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## Labor market policies during an epidemic

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Federal Reserve Bank of New York  
Staff Reports

# Labor Market Policies during an Epidemic

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Staff Report No. 943  
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## **Labor Market Policies during an Epidemic**

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### **Abstract**

We study the positive and normative implications of labor market policies that counteract the economic fallout from containment measures during an epidemic. We incorporate a standard epidemiological model into an equilibrium search model of the labor market to compare unemployment insurance (UI) expansions and payroll subsidies. In isolation, payroll subsidies that preserve match capital and enable a swift economic recovery are preferred over a cost-equivalent UI expansion. When considered jointly, however, a cost-equivalent optimal mix allocates 20 percent of the budget to payroll subsidies and 80 percent to UI. The two policies are complementary, catering to different rungs of the productivity ladder. The small share of payroll subsidies is sufficient to preserve high-productivity jobs, but it leaves room for social assistance to workers who face inevitable job loss.

Key words: COVID-19, fiscal policy, labor productivity, unemployment, job search

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# 1 Introduction

The ongoing COVID-19 pandemic has resulted in a rapid contraction of economic activity and a severe deterioration of labor market conditions in the U.S. To mitigate the effects of massive dislocation in the labor market, the U.S. government introduced policy measures through the Coronavirus Aid, Relief, and Economic Security (CARES) Act with an initial size of about two trillion dollars. In this paper, we study the two prominent components of this package: the expansion of unemployment insurance (UI) benefits and the introduction of payroll subsidies, and make two broad contributions. On the positive side, we analyze the differential effects of direct transfers to the unemployed through a UI benefit expansion vis-à-vis granting firms payroll subsidies to preserve matches. Taking these differential effects into account, our normative contribution answers an important question: How should the government allocate limited resources between programs?

The two policies have distinct goals and labor market effects. The expansion of UI payments provides additional income to the large influx of job losers during the downturn. In comparison, the Payroll Protection Program (PPP), which extends forgivable loans to firms, aims to prevent business closures and keep worker-firm matches intact so that when labor demand rebounds, a swifter recovery follows. A key advantage of this program is that it preserves match capital that has been formed in the labor market after many years of investment.

We analyze these policies during the pandemic and the recovery thereafter. To do so, we combine the classical Susceptible-Infected-Recovered-Dead (SIR) epidemiological model of Kermack and McKendrick (1927) with an equilibrium search model of the labor market in the Diamond-Mortensen-Pissarides (DMP) tradition in Section 2. Our model consists of two sectors (essential and non-essential) with ex-ante identical, risk averse, hand-to-mouth households and a continuum of firms. The model has four features to capture key aspects relevant for policy analysis.

First, the infection probability depends on the individual's involvement in production and aggregate labor supply of the infected, in addition to the total number of infections in the economy. The spread of the infection thus depends on (public) containment policies as well as (private) behavioral responses through labor supply. This allows us to study the interaction between containment measures and labor market policies.

Second, the model incorporates financial frictions and wage rigidity, both of which lead to inefficient job separations. Some firms are subject to financial frictions in that their per-period net profits have to remain above a certain threshold. If this constraint binds, the match dissolves temporarily. In addition, downward wage rigidity implies that getting infected reduces workers' productivity but does not result in lower pay. Hence, the epidemic increases the probability of inefficient separations by reducing the surplus to the firm.

Third, the labor market features match-specific productivity that grows stochastically over time, capturing the idea that preserving long-tenure jobs is important for aggregate productivity and output. Firms have a recall option when temporary separations occur in the absence of payroll protection, which allows us to discipline a policy's contribution to match preservation. In addition, labor market policies that affect firm viability during containment can, in turn, affect the rate at

which recalls materialize during the recovery.

Finally, the government has two types of policy instruments. The first is a containment policy, expressed as a tax on production. The second are fiscal policies: UI benefits and payroll subsidies. Our framework allows us to study the differential effects of these in isolation and solve for their optimal mix. Importantly, these two policies are distinct because when UI is generous and payroll subsidies are absent, the severance of a match may result in permanent dissolution as i) some firms may no longer be operational to even rehire, ii) labor market frictions may hinder rehiring, iii) workers may find new matches, and finally iv) recall rejection rates may be higher.

We calibrate the steady state of the model to match key moments of the U.S. labor market prior to the epidemic (Section 3) and introduce the epidemic as a one-time unanticipated shock through a sudden infection of a small share of the population (Section 4). Concurrently, the government introduces a containment policy. The relationship between match productivity and the financial constraint determines the composition of job losses during the epidemic: If more-productive firms can borrow more relative to low-productivity ones, a larger share of match destruction occurs at low-wage jobs. We discipline this relationship using micro data on the magnitude and composition of job losses during the epidemic.

We use the model to evaluate the policy options by simulating an increase in UI generosity similar to the CARES Act and a cost-equivalent payroll subsidy. Implementing a UI expansion in isolation leads to a large rise in unemployment. Lost match capital results in persistently low average labor productivity (ALP) and output post-containment, as newly formed jobs have low productivity. Payroll subsidies achieve the opposite by preserving existing matches because they allow financially constrained firms that would have otherwise engaged in layoffs to continue operating. The preservation of match capital softens the decline in employment, productivity and output, and the economy recovers faster. In this sense, UI causes workers to fall off the ladder but provides additional insurance to job losers, whereas payroll subsidies preserves workers' position along the ladder. However, payroll subsidies have two drawbacks relative to UI. First, there is no direct insurance benefit to job losers. Second, while subsidies allow some firms to retain matches while idle, they also enable others to continue active production. The ensuing higher economic activity results in more infections. Comparing a UI expansion to a payroll subsidy in isolation, the former yields welfare gains of 0.18 percent in additional lifetime consumption, while the latter yields 0.76 percent, implying that a payroll subsidy is preferred over a cost-equivalent UI expansion.

We then proceed to compute the optimal policy mix, subject to the same amount of total government spending. The optimal policy allocates 20 percent of the budget to payroll subsidies and the remaining 80 percent to UI expansion. Although payroll subsidies comprise a smaller share of spending, we show that this partial expenditure achieves most of the gains that can be obtained by allocating the entire budget on payroll subsidies. In this sense, the marginal gains of initial spending on payroll subsidies are large. Thus, the optimal policy sets the payroll subsidy just enough to preserve high-productivity matches as any payments in excess yield limited marginal gains and, importantly, the optimal policy leaves fiscal space for UI payments. Increased UI generosity

helps workers who highly value consumption insurance because their jobs are not saved by payroll subsidies. Given the generous UI payments, the unemployment rate rises more, but the additional decline and the slow recovery of output are completely offset through payroll subsidies that preserve high-productivity matches. Thus, the two labor market policies are *complementary*.

It is important to understand how the optimal policy response depends on the strength of containment, since different countries have implemented lockdowns of different magnitude. We show that the share of the budget allocated to payroll subsidies increases with the strictness of containment measures. A stronger containment policy leads to the permanent dissolution of high-productivity matches that would have survived under a more lax one, raising the importance of firm preservation, and thereby the value of payroll subsidies.

This paper contributes to the emerging literature on the economic and health effects of the COVID-19 pandemic (see Alvarez, Argente, and Lippi, 2020; Atkeson, 2020; Berger, Herkenhoff, and Mongey, 2020; Bick and Blandin, 2020; Ganong, Noel, and Vavra, 2020; Garriga, Manuelli, and Sanghi, 2020; Glover, Heathcote, Krueger, and Ríos-Rull, 2020; Guerrieri, Lorenzoni, Straub, and Werning, 2020; Jones, Philippon, and Venkateswaran, 2020; Kurmann, Lale, and Ta, 2020, among others). Our paper is more closely related to studies that analyze the labor market effects of the pandemic in detail (see Fang, Nie, and Xie, 2020; Gregory, Menzio, and Wiczer, 2020; Kapicka and Rupert, 2020; Mitman and Rabinovich, 2020). Relative to these papers, we jointly study UI and payroll subsidies and analyze their differential effects on the labor market. To the best of our knowledge, this paper is the first in analyzing the interactions, trade-offs, and optimal mix of these two policies as well as their interactions with the strength of containment measures.

## 2 An Equilibrium Labor Market Model in an Epidemic

We synthesize a basic epidemiological SIR model with an equilibrium search model of the labor market that features match-specific productivity and recalls. We then use our model to study labor market policies proposed to lessen the economic impact of the epidemic.

### 2.1 The Environment

Time is discrete and runs forever. The economy is populated by a measure one of workers and a continuum of ex-ante identical firms in two sectors: essential and non-essential. Households in each sector are ex-ante identical and there is no mobility across sectors. Here we describe the non-essential sector in detail and only outline key differences in the essential sector.

**Households.** Households are risk averse and differ in terms of their employment status, health status  $h$ , match-specific capital  $z$ , and wage  $w$ . A worker can be either employed  $W$ , unemployed on temporary layoff  $U_T$ , or unemployed and permanently separated  $U_P$ . Employed workers can be attached to firms that are either actively producing or idle, while workers on temporary layoff can be recalled back to their previous employers. Employed households have the option to quit and

dissolve the match permanently each period. Unemployed households search for jobs and, upon contact, decide whether to accept an offer. Thus, individuals can reduce their own risk of infection by quitting from a job or refusing a new offer.

In terms of health, households are classified as either susceptible  $S$ , infected  $I$ , recovered  $R$ , or dead  $D$ . Susceptible workers can become infected by engaging in production or by meeting infected agents for reasons unrelated to economic activity, e.g. meeting an infected neighbor. Similar to Eichenbaum, Rebelo, and Trabandt (2020), we model this infection probability as

$$e_n(N^I, I) = \pi_1 n N^I + \pi_2 I, \quad (1)$$

where  $n \in \{0, 1\}$  indicates if the individual is employed and actively producing;  $N^I$  denotes the aggregate mass of actively employed workers that are infected; and  $I$  denotes the total mass of infected people in the economy. We assume that infected people recover or die at exogenous rates  $\pi^R$  and  $\pi^D$ , respectively, and that recovered people develop full immunity to the disease. Hence, transition probabilities between health states can be summarized by

$$\Pi_n(h, h') = \begin{array}{c|cccc} & S & I & R & D \\ \hline S & 1 - e_n & e_n & 0 & 0 \\ I & 0 & 1 - \pi^R - \pi^D & \pi^R & \pi^D \\ R & 0 & 0 & 1 & 0 \\ D & 0 & 0 & 0 & 1 \end{array}$$

**Firms, wages and the labor market.** Firms match with workers in a frictional labor market subject to random search. The output from a match is given by  $y = \alpha^h z$ . We assume  $\alpha^I < \alpha^S = \alpha^R$ , i.e. infection reduces productivity but recovery fully restores it. Match-specific productivity takes on a discrete set of values,  $z \in \{z_0, \dots, z_{N_z}\}$ . The productivity of a new match starts at the lowest value  $z_0$  and increases to the next level with probability  $\xi$  as long as the match is actively producing.

Once matched with a worker, firms face three choices every period: i) keep the match active and produce, ii) pause production and become idle, or iii) permanently terminate the match. Active firms produce, pay workers their wage  $w$  (discussed below) and incur a fixed operating cost  $c_F$ . Pausing production allows firms to avoid this fixed cost, but they still have to fulfill their payroll obligations. Firms can pause production if output falls to a level that is unable to offset operating costs, possibly due to worker infection or government-imposed lockdown.<sup>1</sup> Once a match is permanently terminated, there is no option to recall the worker. Therefore, firms exercise this option only when the surplus of the match that accrues to the firm is negative.

There are two types of firms in the non-essential sector. An  $\omega$  share of firms are financially constrained (C), and they cannot run a per-period loss larger than a productivity-specific limit  $\underline{a}(z)$ .<sup>2</sup> This dependence on productivity allows us to capture any systemic variation in the amount

<sup>1</sup>The decision of pausing or resuming production is frictionless. Further, workers in idle matches remain on payroll and do not look for jobs.

<sup>2</sup>This friction captures the idea that not all firms can access financial markets under the same terms, and they

of borrowing that firms can tap into. When the financial constraint binds, the firm is forced to put its worker on temporary layoff. The recall option arrives at exogenous rate  $r$ , but recalls occur only if both parties agree to resume the match. This recall option may disappear permanently with exogenous probability  $\chi_r$  each period or when the worker finds another job while on layoff. Other firms are unconstrained (U), and their per-period profits are not subject to any requirement.

In addition to endogenous separations initiated by the firm or the worker, matches also separate exogenously at rate  $\delta$ . This type of separation also leads to a temporary layoff with a recall option.

In summary, temporary layoffs occur because of i) binding financial constraints or ii) exogenous separations. Meanwhile, permanent separations occur when i) the firm or worker's match surplus is negative, ii) a worker on temporary layoff finds a new job, or iii) the recall option expires.

Wages are paid as a piece rate  $\phi\alpha^h$  of match productivity  $z$ , which depends on the worker's health.<sup>3</sup> The piece-rate contract implies that wages rise with productivity. We assume downward wage rigidity: Getting infected reduces productivity but does not result in lower pay. This possibility of job dissolution and loss of match capital implies that infection can result in long-term earnings losses for the households.

To sum up, the model allows for inefficient separations through several margins. First, financial frictions potentially lead to separations of highly productive matches. While these have a recall option, that option may expire or the worker may accept a new job. Second, some exogenous separations eventually lead to permanent separations and are potentially inefficient. Lastly, sticky wages, in conjunction with financial frictions, cause otherwise perfectly viable matches to separate.

To match with workers, entrants pay a cost  $\kappa$  to post a vacancy. Meetings with a worker happen with probability  $q(\theta)$ , where labor market tightness  $\theta = v/u$  is the ratio of the mass of vacancies and unemployed workers. The analogous probability for workers is  $f(\theta) = \theta q(\theta)$ . Labor markets are segmented, i.e. workers in a given sector can only meet with firms in the same sector.

**Government.** The government has several policy tools. It can reduce economic interactions through a containment policy in the form of a proportional tax  $\tau_q \in [0, 1]$  on match output in the non-essential sector. It can pay unemployment benefits  $b$  to households and provide payroll subsidies to non-essential firms by covering a fraction  $\tau_p \in [0, 1]$  of wages.

**Key differences of the essential sector.** Essential firms differ from non-essential firms in three ways. First, essential firms do not have the option to pause production. Second, all essential firms are financially unconstrained. Third, payroll and containment policies do not apply to essential firms, while changes in UI generosity affect both sectors through a worker's outside option.

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may be forced to temporarily close business if economic conditions deteriorate, even if the net present value of the match to the firm is still positive.

<sup>3</sup>The dependence on health captures the fact that in a bargaining model, the outside option of a worker depends on her health.



**Timing.** Each period opens during the production and consumption stage: Matched firms decide whether to operate or pause production; active worker-firm pairs produce; wages are paid to workers; and UI benefits are paid to the unemployed. Next, health shocks are realized. Then the labor market opens: Recall options stochastically expire; firms create vacancies; new matches are formed; temporarily laid off workers may be recalled; and exogenous job separations occur. Next, match productivity in active matches stochastically improve. Finally, matched workers and firms unilaterally decide whether to keep or terminate the match before entering the next period.

Below, we present the problem of households and firms in the *non-essential* sector.<sup>4</sup>

## 2.2 Household Problem

Let  $W_k^h(z, w)$  denote the value of an employed household with health  $h \in \{S, I, R\}$ , matched to a firm of financial constraint type  $k \in \{C, U\}$ , with productivity  $z$  and wage  $w$ .<sup>5</sup> Similarly, let  $U_{T,k}^h(z, w)$  and  $U_P^h$  denote the values of unemployed households on temporary and permanent layoff (i.e. with and without a recall option), respectively. Finally, let  $J_k^h(z, w)$  be the value of a firm that is matched with a worker,  $V_{T,k}^h(z, w)$  be the value of a vacant firm with a worker on temporary layoff, and  $V$  be the value of a new entrant.

In each period, the worker and the firm have the option to dissolve an existing match permanently. Let  $d_{W,k}^h, d_{J,k}^h \in \{0, 1\}$  indicate that an *existing* match yields positive surplus to the worker and firm, respectively. The joint outcome is then given by  $d_k^h(z, w) = d_{W,k}^h(z, w) \times d_{J,k}^h(z, w)$ . These indicators solve the following problems:

$$\begin{aligned} d_{W,k}^h(z, w) &= \arg \max_{d \in \{0,1\}} \left\{ d \times W_k^h(z, w) + (1 - d) \times U_P^h \right\} \\ d_{J,k}^h(z, w) &= \arg \max_{d \in \{0,1\}} \left\{ d \times J_k^h(z, w) + (1 - d) \times V \right\}. \end{aligned}$$

Upon contact, firms and unemployed workers decide whether to initiate an employment relationship. Let  $d_{U_T,k,k'}^h \in \{0, 1\}$  indicate whether a *new* match with a firm of type  $k'$  yields positive surplus to a worker on temporary layoff from a firm of type  $k$ , with productivity  $z$  and wage  $w$ :<sup>6</sup>

$$d_{U_T,k,k'}^h(z, w) = \arg \max_{d \in \{0,1\}} \left\{ d \times W_{k'}^h(z_0, w^h) + (1 - d) \times U_{T,k}^h(z, w) \right\}.$$

If the worker declines this new job offer, she remains unemployed and keeps the recall option from the previous match  $U_{T,k}^h(z, w)$ . Otherwise, she starts at the lowest productivity and the wage dictated by the wage rule, which is affected by her current health. A contact results in a new job if both parties agree:  $d_{k,k'}^h(z, w) = d_{U_T,k,k'}^h(z, w) \times d_{J,k}^h(z_0, w^h)$ .

<sup>4</sup>We suppress dependence on time since we present the model in steady state.

<sup>5</sup> $w$  is a state variable because wage rigidity implies that health status does not pin down wages. For example, an infected worker that started prior to being infected would be paid the wage of a non-infected worker.

<sup>6</sup>Note that state variables  $(z, w)$  in this indicator function refer to the *outside* option, i.e. the productivity and wage in the latest job to which the worker might be recalled.

The value of an employed household working for a firm of type  $k \in \{C, U\}$  is:

$$W_k^h(z, w) = u(w) + \beta \sum_{h' \in \{S, I, R\}} \Pi_l(h, h') \left[ \delta \mathbb{E}_{z'|z, l} U_{T, k}^{h'}(z', \max\{w, w^{h'}\}) \right. \\ \left. + (1 - \delta) \mathbb{E}_{z'|z, l} \widetilde{W}_k^{h'}(z', \max\{w, w^{h'}\}) \right], \quad (2)$$

where  $l$  refers to the firm's production decision (active or idle), defined in Section 2.3.<sup>7</sup> The max operator captures downward wage rigidity, which only binds when a susceptible worker becomes infected on the job or during temporary layoff. The match exogenously dissolves with probability  $\delta$ , leading to a temporary layoff. If the match survives with the complementary probability, the worker moves to the endogenous decision stage and obtains continuation value  $\widetilde{W}_k^{h'}$  given by:

$$\widetilde{W}_k^h(z, w) = \left(1 - \gamma_k^h(z, w)\right) \left[ d_k^h(z, w) W_k^h(z, w) + \left(1 - d_k^h(z, w)\right) U_P^h \right] + \gamma_k^h(z, w) U_{T, k}^h(z, w).$$

Indicator  $\gamma_k^h \in \{0, 1\}$  denotes whether the financial constraint binds. If it does, the worker goes on temporary layoff. The financial constraint is a requirement on per-period profits given by:

$$\gamma_C^h(z, w) = \mathbb{I} \left\{ (1 - \tau_q) \alpha^h z - (1 - \tau_p) w - c_F \leq -\underline{a}(z) \right\} \quad \text{and} \quad \gamma_U^h(z, w) = 0,$$

where  $\tau_q$  is the containment policy modeled as a tax on output and  $\tau_p$  controls the payroll subsidy provided to firms.

The value of a worker on temporary layoff is given by:

$$U_{T, k}^h(z, w) = u(b) + \beta \sum_{h' \in \{S, I, R\}} \Pi_0(h, h') (1 - \chi_r) \left[ f(\theta) \mathbb{E}_{k'} \widetilde{W}_{k, k'}^{h'}(z, w) \right. \\ \left. + r \widetilde{W}_k^{h'}(z, \max\{w, w^{h'}\}) + (1 - f(\theta) - r) U_{T, k}^{h'}(z, \max\{w, w^{h'}\}) \right] \quad (3) \\ + \sum_{h' \in \{S, I, R\}} \Pi_0(h, h') \chi_r \left[ f(\theta) \mathbb{E}_{k'} \widetilde{W}_{k'}^{h'}(z_0, w^{h'}) + (1 - f(\theta)) U_P^{h'} \right].$$

The recall option survives with probability  $(1 - \chi_r)$ , in which case the worker gets recalled with probability  $r$  and the match maintains the pre-layoff productivity  $z$ . The worker can receive a new offer with probability  $f(\theta)$  from a firm of type  $k'$  and decides whether to accept. The value of having this offer is given by:<sup>8</sup>

$$\widetilde{W}_{k, k'}^h(z, w) = \left(1 - \gamma_{k'}^h(z_0, w^h)\right) \left[ d_{k, k'}^h(z, w) W_{k'}^h(z_0, w^h) + \left(1 - d_{k, k'}^h(z, w)\right) U_{T, k}^h(z, w) \right] \\ + \gamma_{k'}^h(z_0, w^h) U_{T, k}^h(z, w). \quad (4)$$

<sup>7</sup>The expectation over match productivity  $z$ ,  $\mathbb{E}_{z'|z, l}$ , also depends on the firm's production decision  $l$  because if the match pauses operating, productivity remains constant.

<sup>8</sup>Similar to the indicator function  $d_{U_{T, k, k'}}^h(z, w)$ , the state variables  $(z, w)$  of  $\widetilde{W}_{k, k'}^{h'}(z, w)$  in the first line of Equation (3) refer to the *outside* option of being recalled and not to the *new* offer. Furthermore, we assume that when the financial constraint of the new firm binds, the worker keeps her previous recall option, not the new recall option. Therefore, in the second line of Equation (4), we have  $U_{T, k}^h(z, w)$ .

The expectation operators in Equation (3) account for the fact that the new firm a worker meets may be financially constrained:

$$\begin{aligned}\mathbb{E}_{k'} \widetilde{W}_{k'}^{h'}(z_0, w^{h'}) &= \omega \widetilde{W}_C^{h'}(z_0, w^{h'}) + (1 - \omega) \widetilde{W}_U^{h'}(z_0, w^{h'}) \\ \mathbb{E}_{k'} \widetilde{W}_{k,k'}^{h'}(z, w) &= \omega \widetilde{W}_{k,C}^{h'}(z, w) + (1 - \omega) \widetilde{W}_{k,U}^{h'}(z, w).\end{aligned}\quad (5)$$

Finally, the value of an unemployed household with no recall option is:

$$U_P^h = u(b) + \beta \sum_{h' \in \{S, I, R\}} \Pi_0(h, h') \left[ f(\theta) \mathbb{E}_{k'} \widetilde{W}_{k'}^{h'}(z_0, w^{h'}) + (1 - f(\theta)) U_P^{h'} \right]. \quad (6)$$

### 2.3 Firm Problem

The value of a firm with financial constraint type  $k$ , productivity  $z$ , matched with a worker of health  $h$  is

$$\begin{aligned}J_k^h(z, w) &= \max_{l \in \{0, 1\}} \left\{ l \times \left[ (1 - \tau_q) \alpha^h z - (1 - \tau_p) w - c_F \right] + (1 - l) \times \left[ - (1 - \tau_p) w \right] \right\} \\ &+ \beta \sum_{h' \in \{S, I, R\}} \Pi_l(h, h') \left[ \delta \mathbb{E}_{z'|z, l} V_{T,k}^{h'}(z', \max\{w, w^{h'}\}) \right. \\ &\left. + (1 - \delta) \mathbb{E}_{z'|z, l} \widetilde{J}_k^{h'}(z', \max\{w, w^{h'}\}) \right].\end{aligned}\quad (7)$$

The first max operator reflects the production decision of the firm denoted by  $l^h(z, w) \in \{0, 1\}$ . If production is paused, i.e.  $l = 0$ , the worker is not subject to infection through economic activity and remains attached to the firm, but match productivity remains constant. If the firm decides to produce, it pays an operating cost  $c_F$  in addition to wages. Here, the worker is subject to additional infection risk from working but match quality stochastically improves. The value of having a worker at the separation decision stage is

$$\widetilde{J}_k^h(z, w) = \left( 1 - \gamma_k^h(z, w) \right) \left[ d_k^h(z, w) J_k^h(z, w) + \left( 1 - d_k^h(z, w) \right) V \right] + \gamma_k^h(z, w) V_{T,k}^h(z, w).$$

The value of a vacant firm with a furloughed employee is given by

$$\begin{aligned}V_{T,k}^h(z, w) &= \beta(1 - \chi_r) \sum_{h' \in \{S, I, R\}} \Pi_0(h, h') \times \\ &\left[ f(\theta) \left[ \mathbb{E}_{k'} \left( 1 - \gamma_{k'}^{h'}(z_0, w^{h'}) \right) \left[ d_{k,k'}^{h'}(z, w) V + \left( 1 - d_{k,k'}^{h'}(z, w) \right) V_{T,k}^{h'}(z, \max\{w, w^{h'}\}) \right] \right. \right. \\ &\left. \left. + \gamma_{k'}^{h'}(z_0, w^{h'}) V_{T,k}^{h'}(z, \max\{w, w^{h'}\}) \right] \right. \\ &\left. + r \widetilde{J}_k^{h'}(z, \max\{w, w^{h'}\}) + (1 - f(\theta) - r) V_{T,k}^{h'}(z, \max\{w, w^{h'}\}) \right] + \beta \chi_r V.\end{aligned}\quad (8)$$

The second line indicates that when a worker on temporary layoff rejects a new offer, she keeps her recall option to her previous employer, but if she accepts the new offer, the firm is left vacant.<sup>9</sup> The third line captures the case when the new firm's financial constraint binds; the worker keeps her recall option from the previous match.

Finally, the value of a new vacancy is given by

$$\begin{aligned}
V = & -\kappa + \beta q(\theta) \frac{1}{u} \sum_{h \in \{S, I, R\}} \Psi_u^h \sum_{h' \in \{S, I, R\}} \Pi_0(h, h') \left[ \left( u_P^h + \chi_r \sum_{k, z} u_{T, k}^h(z) \right) \mathbb{E}_{k'} \tilde{J}_{k'}^{h'}(z_0, w^{h'}) \right. \\
& + (1 - \chi_r) \sum_{k, z} u_{T, k}^h(z) \mathbb{E}_{k'} (1 - \gamma_{k'}^{h'}(z_0, w^{h'})) \left[ d_{k, k'}^{h'}(z, w) J_{k'}^{h'}(z_0, w^{h'}) \right. \\
& \left. \left. + \left( 1 - d_{k, k'}^{h'}(z, w) \right) V \right] + \gamma_{k'}^{h'}(z_0, w^{h'}) V \right]. \tag{9}
\end{aligned}$$

Here,  $\Psi_u^h$  is the measure of unemployed individuals with health status  $h$ ,  $u_{T, k}^h(z)$  and  $u_P^h$  denote the mass of unemployed workers on temporary and permanent layoff, respectively, and  $u = \sum_h \left( u_P^h + \sum_{k, z} u_{T, k}^h(z) \right)$  is the total mass of unemployed. When this firm meets with a worker, its financial type is revealed. If the firm-worker pair decides to keep the match, it becomes productive in the next period. We assume free entry: an infinite supply of potential new entrants pushes the value of posting a new vacancy to zero,  $V = 0$ .

We define the stationary equilibrium of the model in Appendix A.1 and provide computational details in Appendix A.2.

### 3 Calibration

We assume the economy is in steady state and calibrate the model to match several targets of the U.S. economy prior to the pandemic. In steady state, we assume that all individuals are susceptible, financial constraints are non binding, and the only government policy is the existing UI program. Table 1 provides a list of calibrated model parameters.

**Externally calibrated parameters.** The model period is a week. The utility function is given by  $u(c) = \bar{u} + \frac{c^{1-\sigma}}{1-\sigma}$  as in Hall and Jones (2007), so that agents value life. We set  $\sigma = 2$  and discuss the calibration strategy for  $\bar{u}$  below.

We assume a CES matching function, implying that job finding rate is  $f(\theta) = \theta(1+\theta^\eta)^{-1/\eta}$ . We set the matching function elasticity  $\eta$  to 0.4 (Hagedorn and Manovskii, 2008). We follow Gascon (2020), who measures the employment share of essential occupations and those that can be done remotely, to assign the essential sector an employment share of 54 percent. Furthermore, we assume that 80 percent of the firms in the non-essential sector become financially constrained at the onset of the epidemic ( $\omega = 0.8$ ). Fujita and Moscarini (2017) show that the probability of exiting from

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<sup>9</sup>Here,  $\mathbb{E}_{k'}$  is the expectation whether the firm's financial constraint binds. Formally, it can be written out similarly to that in Equation (5).



unemployment through a recall approaches zero after six months of unemployment. This requires setting  $\chi_r$ , the stochastic expiration rate of the recall option to  $1/26$ . We set the worker’s share in output to  $\phi = 2/3$ . Finally, we target a pre-COVID monthly separation rate of 1.65 percent computed using the Current Population Survey (CPS) and set  $\delta$  to 0.0042.

To discipline the model’s SIR component, we follow Eichenbaum, Rebelo, and Trabandt (2020). Assuming a mortality rate of 0.5 percent and that infected individuals either recover or die from infection within 18 days on average, i.e.  $\pi^D + \pi^R = 7/18$ , we obtain  $\pi^D = 0.005 \times 7/18$  and  $\pi^R = (1 - 0.005) \times 7/18$ . Finally, we normalize the productivity of susceptible and recovered workers,  $\alpha^S$  and  $\alpha^R$ , to one, and assume a 20 percent loss in productivity when infected, i.e.  $\alpha^I = 0.8$ , as in their study.

**Internally calibrated parameters.** We calibrate eight of the remaining 11 parameters to match steady-state moments of the U.S. economy prior to the pandemic, and the remaining three by simulating the COVID-19 pandemic and matching moments along the transition.

We first start by discussing the steady-state moments. The probability  $\xi$  of a productivity upgrade of an actively producing match has a pronounced effect on earnings dispersion. Therefore, we target the 90th to 10th percentile ratio of the labor earnings distribution among employed workers, which is 6.30 in the Survey of Program and Income Participation (SIPP).

We target a replacement rate of 40 percent to discipline UI benefits  $b$ . We choose the recall probability  $r$  to match a 40 percent share of recalls among UE flows (Fujita and Moscarini, 2017).

Firms face two fixed costs. We choose the vacancy posting cost  $\kappa$  to match an unemployment rate of 3.7 percent. Using aggregate income statements from the Internal Revenue Service (IRS), we find that the ratio of profits to business expenses is around 25 percent for sole proprietorships in 2017. We calibrate the fixed operating cost incurred by active firms  $c_F$  to match this.

We now describe the calibration of parameters related to the epidemic. We choose  $\pi_1$  such that the infections resulting from labor market activity account for one third of all infections. To pin down  $\pi_2$ , we target a 60 percent combined share of recovered and dead individuals in a simple SIR model with no behavioral response from households.<sup>10</sup> Finally,  $\bar{u}$  governs how much individuals value life over death. We therefore target a statistical value of life of \$10 million, similar to Glover et al. (2020). We provide more details in Appendix A.3.

Finally, we calibrate the remaining three parameters by simulating the COVID-19 pandemic and matching moments along the transition. Specifically, we populate the economy with an initial mass of 0.001 infected individuals.<sup>11</sup> We assume that financial constraints in the non-essential sector become operational, and that the only government response is to implement a containment measure  $\tau_q$  in the non-essential sector during the first quarter of the pandemic.

The financial constraint is important for our substantive results, so we discuss its calibration in

<sup>10</sup>To do so, we simulate the system of equations given in Equation (10) in Appendix A.1 under  $\pi_1 = 0$  and calculate the total number of recovered and dead individuals in the steady state as a share of initial population.

<sup>11</sup>We apportion this total initial infected mass to different labor market states based on the population shares of workers in steady state.

more detail. The constraint depends linearly on productivity:  $\underline{a}(z) = \underline{a}_0 + \underline{a}_1 z$ . The constant  $\underline{a}_0$  has a pronounced effect on the level of unemployment during the epidemic. We choose this to match a maximum unemployment rate of 20 percent during the first quarter of the epidemic.<sup>12</sup> The slope of the constraint,  $\underline{a}_1$ , determines which matches are predisposed to separation during the epidemic. If  $\underline{a}_1 = 0$ , wage rigidity implies that high wage matches get destroyed. A positive  $\underline{a}_1$  makes high wage matches more likely to survive. Since  $\underline{a}_1$  determines the wage composition of job losses, we choose it to match the incidence of the rise in unemployment across the earnings distribution. Using the CPS, we divide occupations into employment-weighted earnings quantiles, and for each quantile, calculate the change in temporary unemployment from January 2020 to April 2020. We find that occupations below the median of the earnings distribution accounted for 72 percent of the total increase in temporary unemployment.<sup>13</sup> We target this moment to discipline  $\underline{a}_1$ .

Finally, we choose the strictness of the containment policy  $\tau_q$  to match the fraction of businesses with temporary closings during the pandemic. According to the Small Business Pulse Survey of the U.S. Census Bureau, the national average of businesses with at least one day of temporary closings in a week during May 2020 was around 30 percent. In the model, we calculate the fraction of idle matches among all matches in the non-essential sector and use  $\tau_q$  to match this target.

## 4 Results

We now analyze the effects of an epidemic under various labor market policies, starting with a baseline of a containment measure of  $\tau_q = 0.75$  and no accompanying fiscal support, which we compare to two extreme but cost-equivalent policy options: channel all additional transfers through UI or through payroll subsidies. We then solve for the optimal mix of these policies. Finally, we consider how the optimal mix of UI and payroll subsidies changes with the strictness of containment measures. In all our experiments, we assume that both containment and labor market policies are introduced coincident with the inception of the epidemic, and last for one quarter (13 weeks).<sup>14</sup>

**No fiscal response.** The first panel of Figure 1 plots infection dynamics over a one year horizon for the baseline. Within a year, around 80 percent of the population is infected and eventually recovers, resulting in the death of 0.43 percent of the initial population.<sup>15</sup> In the labor market, the

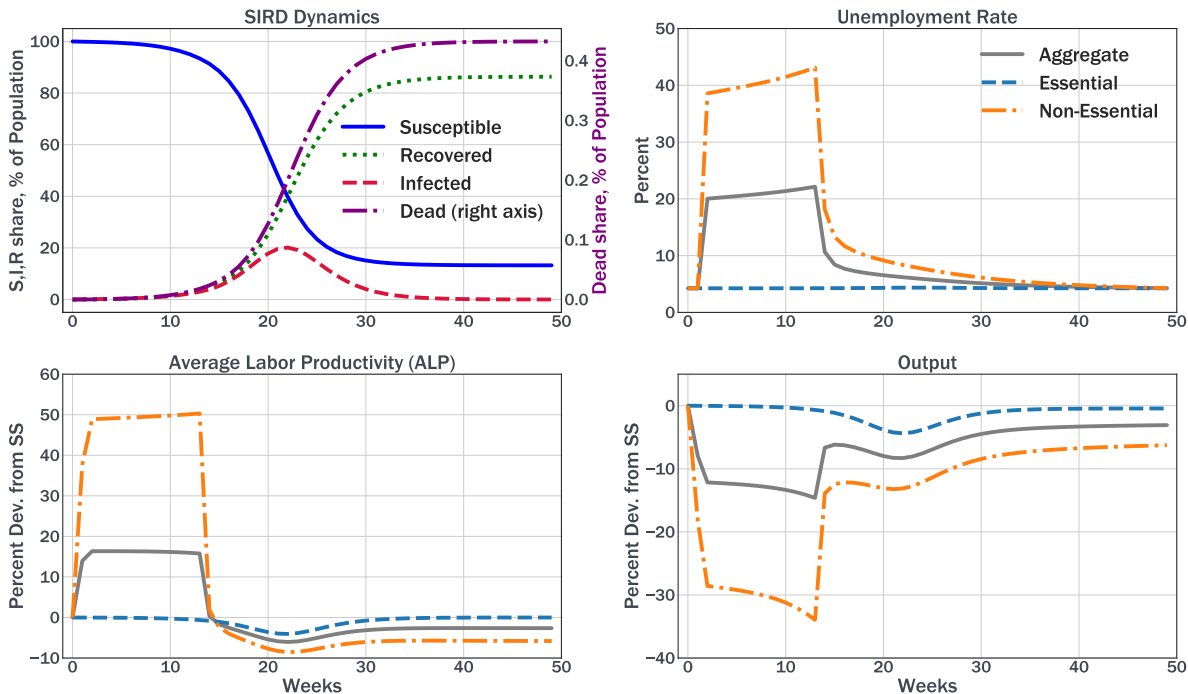
<sup>12</sup>During the early stages of the economic shut down in the U.S., there were many estimates of the peak unemployment rate in the absence of a policy response. Şahin, Tasci, and Yan (2020) estimated 16 percent; Treasury Secretary Steven Mnuchin stated a peak of 25 percent; and Faria-e Castro (2020) estimated 32.1 percent. We take 20 percent as our target for the baseline and show the results when unemployment peaks at 35 percent under stricter containment.

<sup>13</sup>Amburgey and Birinci (2020) present further findings on the compositional differences in job losses during the pandemic. Job losses are more prevalent for low income workers within both the sample of temporarily unemployed workers and all unemployed workers.

<sup>14</sup>We have also considered longer containment measures. A containment policy that lasts two quarters has a larger impact on match surplus, thereby making higher productivity matches more likely to terminate relative to a shorter containment. This raises the value of granting payroll subsidies that can save these jobs.

<sup>15</sup>Our model predicts a high infection rate relative to the data, given that our exercise only limits contagion through reduced economic activity but does not account for other behavioral responses such as social distancing, increased hygiene, and the use of protective equipment that may reduce infections, which could be captured by a lower  $\pi_2$ .

Figure 1: No Fiscal Measures



Notes: This figure plots the effects of the epidemic on health and labor market dynamics when the government implements a containment for one quarter without any accompanying fiscal support.

non-essential sector unemployment rate rises to around 40 percent, resulting in a peak aggregate unemployment rate of 22 percent. In the data, around three-fourths of the total increase in unemployment is attributable to occupations below the median of the earnings distribution (Section 3). Since our model is calibrated to match this feature, non-essential sector layoffs are concentrated among these lower-quality matches, which face stricter financial constraints and smaller surpluses. This leads to a short-lived rise in average labor productivity (ALP) during the containment. Match terminations that result in permanent separations imply the loss of match capital built over time. As new but minimum-productivity  $z_0$  matches are formed post-containment, non-essential ALP falls to nine percent below steady state and remains persistently low. In the essential sector, which is not subject to containment, a limited drop in ALP is driven mostly by infections reducing worker productivity. As such, this provides a benchmark on the effects of infection-related productivity losses. Meanwhile, aggregate output declines by 14 percent during containment. Despite the full recovery of employment after one year, aggregate output remains three percent lower than its pre-crisis level due to the loss of match capital built over long-term employment relationships.

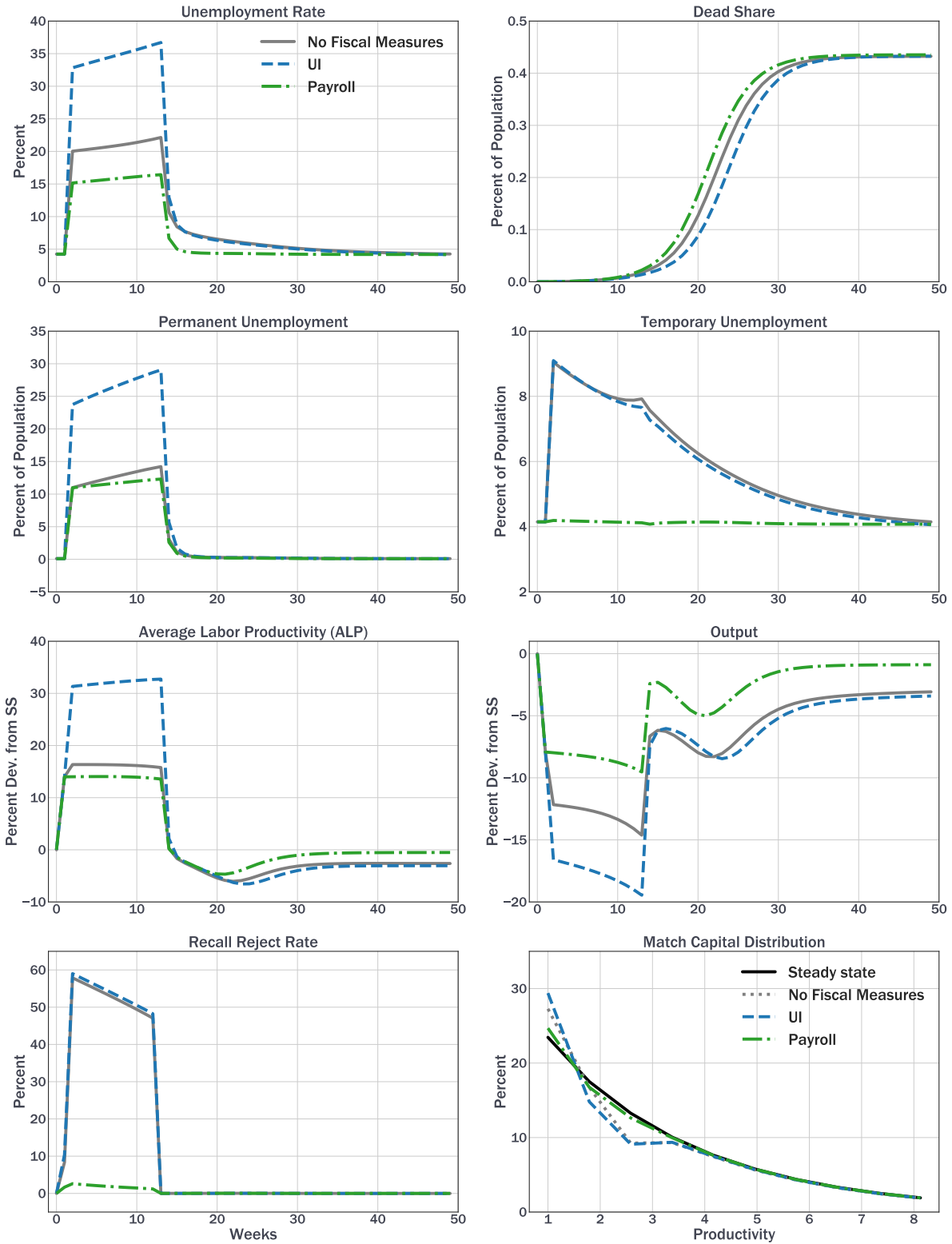
**UI vs. payroll subsidies.** We now study the expansion of the UI program and payroll subsidies one at a time. The UI benefit expansion is motivated by the CARES Act, which provides an

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Furthermore, reported data on infections are beset by undercounting due to hidden cases, testing constraints, and asymptomatic individuals.

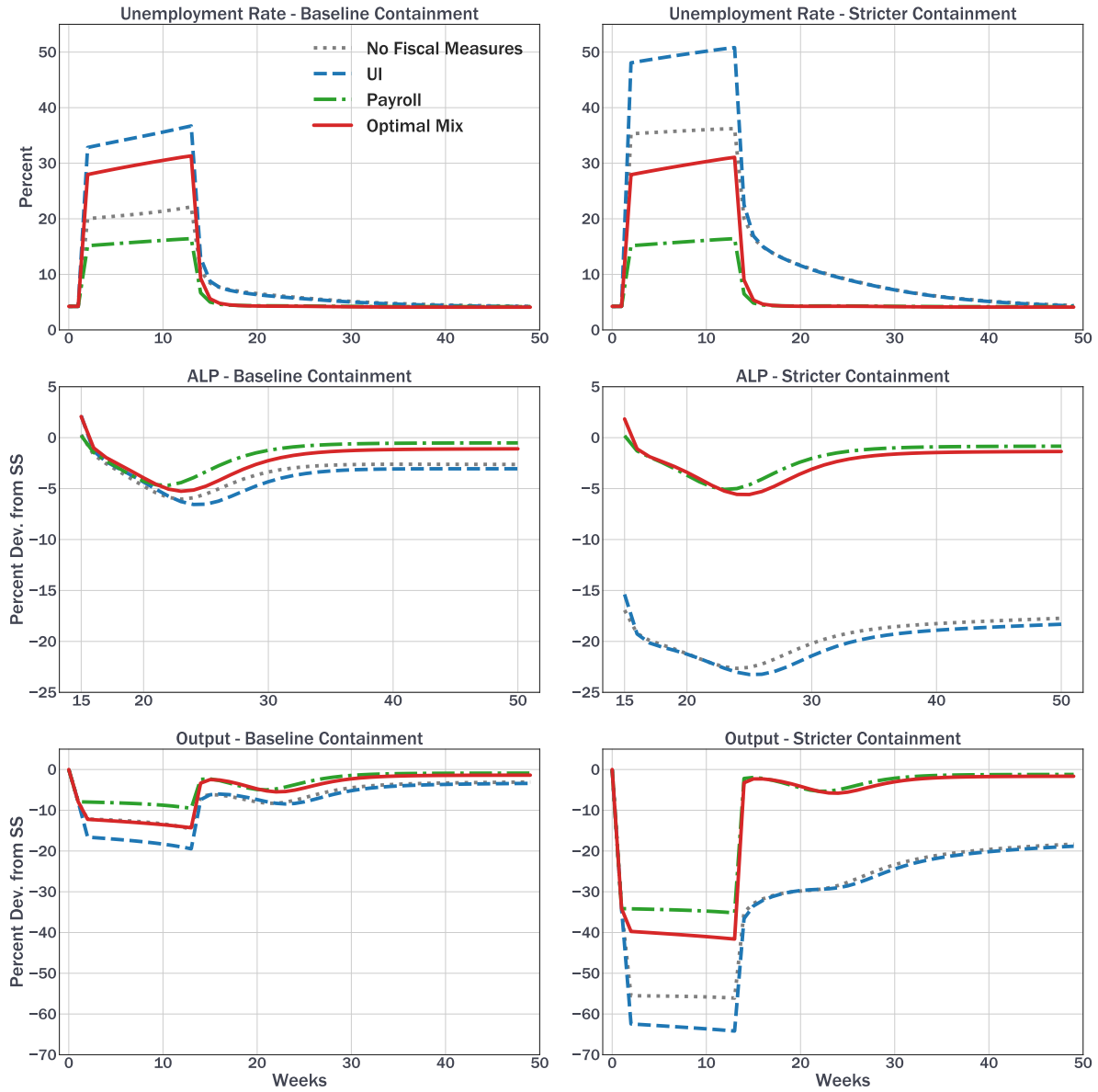


Figure 2: UI Expansion vs. Payroll Subsidies



Notes: This figure plots the effects of the epidemic on health and labor market dynamics when the government implements a containment with either an expansion of UI policy or introduction of payroll subsidies for one quarter. The present discounted value of government spending under only a UI expansion policy and only a payroll subsidy policy are equal. In all figures except the last one, the horizontal axis denotes weeks.

Figure 3: Optimal Policy Mix under Baseline and Stricter Containment Measures



Notes: This figure plots the effects of the epidemic on labor market dynamics when the government implements a containment with either i) only an expansion of UI policy, ii) only an introduction of payroll subsidies, or iii) only the optimal policy mix for one quarter. The present discounted value of government spending across these three alternatives are equal. In the middle panels, we plot Average Labor Productivity (ALP) after the containment period ends.

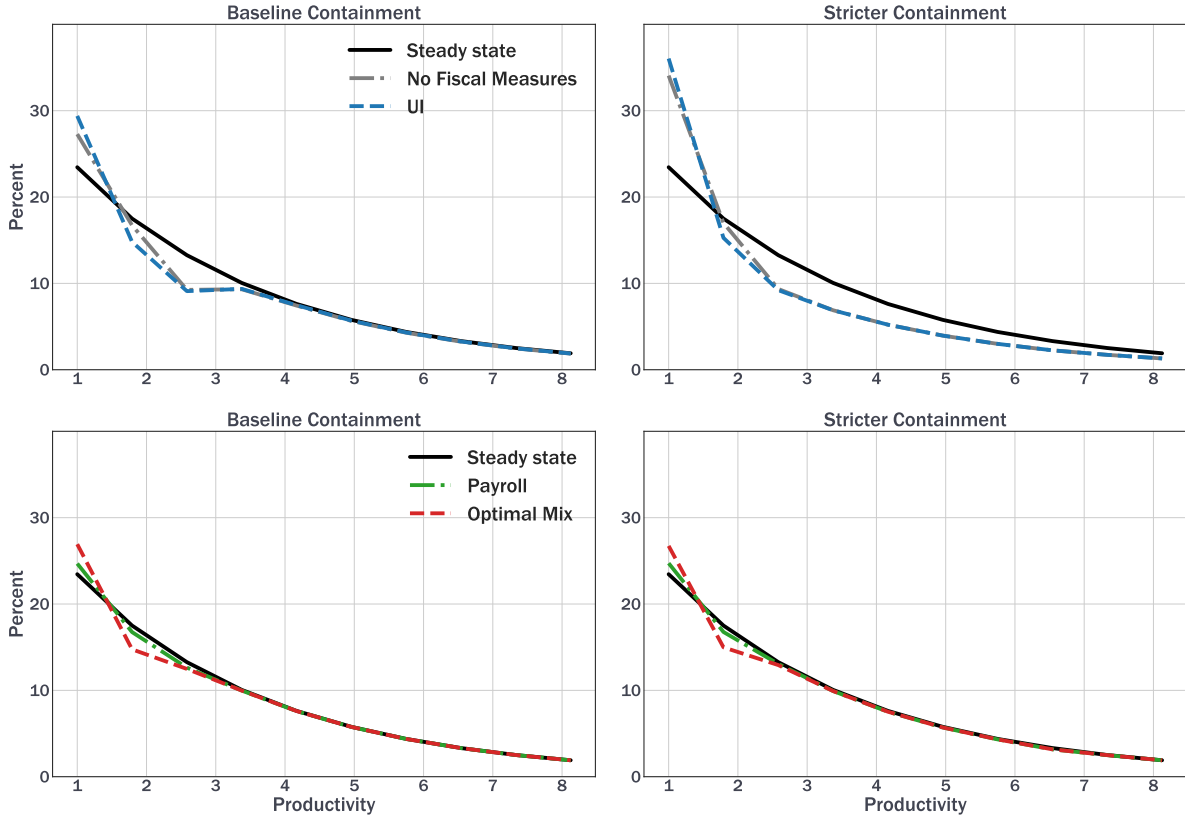
additional \$600 in weekly unemployment benefits on top of regular payments that average \$400. To make cost-equivalent comparisons, we consider an alternative where the cost incurred by this UI expansion is instead diverted toward payroll subsidies, implying  $\tau_p = 0.45$ .<sup>16</sup> Figure 2 plots the infection dynamics and labor market outcomes under these two cases. Relative to the no-fiscal-policy scenario, UI expansion results in a larger increase in unemployment driven by additional permanent dissolutions since a high value of unemployment yields a negative surplus for low-value matches. In contrast, payroll subsidies dampen the rise in unemployment by preventing temporary layoffs otherwise undertaken by financially-constrained firms. The larger reduction in economic activity under the UI expansion leads to a slower rise in infections, leading to both a delay and a decline in the number of deaths.<sup>17</sup> Under the UI expansion, ALP rises temporarily due to the destruction of low-productivity matches but experiences a more severe and persistent fall to seven percent below pre-crisis levels. ALP dynamics post-containment mirrors a similarly persistent drop in output. Payroll subsidies, on the other hand, allow firms to retain matches without resorting to temporary layoffs that may eventually dissolve, if recalls do not materialize. Conditional on being temporarily laid off, payroll subsidies also increase the incidence of recalls, given that firms engaged in rehiring are less likely to face financial constraints that may cause recall rejections. These result in a less-severe drop and faster recovery of both ALP and output. In order to understand ALP and output dynamics, the final panel of Figure 2 compares the match-capital distribution pre-containment (steady state) and post-containment under different policy responses. Under the no-fiscal-measure scenario (gray line), relative to the steady state, the post-containment distribution shifts toward low-match capital jobs as accumulated capital is destroyed. This effect is exacerbated by the UI expansion (blue line), but payroll subsidies (green line) preserve match capital so much so that the post-containment employment distribution remains close to the steady state. The distributions demonstrate that the UI expansion and payroll subsidies have differential effects on the productivity ladder—the former causes workers to fall off the ladder but provides insurance to job losers, while the latter preserves workers’ position along the ladder but is a less-potent direct insurance mechanism for job losers. In terms of welfare, relative to the no-fiscal-measure scenario, UI expansion results in a welfare gain equivalent to 0.18 percent of additional lifetime consumption, while payroll subsidies result in a welfare gain of 0.76 percent.<sup>18</sup> This implies that when considered in isolation, a payroll subsidy is preferred over a cost-equivalent UI expansion.

<sup>16</sup>In the baseline calibration,  $b = 0.911$  corresponds to an average \$400 weekly benefit amount and 40 percent replacement rate. Under the CARES Act, the total weekly benefit amount in the model then becomes  $2.5 \times b$ . The present discounted value of providing the additional benefit amount of  $1.5 \times b$  over a quarter is cost-equivalent to the 45 percent payroll subsidy provided to the firms in the non-essential sector over a quarter.

<sup>17</sup>The payroll subsidy program results in roughly 15,000 more deaths after one year. Since we do not model how delaying infections under the UI expansion may result in improved preparedness of the health system, we view this difference in death toll as a lower bound. However, in the absence of an option to pause production, the death gap between UI and payroll would be higher, given that some firms that receive payroll subsidies choose to pause production in the current model.

<sup>18</sup>See Appendix A.4 for details of the welfare calculation.

Figure 4: Match Capital Distribution under Baseline and Stricter Containment Measures



Notes: This figure plots the pre-containment (steady state) and post-containment (7 weeks after the containment) match capital distribution. The post-containment distributions are shown separately i) without any fiscal response (no-fiscal-measure), ii) with only an expansion of UI policy, iii) with only an introduction of payroll subsidies, and iv) with only the optimal policy mix.

**Optimal mix of policies.** What is the optimal policy mix? Given a baseline containment rate of  $\tau_q = 0.75$ , we solve for  $b$  and  $\tau_p$  to maximize welfare subject to preserving the cost as above. The optimal policy prescribes an 80 percent budget allocation toward UI while the remaining 20 percent is spent on payroll subsidies, yielding a welfare gain of 0.85 percent in additional lifetime consumption relative to a no-fiscal-measure alternative. This implies  $b^* = 2.2$  and  $\tau_p^* = 0.1$ . The left column of Figure 3 shows that under the optimal policy, the relatively generous UI payments induce a large increase in unemployment, more than halfway between the no-fiscal-measures and the full UI scenario. However, the 10 percent payroll subsidy goes a long way toward preserving match capital, as evidenced by the less-severe drop in ALP under the optimal policy. An important implication is that even if the unemployment rate is drastically higher under the optimal policy (red) relative to the no-fiscal measure (gray), output during containment is the same and recovers much faster under the optimal policy. The faster recovery occurs because firm-worker pairs with high match capital resume production once the containment period ends. This is supported by the left column of Figure 4, where the match capital distribution significantly worsens under both no-fiscal-measure (gray) and full UI (blue), but the optimal policy with *only*  $\tau_p^* = 0.1$  (red) is

capable of preserving match capital close to steady-state levels and, importantly, accomplishes what a large payroll subsidy of  $\tau_p = 0.45$  (green) would have achieved. This brings us to two important conclusions. First, a payroll subsidy that is just enough to prevent high-productivity matches from dissolving, eliminates the need for generous subsidies in excess of what firms need to weather the containment period. Second, UI and payroll subsidies target workers on different rungs of the productivity ladder. On the one hand, payroll subsidies seek to preserve matches for highly productive workers and prevent their inflow into unemployment. On the other hand, for less-productive matches predisposed to dissolution even with payroll subsidies, UI serves as an insurance mechanism to smooth consumption. Thus, when considered in isolation, payroll subsidies prevail over UI expansions, but under an optimal policy mix, these two policies are complementary. A partial allocation of resources for payroll subsidies preserves match capital and also leaves a substantial budgetary space for additional UI payments for the inevitable increase in job loss.

Finally, we ask how the optimal policy mix would change if the government had imposed a stricter lockdown ( $\tau_q = 0.90$ ), which results in a peak unemployment rate of 35 percent. In this exercise, we once again hold the government budget fixed to the level in the previous exercise. We find that the optimal policy mix now prescribes a higher fraction, 40 percent, of the budget on payroll subsidies and the remaining 60 percent on UI, implying less generous UI benefits  $b^* = 1.9$  and twice the payroll subsidy  $\tau_p^* = 0.2$ .<sup>19</sup> This yields a welfare gain of 3.4 percent. The second column in Figure 3 shows that compared with the lax (baseline) containment, the no-fiscal-measures scenario induces a much larger increase in the unemployment rate, as well as a significantly larger drop in ALP and, correspondingly, output. These effects are once again exacerbated by the UI-only policy, because strict containment turns even high-productivity matches to low surplus ones and makes them vulnerable to dissolution. The top right panel of Figure 4 shows that under no-fiscal-response (gray) and UI (blue), matches even at the top of the productivity distribution are lost. Firms that would have otherwise preserved their relationship with an experienced worker under a lax containment policy are no longer capable of doing so under strict containment. Thus, the optimal policy features a stronger payroll subsidy ( $\tau_p^* = 0.2$ ). The bottom right panel of Figure 4 shows that the match quality distribution under the optimal policy (red) gets close to the pre-crisis levels, while a full-payroll subsidy (green) yields only marginal gains. As a result, the optimal policy significantly alleviates the drop in productivity and output even during containment, which is the reason why the welfare gains from the optimal mix become much higher under strict containment. Once again, we note that the 40 percent budget allocation on payroll subsidies captures most of the gains that a full budget allocation to payroll would have achieved.

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<sup>19</sup>When we consider UI and payroll subsidy policies under stricter containment in isolation, we again find that payroll subsidies are preferred over the UI extension. Relative to no-fiscal policy, the welfare gains of the former is 3.33 percent and the welfare gains of the latter is 0.25 percent.

## 5 Conclusion

The COVID-19 pandemic and the ensuing policy interventions to contain it have had unprecedented negative effects on the U.S. labor market. In response, the U.S. government implemented two types of labor market policies: expanding UI payments and granting payroll subsidies to vulnerable firms. In this paper, we study the usefulness of these policies both in isolation and in conjunction. The introduction of payroll subsidies alone is preferred over a cost-equivalent UI expansion as it preserves highly productive matches during containment, thus enabling a faster recovery of productivity and output following the lifting of containment measures. When considered jointly, however, a cost-equivalent optimal mix allocates 20 percent of the budget to payroll subsidies and 80 percent to UI expansion. This allocation is sufficient to save high-productivity jobs from dissolution, while the remaining funds are used to provide income to less-productive workers who face inevitable job loss.

We abstract from two potentially important margins. First, we assume away any labor mobility across sectors. If the pandemic has a disproportionately persistent effect on labor demand in one of the sectors, policies that tie workers to jobs, such as payroll subsidies, would become less desirable. Second, we abstract away from welfare gains through demand stabilization. Because payroll subsidies and UI policies benefit different groups of people with potentially different marginal propensities to consume, their effects on aggregate demand may be different. We leave these important considerations for future research.

## References

- ALVAREZ, F., D. ARGENTE, AND F. LIPPI (2020): “A simple planning problem for covid-19 lockdown,” .
- AMBURGEY, A. AND S. BIRINCI (2020): “Which Earnings Groups Have Been Most Affected by the COVID-19 Crisis?” *Economic Synopses*.
- ATKESON, A. (2020): “What will be the economic impact of COVID-19 in the US? Rough estimates of disease scenarios,” .
- BERGER, D. W., K. F. HERKENHOFF, AND S. MONGEY (2020): “An seir infectious disease model with testing and conditional quarantine,” .
- BICK, A. AND A. BLANDIN (2020): “Real time labor market estimates during the 2020 coronavirus outbreak,” *Unpublished Manuscript, Arizona State University*.
- EICHENBAUM, M. S., S. REBELO, AND M. TRABANDT (2020): “The macroeconomics of epidemics,” .
- FANG, L., J. NIE, AND Z. XIE (2020): “Unemployment insurance during a pandemic,” *FRB Atlanta*.
- FARIA-E CASTRO, M. (2020): “Back-of-the-envelope estimates of next quarter’s unemployment rate,” *Saint Louis Fed Blogs*.
- FUJITA, S. AND G. MOSCARINI (2017): “Recall and unemployment,” *American Economic Review*, 107, 3875–3916.
- GANONG, P., P. J. NOEL, AND J. S. VAVRA (2020): “US Unemployment Insurance Replacement Rates During the Pandemic,” Tech. rep., National Bureau of Economic Research.
- GARRIGA, C., R. MANUELLI, AND S. SANGHI (2020): “Optimal management of an epidemic: Lockdown, vaccine and value of life,” .
- GASCON, C. (2020): “COVID-19: Which Workers Face the Highest Unemployment Risk?” *St. Louis Fed On the Economy*, <https://www.stlouisfed.org/on-the-economy/2020/march/covid-19-workers-highest-unemployment-risk>.
- GLOVER, A., J. HEATHCOTE, D. KRUEGER, AND J.-V. RÍOS-RULL (2020): “Health versus wealth: On the distributional effects of controlling a pandemic,” .
- GREGORY, V., G. MENZIO, AND D. G. WICZER (2020): “Pandemic Recession: L or V-Shaped?” Tech. rep., National Bureau of Economic Research.
- GUERRIERI, V., G. LORENZONI, L. STRAUB, AND I. WERNING (2020): “Macroeconomic Implications of COVID-19: Can Negative Supply Shocks Cause Demand Shortages?” .
- HAGEDORN, M. AND I. MANOVSKII (2008): “The cyclical behavior of equilibrium unemployment and vacancies revisited,” *American Economic Review*, 98, 1692–1706.
- HALL, R. E. AND C. I. JONES (2007): “The value of life and the rise in health spending,” *The Quarterly Journal of Economics*, 122, 39–72.
- JONES, C. J., T. PHILIPPON, AND V. VENKATESWARAN (2020): “Optimal mitigation policies in a pandemic: Social distancing and working from home,” .
- KAPICKA, M. AND P. RUPERT (2020): “Labor Markets during Pandemics,” *Manuscript, UC Santa Barbara*.
- KERMACK, W. O. AND A. G. MCKENDRICK (1927): “A contribution to the mathematical theory of epidemics,” *Proceedings of the royal society of london. Series A, Containing papers of a mathematical and physical character*, 115, 700–721.
- KURMANN, A., E. LALE, AND L. TA (2020): “The impact of COVID-19 on U.S. employment and hours: Real-time estimates with homebase data,” .
- MITMAN, K. AND S. RABINOVICH (2020): “Optimal Unemployment Benefits in the Pandemic,” .
- ŞAHİN, A., M. TASCI, AND J. YAN (2020): “The Unemployment Cost of COVID-19: How High and How Long?” *Economic Commentary*.

# A Appendix

## A.1 Stationary Equilibrium

Let  $s \in \{E, N\}$  denote the essential  $E$  and non-essential  $N$  sectors. A recursive equilibrium for this economy is a list of household and firm policy functions for whether to keep an existing match  $d_{W,k,s}^h$ ,  $d_{U_T,k,k',s}^h$ , and  $d_{J,k,s}^h$ ; whether to produce or pause  $l_s^h$ ,  $\forall h \in \{S, I, R\}$ ,  $\forall s \in \{E, N\}$ , and  $\forall k \in \{C, U\}$ ; labor market tightness  $\theta_s$   $\forall s \in \{E, N\}$ ; an aggregate law of motion for the mass of susceptible  $S$ , infected  $I$ , recovered  $R$ , and dead  $D$  people; and the distribution of households across states  $\mu$  such that:

1. Given government policies, household and firm policy functions solve their problems.
2. Labor market tightness in sector  $s$  satisfies free-entry condition  $V = 0$ .
3. Aggregate laws of motion for health status are given by

$$\begin{aligned}
 S_{t+1} &= S_t - T_t \\
 I_{t+1} &= I_t + T_t - (\pi^R + \pi^D) I_t \\
 R_{t+1} &= R_t + \pi^R I_t \\
 D_{t+1} &= D_t + \pi^D I_t,
 \end{aligned} \tag{10}$$

where total number of new infections in period  $t$  is  $T_t = \pi_1 N_t^S N_t^I + \pi_2 S_t I_t$  and  $N^h$  is the total number of actively employed households with health status  $h$ .

4.  $\mu$  is the invariant distribution implied by contact rates in the labor market, transition matrices  $\Pi_n$  for health status,  $P$  for match-specific productivity, and household and firm decision rules.

## A.2 Computational Details

In this section, we describe how we solve and simulate our model.

### A.2.1 Steady State

We use value function iteration to solve the worker and firm optimization problems. The algorithm we use to obtain the stationary equilibrium of the model is outlined below.

For a given parameterization of the model and for each sector  $s \in \{E, N\}$ :

1. Start with an initial guess of market tightness  $\theta_0^s$ .
2. For each guess of  $\theta_n^s$  in iteration  $n$ :
  - (a) Iterate on worker and firm value functions in Equations (2), (3), (6), (7) and (??) until convergence.



- (b) Iterate on the laws of motion implied by the model to compute the stationary worker distribution over employment states, health status and productivity.
- (c) Solve the market tightness level  $\tilde{\theta}_{n+1}^s$  that satisfies the free-entry condition  $V = 0$ , where  $V$  is given in Equation (9). Calculate its absolute deviation from  $\theta_n^s$ .
- (d) If the deviation is less than a tolerance level, stop. Otherwise update the guess for market tightness to  $\theta_{n+1}^s = \zeta\theta_n + (1 - \zeta)\tilde{\theta}_{n+1}^s$  with dampening parameter  $\zeta < 1$  and return to Step 2.

## A.2.2 Transition

For each policy, in calculating impulse responses, we focus on perfect foresight transition dynamics following one-time and unanticipated shocks out of steady state, using a shooting algorithm that we outline below.

1. Fix the number of time periods it takes to reach the new steady state,  $T$ .
2. Compute the initial (no-infection) steady-state equilibrium for a given set of model parameters according to the algorithm in Section A.2.1. As the epidemic is transitory and there is no permanent productivity difference between susceptible and recovered workers, worker and firm value functions in the terminal steady state are the same as in the initial steady state, as is the labor market tightness for each sector.
3. Guess a sequence of infected worker labor supply and the total number of infected in the economy as a whole,  $\{N_t^{I,0}, I_t^0\}_{t=1}^{T-1}$ . For each sector  $s \in \{E, N\}$ :
  - (a) Guess a sequence of labor market tightness,  $\{\theta_t^{s,0}\}_{t=1}^{T-1}$ .
  - (b) Solve for the path of worker and firm value functions for  $t \in \{1, \dots, T-1\}$  backwards, given the shocks, path of infection  $\{N_t^{I,0}, I_t^0\}_{t=1}^{T-1}$ , market tightness  $\{\theta_t^{s,0}\}_{t=1}^{T-1}$ , and terminal worker and firm values in period  $T$ .
  - (c) Compute the sequence of labor market tightness  $\{\theta_t^{s,1}\}_{t=1}^{T-1}$  consistent with the free-entry condition and worker laws of motion over the state space, induced by the decisions implied by the path of value functions over  $t \in \{1, \dots, T-1\}$ .
  - (d) Check if  $\max_{1 \leq t < T} |\theta_t^{s,1} - \theta_t^{s,0}|$  is less than a tolerance level. If yes, continue; if not, update  $\{\theta_t^{s,0}\}_{t=1}^{T-1}$  and go back to Step (b).
  - (e) Check if  $|\theta_T^{s,1} - \theta_T^{s,0}|$  is less than a tolerance level. If yes, stop; if not, increase  $T$  and go back to Step 1.
4. Calculate the sequence of infected worker labor supply and the total number of infected,  $\{N_t^{I,1}, I_t^1\}_{t=1}^{T-1}$ , implied by the path of worker distribution over the transition.
5. Check if  $\max_{1 \leq t < T} |N_t^{I,1} - N_t^{I,0}|$  and  $\max_{1 \leq t < T} |I_t^1 - I_t^0|$  are less than a tolerance level. If yes, continue; if not, update  $\{N_t^{I,0}\}_{t=1}^{T-1}$  and  $\{I_t^0\}_{t=1}^{T-1}$  and go back to Step 3.

6. Check if  $|N_T^{I,1} - N_T^{I,0}|$  and  $|I_T^1 - I_T^0|$  are less than a tolerance level. If yes, stop; if not, increase  $T$ , and go back to Step 1.

### A.3 Computing the Statistical Value of Life

To calculate the model-implied statistical value of life (SVL), we first compute the fraction of lifetime consumption  $\pi$  all agents in the steady-state economy are willing to forgo in order to prevent a rise in the probability of death by  $\psi = \frac{1}{10,000}$ . We do this by resolving our no-infection model with a discount factor  $\tilde{\beta} = (1 - \psi)\beta$  adjusted by this mortality rate and finding the  $\pi$  that renders workers indifferent between these two economies behind the veil of ignorance.

Second, to convert fraction  $\pi$  to a dollar amount, we take the quarterly consumption amount from the National Income Accounts. U.S. consumption per capita in the fourth quarter of 2019 was \$40,748. We divide this number by 52.14 to arrive at a weekly consumption of  $c_w^{NIPA} = \$781.5$ . The model-implied weekly dollar amount that workers are willing to forgo is then given by  $\pi \times c_w^{NIPA}$ .

In the final step, we convert the weekly consumption that workers are willing to forgo into a present value term by taking its geometric sum, i.e.  $\frac{\pi c_w^{NIPA}}{1 - \beta}$ . This implies that the total amount that workers are willing to pay to avoid one death is  $\frac{1}{\psi} \frac{\pi c_w^{NIPA}}{1 - \beta}$ , which is the definition of SVL. We choose the constant  $\bar{u}$  in the utility function such that  $SVL = \$10M$ .

### A.4 Computing Welfare

To compute a welfare metric, we solve for the percent change in lifetime consumption  $\pi$  that renders a household, behind the veil of ignorance, indifferent between the baseline economy and the economy under a new labor market policy, accounting for all policy changes during the transition period. The expected value of a particular policy  $p$ , just as that policy is implemented, is given by

$$\mathbb{E}V(\pi, p) \equiv \sum_{t=1}^{T-1} \beta^{t-1} \left[ \int u((1 + \pi) c_{it}(p)) d\Lambda_{it}(p) \right] + \beta^{T-1} \int V_{iT}(\pi, p) d\Lambda_{iT}(p),$$

where  $c_{it}(p)$  denotes the consumption of individual  $i$  under policy  $p$  in period  $t$ ,  $\Lambda_{it}(p)$  is the cross-sectional cumulative density function of workers, and  $V_{iT}(\pi, p)$  is the steady-state value of individual  $i$ , where she receives an additional  $\pi$  percent of her consumption under that policy. The underlying assumption here is that the economy is close enough to its terminal steady state by the end of period  $T$ . In practice, we choose  $T = 500$  weeks in our computations, which we observe to be long enough for the economy to have converged to a stationary equilibrium.

Finally, to arrive at the welfare metric  $\pi(p)$  under policy  $p$ , we solve the following condition:

$$\mathbb{E}V(\pi, 0) = \mathbb{E}V(0, p),$$

where we use the convention that  $p = 0$  denotes the baseline economy, i.e. there are no fiscal measures introduced. Otherwise, we consider  $p \in \{\text{UI, Payroll, Mix}\}$  for various policy scenarios.