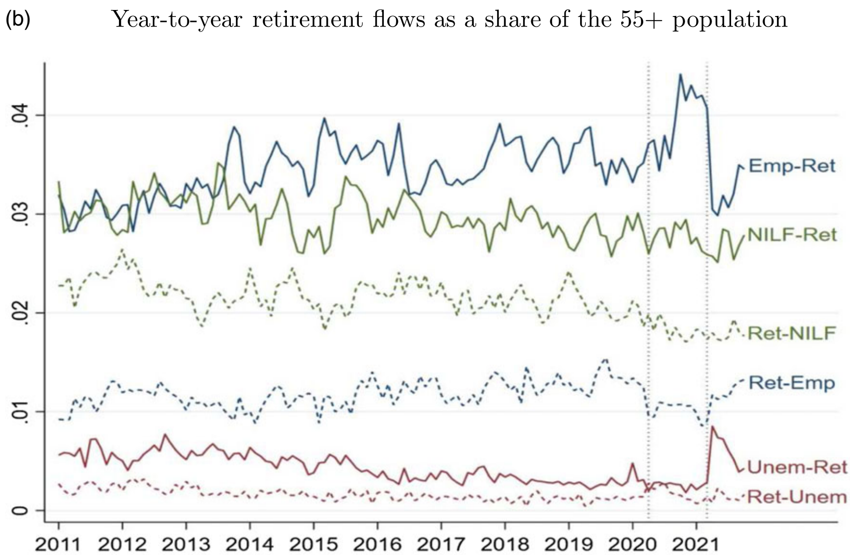


Source: Nie and Yang (2021).



Source: Davis (2021a).

Figure 1. Retirement trends.

involuntary, as COVID-19 deteriorates older workers' health conditions to force them to exit or tighter labor market conditions drive them to retire.

Although several factors are believed to contribute to the increase in retirement, the one that uniquely stands out during this pandemic is related to health concerns. According to Goldman Sachs (2021) Retirement Survey and Insight Reports, 51 percent of respondents retired earlier than expected, and health reasons (24 percent) were the top reason for their retirement. Faria-e Castro (2021), Nie and Yang (2021) point out that health concerns provide natural explanations for a higher retirement rate as older people are more vulnerable to COVID-19 and thus motivated to leave the workforce facing the severe risk of infection at work. Davis (2021b) also suggests that retirement increased significantly in jobs with high physical proximity to others, implying that health concerns play an important role in the retirement decision.

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In this regard, our study analyzes the impact of aggregate health shock, which can characterize such events as the COVID-19 pandemic, on older households' retirement decisions. It is challenging to empirically identify this effect because the pandemic simultaneously brought several other "shocks." For example, as well as a heightened health risk, workers faced a significant reduction in labor income, much tighter labor market conditions, and a possible increase in wealth due to the rallies in stock and housing markets. Isolating the effect of the health shock on retirement among those compounding factors is not easy.

Therefore, to investigate this question, we take a structural approach by using a life cycle model in which agents value health in their preference, face the mortality risk, and are entitled to receive social security benefits such as retirement and disability benefits. Agents may receive an adverse idiosyncratic health shock each period, and they can invest in health to maintain health conditions. Health insurance helps agents reduce health investment spending. Agents may have health insurance tied to the job, retiree health insurance, or no health insurance. The aggregate health shock is then defined as a shock that changes the nature of the economy to the one with a higher probability of receiving idiosyncratic health shock ("pandemic" state), especially if the agent is working. Specifically, we assume that the aggregate health shock increases the probability of idiosyncratic health shock compared to the normal state by the risk ratio of 1.3 if the agent is working and 1.1 if not working. After the aggregate health shock occurs, agents place positive probabilities on both scenarios that (1) the economy reverts to a normal state in the next period and (2) it remains in the pandemic state.

Our simulation results suggest that the aggregate health shock substantially speeds up the retirement of agents aged over 60. Especially, the increase in retirement is significant at ages 60–64 when agents become eligible to receive pensions, and at ages over 70, when agents are more sensitive to health because of their higher mortality risk. By comparing to another counterfactual economy that features the income shock, we find that the effect of the aggregate health shock on retirement is quantitatively more significant than the effect induced by a five percent reduction in labor income, which is comparable to income loss during the Great Recession.

Given the aggregate health shock, non-college and college agents experience similar increases in retirement. However, responses are more significant for tied and retiree insurance groups than the no insurance group. This finding can be interpreted that tied and retiree insurance groups, with their income comparably higher than no insurance group, are in better financial shape to retire, facing heightened health risk.

The effect of the aggregate health shock on retirement is significant even though the shock is expected to be temporary; that is, agents know the pandemic will disappear the next year. It is more difficult for older agents to regain health status once it declines to a bad state than young ones. Thus, even a temporary shock has a significant implication for agents in the "marginal" age who contemplate and make retirement decisions. Also, the effect of the aggregate health shock hinges on the assumption that working poses a greater risk of receiving a negative health shock than retiring. If the shock provides the same health risk between working and retirement, retirement no longer offers additional benefits to agents, and retirement decisions are barely affected.

During the COVID-19 pandemic, extensive government relief packages and loose monetary policy led household post-tax income and wealth to rise, despite reduced labor income. In a counterfactual experiment featuring large income and wealth changes the US household experienced in 2020, we still find that the aggregate health shock plays a prominent role in increasing retirement.

1.1. Literature review

Various factors are known to affect retirement decisions. Coile (2015) surveys the economic factors that affect retirement decisions, such as social security, pension, and wealth. Empirical research generally acknowledges pension benefits as a key determinant for retirement decisions.

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One piece of evidence is the spike in retirement at the early eligibility age of the pension (age 62 for the USA), remarked by Burtless and Moffitt (1986), and Costa (1998). Also, studies find that various measures of pension benefits, such as social security wealth (present discount value of pension benefit) and peak value (the financial gain from working to the future retirement date that maximizes social security wealth), are positively associated with retirement. (Mitchell and Fields (1982), Coile and Gruber (2001), Coile and Gruber (2007)). Moreover, pension reforms, for example, delaying retirement age and redesigning payment schemes, can increase the labor participation of older people (Gruber and Wise (2004), Hanel and Riphahn (2012), Staubli and Zweimüller (2013), Laun and Wallenius (2015)) which is another evidence that pension benefits influence retirement decisions.

The empirical evidence of the relationship between workers' wealth and retirement decisions is mixed. A large, sudden increase in wealth from lottery gains (Imbens et al. (2001)) or inheritance (Brown et al. (2010)) can encourage retirement. However, Coile and Levine (2006), Hurd et al. (2009) find little relationship between stock market gains and retirement behavior. Also, Gorodnichenko et al. (2013) find no significant impact on housing prices on retirement timing.

As for macroeconomic factors, adverse job market conditions discourage labor supply in general, inducing older workers into retirement. For example, Coile and Levine (2007), Hallberg (2011), Gorodnichenko et al. (2013) find that the transition to retirement increases when the labor market is tight.

Among noneconomic factors, health is considered a critical determinant of retirement. Using various measures of health, Hall and Johnson (1980), Diamond and Hausman (1984), Anderson and Burkhauser (1985), Berkovec and Stern (1991), Disney et al. (2006) find that bad health is a significant determinant that increases the probability of retirement or planned retirement age. McClellan (2007) also finds that adverse health shocks, such as heart attack or cancer diagnosis, can induce workers to retire. Retirement decision is also affected when health insurance is linked with jobs. Madrian (1994) and Rogowski and Karoly (2000) suggest empirical findings that workers with retiree health insurance do retire early. The result from structural approaches such as Laun and Wallenius (2016) also supports this finding.

This study is also related to the literature that studies the change in labor supply during the COVID-19 pandemic. The pandemic caused a sharp contraction in overall employment. While labor demand was hampered by lower economic activities, especially in the sectors related to social contact, a significant reduction in labor supply was also documented. For example, Brinca et al. (2021) estimate the contribution of labor supply and demand shocks during the pandemic and find that labor supply shock played a more significant role in hour contraction than labor demand shock. Also, Albanesi and Kim (2021) stress the role of reduced labor supply during the pandemic, especially that of women. The increase in retirement is one of the vital phenomena associated with this labor supply contraction (Nie and Yang (2021); Davis (2021b)).

As mentioned earlier, while it is not easy to identify the effect of health concerns on retirement among other socioeconomic factors during the pandemic, our study is the first to present a quantitative result that pure health concerns during the pandemic can significantly accelerate old workers' retirement. Our contribution also extends to the finding that the effect of the aggregate health shock can be significant even if agents expect that the pandemic is only temporary, and it depends mainly on the assumption that working is associated with a higher health risk than retiring. Also, we find heterogeneity across household types in their responses to greater health risks.

2. Model

This section describes our model of endogenous retirement decisions to simulate the effect of the aggregate health shock on retirement. The main structure of the model is based on the discrete-time life cycle model by Laun and Wallenius (2016), which studies the effect of social

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insurance on retirement. We additionally introduce the aggregate health shock and mortality risk to the model. The economy is populated by overlapping generations of household agents. The time interval is annual. Agents enter the economy and begin to work at age 25. The maximum age is 80, but agents face stochastic mortality risk that varies over age and health. We do not assume bequest motives. We consider different agent types concerning education (non-college and college), health insurance (none, health insurance tied on working, retiree health insurance), and the preference toward labor (high disutility, low disutility). Later, we discuss how these heterogeneous agent characteristics affect agents' responses to the aggregate health shock.

2.1. Agents

Agents are distinguished between their work preference (high and low disutility from working) and education status (non-college and college). Subscript i denotes those agent types. Lifetime utility of type i agent at the age of 25 ($t=0$) is given as

$$\sum_{t=0}^{55}\left(\Pi_{j=0}^{t}\gamma_{h,j}\right)\beta^{t}[\ln c_{i,t}-\rho(h,i,t)l_{i,t}+h_{i,t}]. \tag{1}$$

where β is a discount factor, $\gamma_{h,j}$ is health- and age-dependent survival rate, $c_{i,t}$ is consumption, and $l_{i,t}$ is a binary variable that equals one if the agent is working and zero if retired. Thus, labor hour is indivisible. Retirement is assumed to be an absorbing state; thus, agents cannot return to work once they retire. $h_{i,t}$ is the health status of the agent. $\rho(h,i,t)$ determines the level of utility loss from work, and it is affected by the agent's health condition $h_{i,t}$, the agent type i, and age t. The preference is chosen to jointly explain the health and retirement distribution across ages. Distinguishing labor preferences between high and low disutility types enables the model to match age patterns of retirement given income and health conditions, which is difficult with homogenous labor preference.

Health status is a random process that has five discrete values (5–1), (5) being the best grade, and (1) being the worst. All agents start with the best health condition when entering the economy. Negative idiosyncratic health shock hits each individual at the end of the period, affecting the next period's health status. The probability of receiving an idiosyncratic health shock differs across age and health status. Health status evolves as

$$h_{i,t+1}=h_{i,t}+I^{h}_{i,t}i^{h}_{i,t}-\epsilon^{h}_{i,t}, \tag{2}$$

where $i^{h}_{i,t}$ is an indicator variable that has value one if the agent conducts health investment and zero otherwise, and $I^{h}_{i,t}$ is a random variable that has value one if the investment is effective and zero otherwise. Therefore, there is a health gain of one grade only if $I^{h}_{i,t}i^{h}_{i,t}=1$; that is, health investment is performed and turns out to be effective.

$\epsilon^{h}_{i,t}$ is an exogenous idiosyncratic health shock which takes discrete values of $\{\bar{\epsilon}_h,\bar{\epsilon}_l,0\}$ where $\bar{\epsilon}_h>\bar{\epsilon}_l$. This specification means that $\epsilon^{h}_{i,t}$ harms one's health seriously (high shock), mildly (low shock), or does not affect at all. The size of the health shock is set such that the high shock lowers the health status by three levels, and the low shock lowers it by one level. That is, $\{\bar{\epsilon}_h,\bar{\epsilon}_l,0\}=\{3,1,0\}$.

Period budget constraint of the agent is given by

$$(1+\tau_c)c_{i,t}+k_{i,t+1}-(1+r)k_{i,t}+p^{h}_{i,t}i^{h}_{i,t}=[1-\tau_l(y_{i,t})]w_{i,t}l_{i,t}+DB_{i,t}-c^{DB}_{i,t}+RB_{i,t}. \tag{3}$$

where $k_{i,t}$ is capital which is the only saving instrument, r is the real interest rate, $p^{h}_{i,t}$ is the cost of health investment, and $w_{i,t}$ is wage. τ_c is the consumption tax rate, $\tau_l(y_{i,t})$ is the income tax rate which progressively depends on the level of labor income ($y_{i,t}=w_{i,t}l_{i,t}$). $DB_{i,t}$ is the disability

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insurance benefits and $c^{DB}_{i,t}$ is the cost of applying the disability insurance benefits. $RB_{i,t}$ is the social security retired benefits. Borrowing is not allowed; thus, $k_{i,t} \geq 0\ \forall i, t$.

The above agent problem can be reformulated as a recursive form,

$$V(x) = \max_{c,k',i^h,l,a^{DB},a^{RB}} u(c,l,h) + \beta EV(x') \tag{4}$$

subject to

$$(1+\tau_c)c + k' - (1+r)k + p^h(x)i^h = [1-\tau_l(x)]w(x)l + DB(x) - c^{DB}(x) + RB(x),\ k' \geq 0. \tag{5}$$

where x represents the set of individual states, which is given by $x = \{i, t, h, k, t^R, t^{DB}, t^{RB}, AIME\}$. i is the agent type, t is the age, h is health status, k is capital, t^R is the age of retirement if the agent is retired, t^{DB}, t^{RB} are the ages that he claimed disability benefit and retirement benefit if receiving, respectively. *AIME* stands for *Average Indexed Monthly Income*. *AIME* is the reference income for social security benefits and is accumulated according to the agent's labor income during their working years. Details about *AIME* will be discussed in the following subsection. Given these individual states, agents make optimal decisions about consumption c, next period's saving k', health investment i^h, working l, applying for disability benefit a^{DB}, applying for retirement benefit a^{RB}.

Calculating the next period's expected value, $EV(x')$ in equation (4) requires the evaluation of the value function under two layers of uncertainty: individual health uncertainty and aggregate health uncertainty. Individual health uncertainty arises because of the idiosyncratic health shock $\epsilon^h = \{\bar{\epsilon}_h, \bar{\epsilon}_l, 0\}$, of which the individual state-dependent probability $\mathbb{P}(x) = \{p_h(x), p_l(x), 1 - p_h(x) - p_l(x)\}$ is given. Once the aggregate health shock hits the economy, the nature of the economy changes to the pandemic state, and the probability of the health shock is reset to $\mathbb{P}'(x) = \{p'_h(x), p'_l(x), 1 - p'_h(x) - p'_l(x)\}$. Agents know that they are in the pandemic state, and they also place a positive probability (p^A) on the case that the next period is in the pandemic state. That is, they expect the next period to be the normal state with the probability $1 - p^A$ and the pandemic state with the probability p^A.

2.2. Social security and tax system

The social security system consists of retirement benefits and disability insurance benefits. The retirement benefit is indexed to *AIME*. The calculation of *AIME* is based on the individual's 35 highest years of earnings. Before the agent's working span reaches 35 years, *AIME* accumulates as

$$AIME_{i,t+1} = AIME_{i,t} + \frac{w_{i,t}l_{i,t}}{35} \quad \text{if} \quad 0 \leq t < 35. \tag{6}$$

If the agent works more than 35 years, *AIME* increases only when the labor income of the additional year exceeds the current *AIME*.

$$AIME_{i,t+1} = AIME_{i,t} + \max\left[0, \frac{w_{i,t}l_{i,t} - AIME_{i,t}}{35}\right] \quad \text{if} \quad t \geq 35. \tag{7}$$

The retirement benefit is determined based on a piecewise linear function of *AIME*, the Primary Insurance Amount (*PIA*).

$$PIA_{i,t} = \begin{cases} 0.9AIME & \text{if} \quad AIME \in [0, b_1), \\ 0.9b_1 + 0.32(AIME - b_1) & \text{if} \quad AIME \in [b_1, b_2), \\ 0.9b_1 + 0.32(b_2 - b_1) + 0.15(AIME - b_2) & \text{if} \quad AIME \in [b_2, \infty). \end{cases} \tag{8}$$

Agents are eligible to claim retirement benefits once they are 62 years old. Agents can collect the benefit even though they are still working. Also, they can choose to delay the benefit even if they are retired. There is a penalty if they claim it before the full retirement age of 65, but additional credit if they delay claiming after 65. This specification implies that the actual retired benefit is defined as $RB_{i,t} = \delta_{i,t}PIA_{i,t}$, where the value of $\delta_{i,t}$ is less than one before age 65, one at 65, greater than one after 65.

Disability benefit is also a function of the agent's previous labor income. It is transferred to retirement benefits after age 65. Agents cannot return to work status once they start receiving disability benefits. When agents apply for disability insurance, the probability of actually receiving the benefit is less than one and is a function of age and health status. There is a cost in applying for the benefit regardless of the application's success.

The government collects two types of tax from agents: consumption tax (τ_c) and income tax (τ_l). Consumption tax is a flat-rate tax, and income tax is a progressive tax based on labor income. Those tax revenues are used to finance retirement and disability benefits, and the remaining revenues are used for government purchases of public goods.

3. Calibration and model solution

3.1. Model parameters

This section discusses the parameter calibration of the model. Parameters for agent preference, individual health process, and disability insurance system are calibrated similarly to the US calibration of Laun and Wallenius (2016).[1] Regarding stochastic mortality design, the baseline death rate for each age is taken from Murphy et al. (2021). As the actual death rate is near zero under age 50, we assign a zero death rate for agents under age 50. For agents whose age is 50 or higher, we assume that the mortality rate is higher if they are in bad health status, as their death rate is assigned to be 1.5 times the baseline death rate. If agents are in good health, the death rate is 0.875 times the baseline rate. These values will yield a weighted average death rate identical to the baseline rate when the population consists of 80 percent good and 20 percent bad health agents. The annual real interest rate is set at 3%. Discount factor β is set at 0.996. Using the baseline survival rate (γ_t=1-death rate), the average value of the mortality-adjusted discount factor ($\gamma_t\beta$) over age 50 is 0.979.

As mentioned in Section 2.1, there are five discrete health grades. Here we classify the top three grades as "good health" and the lower two as "bad health." $\rho(h, i, t)$, the relative degree of disutility from work, differs across health status(good and bad), type, and age. Disutility from working is greater when agents are in bad health conditions than they are in good status. Agent type is distinguished between work preference (high and low disutility) and education status (non-college and college). Moreover, we assume that disutility from labor increases with age. Therefore, agents receive higher disutility from working if they are high disutility type, older, and in bad health status. Combining these factors yields various values for $\rho(h, i, t)$. The specific values of $\rho(h, i, t)$ are calibrated to match the sample retirement rate across age and education groups. Specifically, we set different parameter values for each education, health, and labor preference type and multiply those values by the age-specific labor preference scale, which varies between 0.6 (age 25) and 1 (age 80). Additionally, to match the retirement rate, we assume that college and non-college workers have 45 percent high disutility type and 55 percent low utility type.

College and non-college agents also differ in their lifetime income profiles. The lifetime labor income profile is derived by a regression model that uses wage as the dependent variable and age and its square term as regressors. The regression uses data from Luxembourg Income Study for US full-time male workers between 25 and 62 and is conducted separately for college and non-college agents.

The consumption tax rate is set at 0.075 following McDaniel (2007). The income tax rate is set progressively following Guvenen et al. (2013) process. This process uses a regression model that

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assigns the tax rate as the dependent variable and different proportions of average wage earnings as regressors. US labor income tax data from the OECD tax database are used for estimation. In the model, half of the social security benefits are counted toward total taxable income, but social security benefits are exempt from tax if total taxable income is below $25, 000.

$p^h_{i,t}$ the cost of health investment is calibrated to match health expenditure by health insurance type and work status. For the agents with no health insurance, their health investment cost is the same regardless of their work status, and they spend more money on health than those covered by health insurance. However, agents aged 65 or higher are covered by Medicare; thus, their payment is reduced. Agents covered with tied health insurance face increased health costs when they retire before age 65, but the worker/non-worker health cost gap decreases for those over 65 because of Medicare. Agents covered with retiree health insurance pay the lowest health cost in general. Retirement increases their health cost, but by a minor degree compared to those with tied health insurance. The proportion of workers covered by no, tied, retiree health insurance in each education group is set to follow Laun and Wallenius (2016).

The probability of idiosyncratic health shock, the success rate of health investment, that of disability insurance application, and the cost of disability insurance application are jointly calibrated to match the health distribution, the application rate for disability insurance, the incidence of disability benefit claimers, and the incidence of type 1 and 2 errors in granting disability benefits by age and education.

The probability of idiosyncratic health shock varies by age, health status, and education status. It is lower if the agent is young, in good health status, and has a college education. The difference of probability by a college education is to capture empirical findings that non-college workers are in worse health and have high disability incidences. The agents with good health conditions have a 2.5 percent chance of receiving the high shock and 13–54 percent of the low shock, depending on age and education. The agents with bad health conditions have 10 percent of receiving the high shock and have the same probability of the low shock as the 80 years old agents with good health. The probability of success in health investment similarly depends on age and health status, as it is higher when the agent is young and in good health condition.

Disability benefit is awarded conditionally on the application if the agent is in bad health, with a probability of 15 percent. There is a cost in applying for a disability benefit if the agent is currently non-retired to capture the earning loss arising from the requirement to stop working to apply for disability insurance. This cost is set at 40 percent of the agent's labor income. Table 1 summarizes the parameter calibration of the model.

Table 2 compares the retirement rate, disability benefit claimer proportion, and the health status distribution of the model and data before the COVID-19 pandemic. The retirement rate is defined as the proportion of retirees in the total population. Those numbers are calculated separately for college and non-college workers and classified by age groups. The model generally matches the retirement rate well in data for each education and age group, especially for ages over 60, which we mainly analyze. In line with the literature, educational attainment matters in the retirement decision: non-college agents tend to retire earlier than college agents. The model also predicts a similar proportion of disability benefit claimers and similar health distribution shown in the data.[2] The health conditions of non-college agents are generally worse than those of college agents, which leads to a higher proportion of disability benefit claimers.

3.2. Aggregate health shock

We define the aggregate health shock to mimic health deterioration in the aggregate level during the COVID-19 pandemic. It increases the probability of receiving negative idiosyncratic health shock at the end of the period to capture a higher likelihood of contagion during the pandemic. Also, this probability is even higher if agents are working because they are likely to engage in more physical contact and thus are more exposed to infection risk. We assume that the probability of

Table 1. Calibrated parameters

Parameter	Value
Real interest rate	0.03
Baseline survival rate	0.949–1
Utility parameters	
Discount factor	0.996
Disutility from work when:	
Non-college, good health, and low disutility type	1.6
Non-college, bad health, and low disutility type	2.65
Non-college, good health, and high disutility type	2.45
Non-college, bad health, and high disutility type	3.4
College, good health, and low disutility type	1.45
College, bad health, and low disutility type	2.44
College, good health, and high disutility type	2.225
College, bad health, and high disutility type	3.25
Age-specific labor preference scale	0.6-1
Disabled insurance (DI) parameters	
Cost of applying for DI	0.4
Probability of receiving DI, bad health	0.15
Probability of receiving DI, good health	0
Health parameters	
Decrease in health from low shock	1
Decrease in health from high shock	3
Probability of low shock, good health, non-college	0.42–0.54
Probability of low shock, good health, college	0.13–0.39
Probability of low shock, bad health, non-college	0.54
Probability of low shock, bad health, college	0.39
Probability of high shock, good health	0.025
Probability of high shock, bad health	0.1
Probability of health investment being effective, good health	0.8–0.9
Probability of health investment being effective, bad health	0.25–0.3

infection for retirees, controlling for health status and health insurance as in our model, would be lower than workers.

Among the researches that study occupational infection risk of COVID-19, Chen et al. (2021), using California Department of Public Health data, report that during March through November 2020, the excessive mortality ratio compared to expected mortality is 1.22 for the total population, 1.12 for non-essential workers, and 1.25 for unemployed/missing information. This result clearly suggests that the overall health risk elevated during the pandemic. However, because unemployed are likely to be in worse health conditions, also financially more constrained to afford medical care, and as Chen et al. (2021) do not control for such factors, we cannot directly interpret this result as unemployed having a higher risk of adverse health shock. Another study, Mutambudzi et al. (2021), using UK Biobank data and controlling for individual characteristics, reports that essential workers, classified by healthcare workers, social and education workers, and other essential workers, have a higher risk of severe COVID-19 relative to non-essential workers by 7.43, 1.88, 1.15 times, respectively. If we assume that the infection risk of retirees is similar to that of

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Table 2. Calibrated economy and sample data (percent)

(a) Retirement rate					
Non-college			College		
Age	Model	Data	Age	Model	Data
50–54	4.2	3.5	50–54	3.0	3.0
55–59	10.0	8.5	55–59	4.8	9.0
60–64	26.4	25.9	60–64	21.4	24.2
65–69	59.9	59.3	65–69	53.0	53.6
70–74	77.6	76.0	70–74	72.6	71.4
(b) Disability benefit claimer proportion					
Non-college			College		
Age	Model	Data	Age	Model	Data
50–54	4.2	8.7	50–54	3.0	3.4
55–59	10.0	10.0	55–59	4.6	4.6
60–64	11.7	11.2	60–64	5.3	4.6
(c) Health distribution, good health status					
Non-college			College		
Age	Model	Data	Age	Model	Data
50–54	81.9	81.4	50–54	90.8	91.9
55–59	78.7	77.8	55–59	89.3	89.5
60–64	75.7	75.0	60–64	87.7	87.4
65–69	72.7	71.1	65–69	86.2	86.7
70–74	69.8	70.6	70–74	84.8	84.2

Note: In (a), the retirement rate is the proportion of retirees in the total population. In (c), good health status stands for the best three states.
Data Source: Current Population Survey (2019) for retirement rate and health distribution, Health and Retirement Study (2004) for disability benefit claimer proportion.

non-essential workers, and apply the population share of essential and non-essential workers in the total workforce, workers on average have a higher risk than retirees by about 1.7 times.

We take a conservative approach and calibrate the risk ratio, defined by the ratio of the pandemic state probability of the idiosyncratic health shock to the normal state probability, to be 1.3 for workers and 1.1 for non-workers. In other words, the risk of adverse health shock, whether the shock is high or low, increases by 1.3 times for workers and 1.1 times for non-workers during the pandemic compared to the normal state.

3.3. *Model solution and simulation*

Given the individual set of states $x = \{i, t, h, k, t^R, t^{DB}, t^{RB}, AIME\}$, the policy space for the next period's saving k' is discretized, to evenly spaced grid points between $[0, \bar{k}_{max}]$ where $\bar{k}_{max}$ is set differently for each individual type. The distance between grid points is set as 850. Agents know their state at the beginning of the period and optimally choose their policy $\left\{c, k', i^h, l, a^{DB}, a^{RB}\right\}$. Among choice variables, consumption is determined as a residual.

The value function at age 81 is known, and the value and policy functions under age 81 are determined by the backward induction method. We assume that retirement, disability benefit

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claim, and retirement benefit claim are absorbing states. Depending on age, agents face different disability insurance and pension application options. For example, agents have the opportunity to retire at any time, but retirement benefit application is only available to agents at least 62 years old. Also, one cannot apply for the disability benefit after age 65. Consumption choice is calculated as a residual arising from each value combination of the other choice variables. Given individual states, we calculate the lifetime utility for each combination of choices and choose the optimizing one as a policy function. The resulting value function is used to calculate the value function of the previous age.

After solving the value and policy functions, we simulate the model economy using baseline calibration, where agents make decisions given that the probability of health shock will remain normal until they die. There are 56 age cohorts from age 25 to 80. Each age cohort has 5,000 individual agents. Each cohort enters the economy as 25 years old; thus, agents at age 26 are those who entered the economy one year ago, and agents at age 80 are those who entered the economy 55 years ago. An individual health shock hits each agent at the end of each period. This provides idiosyncratic uncertainty in the model.

We also simulate a counterfactual economy where unanticipated aggregate health shock hits the economy. Agents in age cohort j, $j = 26, \ldots, 80$ behave the same way as the baseline economy until age $j - 1$, and agents in cohort $j = 25$ enter the economy. They receive the aggregate health shock at age j, choose their policy, then we calculate the retirement rate of each age cohort. Their decision at age j is affected by two changes induced by the shock. First, in the pandemic state, the probability of current idiosyncratic health shock changes to $\mathbb{P}'(x) = \{p'_h(x), p'_l(x), 1 - p'_h(x) - p'_l(x)\}$, $\{p'_h(x), p'_l(x)\} = rr(x) \times \{p_h(x), p_l(x)\}$, where $rr(x)$ is the risk ratio defined in the section 3.2. Second, once in the pandemic state, there exists a positive probability (p^A) that the next period is again the pandemic state where the probability of health shock remains at $\mathbb{P}'(x)$. This assumption provides persistency to the aggregate health shock. However, agents believe that once the economy returns to the normal state with the probability 1-p^A, the pandemic does not recur. We assign a small but meaningful probability to the continuation of the pandemic by setting $p^A = 0.2$. Later, we also analyze the case in which the aggregate health shock is expected to be temporary or more persistent, as setting $p^A = 0$ or $p^A = 0.4$, respectively.

4. Results

In this section, we compare the retirement decision of the baseline economy and the economy hit with the aggregate health shock. As a benchmark, we also show the retirement response of the economy hit with the labor income shock. The income shock is defined as a five percent reduction in current labor income. This magnitude of the income shock is comparable to income loss during the Great Recession when the US real median household income decreased by about seven percent during 2008–2010. Similar to the assumption made for the aggregate health shock, once the income shock realizes, there is a 20 percent chance that it will remain the following year.

Table 3 compares the retirement rate of each model by age and educational attainment. Our simulation predicts that agents facing health and income shocks retire earlier than the baseline model. The aggregate health shock, which increases the workers' risk ratio to 1.3, has a more substantial impact on retirement decisions than the income shock for both college and non-college agents. The surge in retirement is the strongest at age 60–64 when agents become eligible to receive the pension. In this age group, retirement increases by about 20 percentage points for both non-college and college agents. The age group 70–74 also strongly respond, as non-college and college agents increase retirement by about 13 and 18 percentage points, respectively. As their mortality risk is relatively high, they become more sensitive to health risks. Meanwhile, the increase in the retirement of age 65–69 is modest compared to the previous two age groups. On the other hand, a five percent reduction in labor income increases retirement to a minor degree, the largest response being 7 percentage points by college agents aged 60–65.

Table 3. Retirement rate by age and education (percent)

Non-college				College			
Age	Baseline	Health	Income	Age	Baseline	Health	Income
50–54	4.2	4.8	4.4	50–54	3.0	3.5	3.1
55–59	10.0	13.1	10.0	55–59	4.8	6.9	5.1
60–64	26.4	45.9	27.3	60–64	21.4	40.9	28.7
65–69	59.9	67.5	60.3	65–69	53.0	57.6	53.2
70–74	77.6	90.5	80.2	70–74	72.6	90.5	78.9

Note: The retirement rate is the proportion of retirees in the total population. “Health” means the aggregate health shock that increases the probability of idiosyncratic health shock by the risk ratio of 1.1 when the agent does not work and 1.3 when the agent works. The probability that the health process reverts to normal in the next period is 80%, and the probability that the current situation continues is 20%. “Income” means the income shock that decreases current labor income by 5%. The probability that labor income reverts to normal in the next period is 80%, and the probability that the current situation continues is 20%.

Table 4. Retirement rate by age and preference (percent)

(a) Low disutility type							
Non-college				College			
Age	Baseline	Health	Income	Age	Baseline	Health	Income
50–54	0.4	1.4	0.7	50–54	0.7	1.5	0.9
55–59	5.8	7.2	6.0	55–59	1.6	3.1	1.8
60–64	9.8	20.2	10.4	60–64	5.2	11.4	5.9
65–69	27.0	41.0	27.8	65–69	14.6	22.9	14.9
70–74	59.2	82.7	64.0	70–74	50.2	82.8	61.6
(b) High disutility type							
Non-college				College			
Age	Baseline	Health	Income	Age	Baseline	Health	Income
50–54	8.8	8.9	9.0	50–54	5.8	5.8	5.7
55–59	15.1	20.4	14.8	55–59	8.8	11.6	9.2
60–64	46.6	77.3	47.9	60–64	41.3	77.1	56.7
65–69	100.0	100.0	100.0	65–69	100.0	100.0	100.0
70–74	100.0	100.0	100.0	70–74	100.0	100.0	100.0

Note: The retirement rate is the proportion of retirees in the total population. “Health” means the aggregate health shock that increases the probability of idiosyncratic health shock by the risk ratio of 1.1 when the agent does not work and 1.3 when the agent works. The probability that the health process reverts to normal in the next period is 80%, and the probability that the current situation continues is 20%. “Income” means the income shock that decreases current labor income by 5%. The probability that labor income reverts to normal in the next period is 80%, and the probability that the current situation continues is 20%.

Table 4 reports the retirement rate by age and types of disutility. Both high and low disutility groups significantly respond to the aggregate health shock. However, the age agents respond the most varies between agent types. The low disutility group, whose retirement rate is relatively low, shows the most significant response at age 70–74, as retirement increases by about 20 percentage points for non-college agents and 30 percentage points for college agents. On the other hand, the high disutility group, whose retirement is completed before age 65 even in the baseline model, exhibits the largest response at age 60–64. In this age group, retirement increases by about 30 percentage points for both non-college and college agents. This result suggests that the significant

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Table 5. Retirement rate by age and health insurance type (percent)

(a) No insurance							
Non-college				College			
Age	Baseline	Health	Income	Age	Baseline	Health	Income
50–54	3.9	4.2	4.1	50–54	2.5	3.0	2.5
55–59	7.7	10.1	8.1	55–59	3.8	5.2	3.8
60–64	19.5	35.0	19.6	60–64	14.6	28.4	14.9
65–69	58.1	61.7	58.7	65–69	51.7	52.9	51.7
70–74	62.6	69.1	62.4	70–74	55.0	59.0	55.3
(b) Tied							
Non-college				College			
Age	Baseline	Health	Income	Age	Baseline	Health	Income
50–54	3.9	4.4	4.0	50–54	2.8	3.3	2.8
55–59	10.1	12.5	9.9	55–59	4.6	6.3	5.0
60–64	22.9	42.7	23.5	60–64	16.2	37.5	24.2
65–69	60.3	68.4	60.5	65–69	53.0	57.6	53.1
70–74	78.4	94.9	85.4	70–74	73.3	92.8	77.7
(c) Retiree							
Non-college				College			
Age	Baseline	Health	Income	Age	Baseline	Health	Income
50–54	4.5	5.4	4.9	50–54	3.1	3.7	3.3
55–59	11.2	15.4	11.0	55–59	5.2	7.6	5.4
60–64	32.5	54.2	34.0	60–64	25.6	44.8	33.5
65–69	60.6	70.3	61.0	65–69	53.3	58.3	53.4
70–74	85.6	100.0	87.1	70–74	74.6	93.3	82.8

Note: The retirement rate is the proportion of retirees in the total population. “Health” means the aggregate health shock that increases the probability of idiosyncratic health shock by the risk ratio of 1.1 when the agent does not work and 1.3 when the agent works. The probability that the health process reverts to normal in the next period is 80%, and the probability that the current situation continues is 20%. “Income” means the income shock that decreases current labor income by 5%. The probability that labor income reverts to normal in the next period is 80%, and the probability that the current situation continues is 20%.

increase in the retirement of age 60–64 in Table 3 is mainly caused by high disutility agents, and low disutility agents cause that of age 70–74.

Table 5 shows the retirement rate by age and health insurance type. Differences in retirement behavior based on health insurance coverage can be substantial, as the table shows that the retiree insurance group retires earlier than other groups in general. Although the aggregate health shock increases the retirement rate of all insurance groups, the response is more substantial in tied and retiree insurance groups. For example, for ages 60–64, increases in retirement are about 20 percentage points for tied and retiree insurance groups, non-college, or college. However, the number is about 15 percentage points for the no insurance group. A similar pattern is observed in older age groups. This finding can be interpreted that tied and retiree insurance groups, with their income and accumulated wealth comparably higher than no insurance group, are in better financial shape to retire, facing heightened health risk. As for the income shock, the response is less than 10 percent for any age insurance group.

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Table 6. Retirement rate by age and education, persistency of aggregate health shock

Non-college					College				
Age	Baseline	Health	Temp	Persist	Age	Baseline	Health	Temp	Persist
50–54	4.2	4.8	4.2	5.3	50–54	3.0	3.5	2.9	3.7
55–59	10.0	13.1	12.3	13.7	55–59	4.8	6.9	6.5	8.0
60–64	26.4	45.9	44.2	47.4	60–64	21.4	40.9	37.2	41.5
65–69	59.9	67.5	66.0	69.0	65–69	53.0	57.6	56.3	58.2
70–74	77.6	90.5	90.2	90.7	70–74	72.6	90.5	88.4	90.6

Note: The retirement rate is the proportion of retirees in the total population. "Temp" represents the temporary health shock that the next period will return to normal with certainty. "Persist" stands for the more persistent health shock; the probability of getting the normal state in the next period is only 0.6, while under the "Health" shock, the world returns to the normal state with a probability of 0.8.

Our primary health shock model assumes that agents expect the world to return to the normal state in the next period with the probability of 0.8 (=1-p^A) or remain in the pandemic state with the probability of 0.2 (=p^A). If we assign different probabilities, results may change. We simulate different scenarios with various probabilities of returning to the normal state in the next period. Apart from the main probability of $p^A = 0.2$, we introduce the absolute temporary shock that the next period is back to normal with certainty ($p^A = 0$) and the (more) persistent shock that the probability of getting the normal state in the next period is only 0.6 ($p^A = 0.4$).

Table 6 summarizes the retirement rate over age given aggregate health shocks with various probabilities of reaching the normal state in the next period. Overall, assigning different probabilities does not produce significant changes in retirement behaviors for the most part. Although the effect of the shock is greater when it is more persistent, temporary health shock still generates a large increase in retirement, to a scale almost similar to baseline or persistent shock for any age-education group.[3]

The above result suggests that the outbreak of pandemic matters more than its expected persistency, at least when persistency is not particularly strong. In other words, the effect of the aggregate health shock on retirement is significant even though agents know the pandemic disappears the following year. One possible explanation is that it is more difficult for older agents to regain health status once it declines to a bad state. Therefore, even a temporary shock has a significant implication for agents in the "marginal" age who contemplate and make retirement decisions. Of course, it needs to be mentioned that we analyze the retirement response during one year that the shock is realized while differing the agents' expectations about the following year's pandemic situation. The result may differ if we examine the two-year period, and the second year is indeed realized to be pandemic again.

Apart from allowing different probabilities of getting the normal state in the next period, we further relax another assumption of our primary health shock scenario. As discussed in section 3.2, in our primary simulation with the health shock, we assume that the increased risk of idiosyncratic health shock under the pandemic differs depending on work status (the discriminative aggregate health shock). We wonder what happens if all agents receive the same high risk. We define the non-discriminative aggregate health shock that increases the risk ratio of the idiosyncratic health shock to 1.3 for all agents, meaning that non-working agents have the same high health risk as workers. Table 7 presents the simulation results of the baseline, the discriminative health shock, and the non-discriminative health shock.[4] The retirement rate given the non-discriminative health shock is almost the same as that in the baseline model. This result suggests that the impact of the aggregate health shock on retirement only appears when there is a difference in risk probabilities between workers and non-workers. In other words, the effect of the aggregate health shock hinges on the assumption that working poses a greater risk of receiving a negative health shock than retiring. If the shock provides the same health risk between working

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Table 7. Retirement rate by age and education, non-discriminative shock (percent)

Non-college				College			
Age	Baseline	Health 1	Health 2	Age	Baseline	Health 1	Health 2
50–54	4.2	4.8	4.3	50–54	3.0	3.5	3.0
55–59	10.0	13.1	10.0	55–59	4.8	6.9	4.8
60–64	26.4	45.9	26.4	60–64	21.4	40.9	21.5
65–69	59.9	67.5	60.2	65–69	53.0	57.6	53.1
70–74	77.6	90.5	77.5	70–74	72.6	90.5	72.8

Note: The retirement rate is the proportion of retirees in the total population. "Health 1" represents the discriminative aggregate health shock with the increased probability of idiosyncratic health shock, by the risk ratio of 1.1 when the agent does not work and 1.3 when the agent works. "Health 2" represents the non-discriminative aggregate health shock that all agents face the increased probability of idiosyncratic health shock by the same risk ratio of 1.3. The probability that the health process reverts to normal in the next period is 80%, and the probability that the current situation continues is 20%.

and retirement, retirement no longer offers additional benefits to agents, and the retirement rate is barely affected. This result is also consistent with empirical findings by Davis (2021b), who documents that retirement during the COVID-19 pandemic is more severe in jobs with high levels of close personal contact, although Davis (2021b) does not distinguish the effect of health concerns from other compounding factors.[5]

To sum up, our results suggest that the aggregate health shock, representing events like the COVID-19 pandemic, can accelerate workers' retirement. The effect is quantitatively more significant than that of a five percent reduction in labor income. The retirement response is most significant in age groups 60–64 and 70–74. The effect is more substantial for tied and retiree health insurance groups with higher income and accumulated wealth. The effect of the aggregate health shock is relatively consistent whether the shock is expected to be temporary or possibly be present the following year; even a temporary shock can significantly increase the retirement of old workers. Finally, those results hinge on the assumption that working is related to a greater risk of receiving negative health shock than retiring. If the shock is not discriminative, retirement behaviors remain quite the same.

4.1. Comparison to other forces during the COVID-19 pandemic

Besides the aggregate health shock mentioned earlier, the COVID-19 pandemic and policy responses by the government brought other economic developments that can affect retirement decisions. This section compares the effect of the aggregate health shock on retirement decisions to that of other economic forces during the pandemic. Specifically, focusing on the unique changes in household income and wealth caused by the pandemic and policy responses, we conduct a counterfactual experiment that includes not only the aggregate health shock but also the income and wealth changes whose scales are similar to those that occurred in 2020.

Adverse economic conditions during the COVID-19 pandemic lowered labor income in 2020. However, the US government implemented aggressive fiscal policy through stimulus payments and tax credits to help households cope with economic difficulties. The policy packages include Coronavirus Aid, Relief, and Economic Security Act (CARES Act) and the Coronavirus Response and Relief Supplemental Appropriations Act (CRRSA Act). Those packages led to an *increase* in post-tax household income in 2020, despite the reduction in labor income. Both the reduction in labor income and the increase in government transfer income can affect retirement decisions, likely to induce earlier retirement. According to the US Census Bureau (Shrider et al. (2021)), median money income, which includes regular compensation and unemployment compensation, decreased by 2.9 percent in 2020 compared to 2019. However, this number is partially affected by job losses. The concept of labor income in our model is more consistent with earnings, which

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are the sum of wage and salary income and nonfarm and farm self-employment income. Median earnings decreased by 1.2 percent in 2020. On the other hand, median post-tax household income, which includes COVID stimulus payments and tax credits, increased by 4.1 percent. One notable feature in data is that all age groups over 45 experienced similar percentage changes in income, whether money income or post-tax income.[6] In line with these estimates, we suppose homogeneous percentage changes in income for all ages. In particular, the experiment assumes pre-tax labor income decreases by 1 percent, but all households receive a government transfer equivalent to 4 percent of their post-tax income. Besides, we do not assume any changes in tax plans. If the aggregate state returns to normal in the future, incomes also revert to the original values.

Another factor that could have affected retirement decisions during the pandemic is the positive wealth shock. Mainly driven by loose monetary policy to alleviate downward pressure in real economic activities, asset markets, including stock and housing markets, experienced an enormous boom. That led to a substantial rise in household wealth in 2020. According to the US Census Bureau (Hays and Sullivan (2022)), median real wealth increased by 17.7 percent in 2020. To simplify the analysis and be consistent with the income shock structure, we assume a homogenous wealth increase of 15 percent for all age groups in the counterfactual analysis. In analyzing this wealth shock, one should consider that this significant capital gain will likely be reduced if the state of aggregate health and the economy returns to normal. However, modeling a non-permanent increase in capital price requires much complexity in our specific recursive computation scheme. Therefore, we use an alternative way to account for the capital gain by assuming agents receive a series of additional endowments, the sum of which in present discounted value equals the capital gain. This endowment is awarded annually in equal amounts until age 80. Therefore, the size of the annual endowment depends on the agent's age and assets. If the aggregate state returns to normal, asset prices are normalized and agents no longer expect this endowment.

Aggregate health shock is assumed to pose the same health risk as in the baseline analysis; that is, the probability of the health shock increases by 1.3 times for workers and 1.1 times for nonworkers during the pandemic. Considering that the earlier analysis suggests a large retirement response even from the baseline aggregate health shock, and there were considerable developments in COVID vaccines at the end of 2020, we place only a small probability for the pandemic to persist. p^A, the probability that the state remains pandemic, is set to 0.05.

Table 8 reports the retirement responses of the counterfactual experiment when the model features all shocks and it only features each of the aggregate health, income, and wealth shocks. When all shocks are present, there is a substantial increase in retirement, especially for age groups 60–64 and 70–74. Comparing the effect of each individual shock suggests that the aggregate health shock still has the most significant impact on retirement among the three shocks. On the other hand, the income shock barely affects retirement. One possible explanation is that the reduction in labor income is not significant enough to induce meaningful change in retirement decisions. The wealth shock increases retirement but to a smaller degree than the aggregate health shock. Given the wealth shock, the increase in retirement is more robust for college agents who have greater wealth and for ages 70–74 who have less remaining life and thus can utilize capital gains more aggressively. The effect of the aggregate health shock is similar to the temporary shock in Table 6 and is most significant for age groups 60–64 and 70–74.

5. Conclusion

The retirement boom of old workers during the COVID-19 pandemic can be influenced by many factors, including reduced labor income, discouraged workers facing tighter labor markets, and the wealth effect caused by strong asset markets. It is not an easy task to identify the effect of health concerns among those compounding factors. In that sense, the contribution of this study

Table 8. Retirement rate by age and education, given income and wealth changes in 2020 (percent)

(a) Non-college					
Age	Baseline	All shocks	Health only	Income only	Wealth only
50–54	4.2	5.0	4.4	4.2	4.3
55–59	10.0	13.9	12.7	9.8	10.2
60–64	26.4	47.4	44.3	26.1	26.9
65–69	59.9	71.6	66.2	59.9	60.0
70–74	77.6	94.3	90.3	77.3	79.7
(b) College					
Age	Baseline	All shocks	Health only	Income only	Wealth only
50–54	3.0	3.8	3.1	2.8	3.1
55–59	4.8	7.8	6.7	4.8	5.2
60–64	21.4	41.7	38.3	21.2	28.9
65–69	53.0	60.2	56.8	53.1	53.3
70–74	72.6	98.3	88.8	72.5	80.6

Note: The retirement rate is the proportion of retirees in the total population. “All shocks” represents the combination of aggregate health shock, income shock, and wealth shock. The aggregate health shock increases the probability of idiosyncratic health shock by the risk ratio of 1.1 when the agent does not work and 1.3 when the agent works. The income shock reduces pre-tax labor income by one percent but increases all types of post-tax income by four percent. The wealth shock increases the asset value by 15%. The probability that the health process reverts to normal in the next period is 95%, and the probability that the current situation continues is 5%.

is to present quantitative research that pure health concerns during the pandemic can significantly accelerate old workers’ retirement. Especially, retirement increases when working is more dangerous than retiring and staying home. This is consistent with empirical facts that retirement increased more distinctly in jobs with high physical proximity during the pandemic.

The above finding suggests that managing health risks at workplaces has a significant implication for keeping workers from early retirement. Improvements are being made in that area as we pass through the pandemic: increased usage of remote work is one example. However, policymakers need to provide better care and support for essential workers who cannot choose remote work, to protect their health and alleviate their health concerns.

Also, our finding that even a temporary shock can significantly impact retirement suggests the importance of an early prevention policy against infectious diseases. Once those diseases spread out to the aggregate level, they bear severe implications for labor markets. Finally, the heterogeneity of retirement responses and related welfare implications are worthy of further investigation, especially by empirical analyses that use individual-level data. We leave this for future research.

Notes

1 For brevity, we only discuss critical features of the calibration of those parameters. For more details, please refer to Laun and Wallenius (2016).

2 Because of data source differential, there is a notable difference in sample data between the disability benefit claimer proportion and the retirement rate of non-college agents of age 50–54. It is not possible to fit both rates simultaneously as disability benefit claiming in our model is treated as retirement. We choose to fit the retirement rate, which is a more critical variable to our research question.

3 Tables A.1-A.2 in the appendix report more detailed results for shock persistency.

4 Tables A.3-A.4 in the appendix report more detailed results for discriminative and non-discriminative health shocks.

5 In Davis (2021b), high physical proximity is measured using the method of Mongey et al. (2021).

6 Age-variation data of earnings changes are not publicly available.

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APPENDIX

Table A1. Retirement rate by insurance type and persistency of aggregate health shock

(a) No insurance									
Non-college					College				
Age	Baseline	Health	Temp	Persist	Age	Baseline	Health	Temp	Persist
50–54	3.9	4.2	3.8	4.7	50–54	2.5	3.0	2.5	3.2
55–59	7.7	10.1	9.0	10.4	55–59	3.8	5.2	4.9	5.7
60–64	19.5	35.0	33.7	35.5	60–64	14.6	28.4	27.9	29.5
65–69	58.1	61.7	60.5	63.0	65–69	51.7	52.9	52.7	53.5
70–74	62.6	69.1	67.9	70.0	70–74	55.0	59.0	58.3	59.5
(b) Tied									
Non-college					College				
Age	Baseline	Health	Temp	Persist	Age	Baseline	Health	Temp	Persist
50–54	3.9	4.4	4.0	5.2	50–54	2.8	3.3	2.8	3.4
55–59	10.1	12.5	11.9	13.6	55–59	4.6	6.3	6.0	7.1
60–64	22.9	42.7	40.0	46.3	60–64	16.2	37.5	33.8	38.1
65–69	60.3	68.4	66.7	70.4	65–69	53.0	57.6	56.0	57.7
70–74	78.4	94.9	94.9	94.9	70–74	73.3	92.8	87.4	92.9

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Table A1. Continued

(c) Retiree									
Non-college					College				
Age	Baseline	Health	Temp	Persist	Age	Baseline	Health	Temp	Persist
50–54	4.5	5.4	4.6	5.8	50–54	3.1	3.7	3.1	3.9
55–59	11.2	15.4	14.6	15.6	55–59	5.2	7.6	7.1	8.8
60–64	32.5	54.2	52.7	54.8	60–64	25.6	44.8	40.7	45.3
65–69	60.6	70.3	68.8	71.7	65–69	53.3	58.3	57.0	59.1
70–74	85.6	100.0	100.0	100.0	70–74	74.6	93.3	93.1	93.3

Note: The retirement rate is the proportion of retirees in the total population. “Temp” stands for the temporary health shock that the next period is back to the normal state with certainty. “Persist” stands for the more persistent health shock that the probability of getting the normal state in the next period is only 0.6, while under the “Health” shock, the world returns to the normal state with the probability of 0.8.

Table A2. Retirement rate by preference and persistency of aggregate health shock

(a) Low disutility type									
Non-college					College				
Age	Baseline	Health	Temp	Persist	Age	Baseline	Health	Temp	Persist
50–54	0.4	1.4	0.4	2.3	50–54	0.7	1.5	0.7	1.7
55–59	5.8	7.2	6.4	7.4	55–59	1.6	3.1	2.4	3.6
60–64	9.8	20.2	18.6	21.5	60–64	5.2	11.4	11.0	12.3
65–69	27.0	41.0	38.2	43.7	65–69	14.6	22.9	20.6	24.0
70–74	59.2	82.7	82.2	83.2	70–74	50.2	82.8	78.9	82.9
(b) High disutility type									
Non-college					College				
Age	Baseline	Health	Temp	Persist	Age	Baseline	Health	Temp	Persist
50–54	8.8	8.9	9.0	9.0	50–54	5.8	5.8	5.7	6.1
55–59	15.1	20.4	19.6	21.4	55–59	8.8	11.6	11.6	13.3
60–64	46.6	77.3	75.4	79.0	60–64	41.3	77.1	69.4	77.3
65–69	100.0	100.0	100.0	100.0	65–69	100.0	100.0	100.0	100.0
70–74	100.0	100.0	100.0	100.0	70–74	100.0	100.0	100.0	100.0

Note: The retirement rate is the proportion of retirees in the total population. “Temp” stands for the temporary health shock that the next period is back to the normal state with certainty. “Persist” stands for the more persistent health shock that the probability of getting the normal state in the next period is only 0.6, while under the “Health” shock, the world returns to the normal state with the probability of 0.8.

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Table A3. Retirement rate by age and health insurance type (percent)

(a) No insurance							
Non-college				College			
Age	Baseline	Health 1	Health 2	Age	Baseline	Health 1	Health 2
50–54	3.9	4.2	3.9	50–54	2.5	3.0	2.4
55–59	7.7	10.1	8.0	55–59	3.8	5.2	3.6
60–64	19.5	35.0	19.6	60–64	14.6	28.4	14.5
65–69	58.1	61.7	58.5	65–69	51.7	52.9	51.6
70–74	62.6	69.1	62.8	70–74	55.0	59.0	55.0
(b) Tied							
Non-college				College			
Age	Baseline	Health 1	Health 2	Age	Baseline	Health 1	Health 2
50–54	3.9	4.4	3.9	50–54	2.8	3.3	2.8
55–59	10.1	12.5	10.1	55–59	4.6	6.3	4.4
60–64	22.9	42.7	22.9	60–64	16.2	37.5	16.4
65–69	60.3	68.4	60.4	65–69	53.0	57.6	53.1
70–74	78.4	94.9	78.5	70–74	73.3	92.8	73.8
(c) Retiree							
Non-college				College			
Age	Baseline	Health 1	Health 2	Age	Baseline	Health 1	Health 2
50–54	4.5	5.4	4.7	50–54	3.1	3.7	3.1
55–59	11.2	15.4	11.0	55–59	5.2	7.6	5.3
60–64	32.5	54.2	32.5	60–64	25.6	44.8	25.8
65–69	60.6	70.3	61.0	65–69	53.3	58.3	53.3
70–74	85.6	100.0	85.3	70–74	74.6	93.3	74.7

Note: The retirement rate is the proportion of retirees in the total population. “Health 1” stands for the discriminative aggregate health shock with the increased probability of idiosyncratic health shock, by the risk ratio of 1.1 when the agent does not work and 1.3 when the agent works. “Health 2” stands for the non-discriminative aggregate health shock that all agents face the increased probability of idiosyncratic health shock by the same risk ratio of 1.3. The probability that the health process reverts to normal in the next period is 80%, and the probability that the current situation continues is 20%.

Table A4. Retirement rate by age and preference (percent)

(a) Low disutility type							
Non-college				College			
Age	Baseline	Health 1	Health 2	Age	Baseline	Health 1	Health 2
50–54	0.4	1.4	0.4	50–54	0.7	1.5	0.7
55–59	5.8	7.2	5.8	55–59	1.6	3.1	1.6
60–64	9.8	20.2	10.0	60–64	5.2	11.4	5.2
65–69	27.0	41.0	27.6	65–69	14.6	22.9	14.8
70–74	59.2	82.7	59.1	70–74	50.2	82.8	50.6

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Table A4. Continued

(b) High disutility type							
Non-college				College			
Age	Baseline	Health 1	Health 2	Age	Baseline	Health 1	Health 2
50–54	8.8	8.9	8.9	50–54	5.8	5.8	5.8
55–59	15.1	20.4	15.0	55–59	8.8	11.6	8.8
60–64	46.6	77.3	46.5	60–64	41.3	77.1	41.5
65–69	100.0	100.0	100.0	65–69	100.0	100.0	100.0
70–74	100.0	100.0	100.0	70–74	100.0	100.0	100.0

Note: The retirement rate is the proportion of retirees in the total population. “Health 1” stands for the discriminative aggregate health shock with the increased probability of idiosyncratic health shock, by the risk ratio of 1.1 when the agent does not work and 1.3 when the agent works. “Health 2” stands for the non-discriminative aggregate health shock that all agents face the increased probability of idiosyncratic health shock by the same risk ratio of 1.3. The probability that the health process reverts to normal in the next period is 80%, and the probability that the current situation continues is 20%.

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