A Social Insurance Perspective on Pandemic Fiscal Policy: Implications for Unemployment Insurance and Hazard Pay

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This appendix is a more formal presentation of the material in the section of the paper on "A Social Insurance Perspective." The organization of the first five sections follows that section of the paper. Sections F and G consider the two extensions of the model that we allude to in the paper but don't analyze in the main text—the possibility of various types of debt and payment "forgiveness," and the treatment of state and local governments. Finally, Section H extends the analysis of incentive and fairness considerations in the text and in Section B to the case where the government has some but less than full information about who should optimally be working in a pandemic.

A. A Baseline Case

***Assumptions*.** The economy lasts for a single period and consists of a continuum of identical individuals with a total mass of 1. Throughout, all markets are perfectly competitive.

There are two sectors, A and B. There are three possible states of the world: no pandemic, A-sector pandemic, and B-sector pandemic. If a sector isn't affected by a pandemic, its production function is linear in employment in the sector: $Q_i = L_i$ ($i = A, B$), where L_i is the amount of labor employed in sector i. If a sector is affected by a pandemic, its production is 0. The probabilities of the A-pandemic state and the B-pandemic state are equal.

Each individual has utility $U(C_A) + U(C_B) - V(L)$, where C_i is their consumption of the output of sector i and L is the amount they work. The functions are assumed to satisfy $U'(\bullet) > 0$, $U''(\bullet) < 0$, and $V(1) > V(0)$. $U(0)$ and $V(0)$ are normalized to 0. Each individual's labor supply can take on only the values 0 and 1. Individuals are mobile between sectors before the state of the world is realized but immobile ex post. We also assume that the utility from consumption is large enough relative to the disutility of working that in the various cases we consider, in equilibrium individuals work unless prevented by a pandemic.[1]

***Equilibrium under different allocation mechanisms*.** Suppose first that there are no insurance markets. The symmetry of the sectors causes half of individuals to be in each sector. In the no-pandemic state, output of each sector is ½, the symmetry causes the prices of the two outputs to be equal, and competition and the assumption about the production function imply that the wage in each sector equals the price of that sector's output. Diminishing marginal utility causes each individual to consume ½ unit of each output. If there's a pandemic in one sector, individuals in that sector earn no income, so their consumption of both outputs is 0. Each individual in the non-pandemic sector earns an amount equal to the price of that sector's output, and so consumes 1 unit of that sector's output.

This outcome involves an inefficient allocation across states. In the A-pandemic state, the marginal utility (from consumption of the output of sector B, which is the only sector that can produce) of individuals in the A sector is $U'(0)$, while the marginal utility of individuals in the B sector is $U'(1)$. In the B-pandemic state, the marginal utilities are reversed. Thus there's scope for insurance across states.

If there are complete markets (achieved either through markets for insurance against a pandemic in each sector or markets in all Arrow-Debreu commodities), it's straightforward to

[1] The exact condition needed for individuals to work when they're able to depends on the case considered. For example, in the very first case discussed below (the case of no insurance markets in the baseline version of the model), the required condition is just $U(1) > V(1)$—in a pandemic, an individual in the sector that remains open prefers to work and spend all their income on the output of that sector than to not work and have no consumption. (For individuals to work in the no-pandemic state, the required condition is $U(1/2) + U(1/2) > V(1)$. However, this condition follows from $U(1) > V(1)$ and our assumptions about $U(\bullet)$. Thus we only need to assume $U(1) > V(1)$ for individuals to always work when they're able to in the case of no insurance markets.)

The one place where we depart from the assumption that individuals always work if they're able to is when we introduce partial ex post labor mobility. We model this possibility by assuming a heterogeneous cost of switching sectors among workers in the sector that's shut. In this case, some individuals who could conceivably continue to work but face a very high cost of doing so don't work.

check that the allocation of individuals to sectors and the no-pandemic allocation are the same as without insurance, and that there's full risk-sharing: if a pandemic hits a sector, the consumption of the output of the sector that stays open is ½ for the individuals in both sectors. To see that this is the equilibrium, note that with these outcomes, in any state every individual has the same marginal utility. Moreover, the allocation satisfies the technological constraints, and individuals in each sector have the same expected utility.

Finally, if there are no insurance markets, the government can use taxes and transfers to implement the allocation that would occur if they were present. In the absence of a pandemic, it takes no action; as a result, the allocation without a pandemic is the same as before. But if a pandemic shuts one sector, it taxes the workers in the sector that remains open half their income and transfers the proceeds to the workers in the sector that shuts. Recall that the wage of each worker in the sector that stays open equals the price of that sector's output. Thus each worker's after-tax-and-transfer income is one-half the price of the output of the sector that remains open, and so everyone's consumption is ½.

Discussion. In the text, we highlight several messages of the baseline case: the optimal social insurance policy consists of targeted transfers; it doesn't involve aggregate demand stimulus; it equalizes income across individuals but doesn't fully replace unemployed workers' lost income; and one can think of it as the government taking the amount the employed would normally spend on the output of the sector that shuts and giving the proceeds to the individuals in that sector.[2]

Here, we highlight an additional implication of the baseline case concerning what happens

[2] As we describe the optimal social insurance policy, not just the transfers but the taxes to finance them are targeted, since they're only levied on the employed. But an equivalent policy is to tax everyone half their normal income and transfer to each unemployed worker the full amount of their normal income (which would mean that the unemployed would have to pay back half of what they receive in transfers as taxes). With this policy, only the transfers are targeted; but as with the policy described in the text, each individual's after-tax-and-transfer income is half their normal income. Or, each individual could be taxed half their actual income; since the unemployed earn no income, the tax would fall only on the employed. Thus, targeted taxes aren't needed to achieve the efficient allocation.

under complete markets: even though the possibility of a pandemic is a systemic risk, the pricing of insurance is actuarially fair. That is, even though a pandemic reduces total output, when individuals can obtain insurance they can trade off consumption in a pandemic state (of the output that can be produced) and consumption in the no-pandemic state (of either output) just according to the relative probabilities of the two states. The reason is that a pandemic doesn't reduce consumption of both sector's outputs, but instead shuts off one type of consumption entirely and leaves the other unchanged. The facts that consumption of the output that can still be produced remains at its usual level and that utility is additively separable imply that marginal utility in a pandemic is the same as in normal times. As a result, individuals don't require a premium to provide insurance against a pandemic state.

The case of deficit-financed transfers. In practice, transfers in the pandemic have been financed not by current taxes but by borrowing, which will presumably be offset by higher taxes (or lower government spending) in the future. Thus, suppose that there are two periods; that a pandemic can only occur in the first period; that if there's a pandemic, the government finances any social insurance payments by taxes on all individuals in the second period; and that all individuals can save and borrow at the same interest rate as the government. Finally, assume an individual's utility is $[U(C_A^1) + U(C_B^1) - V(L^1)] + \beta[U(C_A^2) + U(C_B^2) - V(L^2)], 0 < \beta < 1$, where superscripts denote time periods.

In this situation, the complete-markets outcome is very similar to that of the baseline case: in the event of a pandemic (which can only occur in the first period by assumption), each individual's consumption of the output of the sector that stays open is ½, with no impact on allocations in the second period. For the government to bring about this outcome through first-period transfers and second-period taxes, it simply makes transfers to unemployed workers to fully offset their lost income in the first period, and then taxes everyone half their usual income in the second. With this policy, everyone saves half their after-transfer income in the first period and then uses their savings to pay the higher second-period taxes, and they all have the same path of consumption as under complete markets.

Notice that in this case, as in the baseline one, the higher consumption of the unemployed relative to what they would have in the absence of insurance or government intervention comes from lower consumption of the employed. In terms of income flows, however, the accounting is more complicated. The unemployed get transfers in excess of their consumption in the period of the pandemic, but they pay some of that back through second-period taxes; and the employed neither get transfers nor pay taxes in the period of the pandemic, but pay taxes in the second period.

Section E on the possibility of an aggregate demand shortfall considers an extension of the model to multiple periods that has more interesting implications.

***Introducing partial labor mobility*.** Allowing for some ex post labor mobility has relatively little effect in the baseline case. However, because it has more significant implications when the government doesn't have full information about who should optimally be working in a pandemic, we describe its impact in the baseline case.

To allow for some labor mobility, we assume that when a pandemic hits, each individual in the sector that shuts down draws a cost of switching sectors. The distribution of the cost is assumed to be continuous, and to be wide enough that some but not all individuals switch out of the sector that shuts. For simplicity, the cost is a direct utility cost (for example, stress or inconvenience), rather than a cost in terms of output (for example, having to hire movers to move to a new location).

In the complete-markets outcome with these assumptions, individuals only purchase insurance against the possibility that a pandemic hits their sector *and* that their moving cost is above some threshold. If a pandemic hits their sector and they drew a low moving cost, they switch sectors and receive no insurance payments. Thus with complete markets, partial labor mobility causes output in the sector that stays open to rise in a pandemic. However, consumption of the sector's output is fully equalized across individuals, as before.[3] All of this can be replicated through targeted government transfers (targeted in this case to workers in the sector that was shut with sufficiently high moving costs, rather than to all workers in that sector).

***Some variations that have little effect on the main messages*.** Many of the assumptions of the baseline case serve only to simplify the analysis and don't affect the main messages:

- It's easy to introduce a fourth state of the world where there's a pandemic in both sectors and so neither produces output. Under any allocation mechanism, the outcome in that state is trivial: no one works, there's no output, and everyone has zero consumption.
- It's not necessary to assume there are only two sectors and a pandemic causes half the economy to shut down. One way to relax this assumption is to assume there's a large number N of sectors; that (as before) they're symmetric; and that a pandemic shuts fraction f of the sectors, with the sectors that are shut chosen at random. Under these assumptions, all the previous results continue to hold, with the obvious changes: in the no-pandemic state, each individual's consumption of the output of each sector is $1/N$ (rather than ½); in a pandemic, the optimal social insurance policy is to tax each individual who remains employed fraction f of their income (rather than half their income) and transfer the proceeds to the unemployed; and so on.
- Relaxing the assumption that the two sectors have the same probability of being shut by a pandemic complicates the equations but doesn't change anything of importance. For example, suppose only one sector faces a risk of being shut. Then individuals who work in that sector always have lower consumption than those who work in the other sector (to counterbalance the fact that they don't always have the disutility of working); and

[3] If the costs of moving take the form of output rather than utility, individuals purchase insurance to cover any moving costs they incur, and what is equalized across individuals is consumption net of any moving costs.

fewer individuals are in the sector that may shut than in the one that always stays open (because the sector that's at risk is on average less productive). But the key results of the baseline case carry over: if the complete-markets outcome is achieved through social insurance, that insurance takes the form of targeted transfers to the workers who lose their jobs in a pandemic, with no "stimulus" and with transfers that don't fully replace the income that unemployed workers lose in a pandemic . In addition, as the probability of a pandemic approaches zero, outcomes converge to those of the baseline case.

- It's straightforward to relax the assumption that utility is additively separable. Suppose an individual's utility, rather than being $U(C_A) + U(C_B) - V(L)$, is $U(C_A,C_B) - V(L)$. Letting subscripts denote partial derivatives, we assume $U_1(\bullet) > 0$, $U_2(\bullet) > 0$, $U_{11}(\bullet) < 0$, and $U_{22}(\bullet) < 0$; we make no assumption about the sign of $U_{12}(\bullet)$ (though we assume $U_{11}(C_A, C_B)U_{22}(C_A, C_B) - [U_{12}(C_A, C_B)]^2 > 0$ for all non-negative C_A and C_B). Finally, to maintain the symmetry of the sectors, we assume that $U(C_A, C_B) = U(C_B, C_A)$ for all non-negative C_A and C_B. With this generalization, everything we say in the text continues to hold. The only substantive change is to the result described above about the actuarially fair pricing of insurance under complete markets. For example, suppose $U_{12}(\bullet) < 0$, which implies that when a pandemic shuts one sector, the marginal utility of consumption of the output of the sector that stays open is higher than in normal times. In this case, equilibrium marginal utility is higher than normal in a pandemic, and so there's a premium on the provision of insurance against a pandemic relative to the actuarially fair price. When $U_{12}(\bullet) > 0$—which seems less plausible—the opposite holds.

In the various extensions and variations on the model considered below, one can make analogous changes to the ones described here without changing the main messages.

B. <u>Incentives and Fairness</u>

<u>The case considered in the text</u>. In the text, we describe several reasons that it might not be feasible or desirable for the allocation in a pandemic to make individuals who continue to work worse off than those who stop working. Here, for concreteness we model these considerations by making the somewhat artificial assumption that everyone in the sector that remains open should work in the pandemic, but that which sector an individual is in isn't observable. With this assumption, for the individuals in the sector that's not affected by the pandemic to continue to work, they must not prefer claiming they're in the other sector to working. This condition is

(A1) $$U(C^E) - V(1) \geq U(C^U),$$

where C^E and C^U are the consumptions of employed and unemployed workers in the pandemic (of the output that's still being produced). Since $V(1) > 0$, this requires $C^E > C^U$.

One can show that the optimal allocation involves satisfying the incentive constraint (A1) with equality. Thus,

(A2) $$U(C^E) - V(1) = U(C^U).$$

The allocation must also satisfy the economy's resource constraint. Since total output in the sector that remains open is ½ and the number of individuals in each sector is ½, this condition is

(A3) $$C^E + C^U = 1.$$

Equation (A3) implies that total consumption is the same as in the baseline, and equation (A2) implies that the employed now consume more than the unemployed. It follows that the consumption of the employed is more than without the constraint, and the consumption of the unemployed is less. Introducing fairness or incentive considerations therefore reduces the optimal level of social insurance. As in the baseline case, the optimal policy can be implemented with targeted transfers to the unemployed and without any type of government stimulus: the government taxes employed workers amount C^U and transfers the proceeds to the unemployed.

Introducing partial labor mobility. Our baseline case assumes individuals are completely immobile between the two sectors in a pandemic. In reality, however, there were large flows of workers from industries that were largely shut by the pandemic to ones that weren't. And—in contrast to what we assume in our analysis of labor mobility in Section A—realistically the government has little information about which workers can move relatively easily.

To analyze these issues, we again model labor mobility by assuming that each individual in the sector that shuts draws a utility cost of switching sectors when a pandemic hits, and that the distribution of the cost is continuous and is such that some but not all workers move. Now, however, we assume the government only knows the distribution of the cost, and not each worker's draw. Thus the government has conflicting objectives. On the one hand, it wants to insure workers for whom switching would be very costly against large falls in their consumption. On the other hand, it wants to provide incentives for individuals with low switching costs to move.

One can show that this tradeoff leads the government to adopt policies with three consequences. First, and least interestingly, partial labor mobility mitigates the fall in output in a pandemic, as in the case where the government has complete information. This follows straightforwardly from the fact that some individuals switch to the sector that stays open. Second, workers who started in the sector that doesn't shut (and so remain employed there) obtain higher consumption than individuals who start in the sector that shuts and don't move. That is, social insurance doesn't fully insure the unemployed, as in the case with incentive or fairness constraints but no labor mobility. Third, and perhaps most interestingly, the optimal policy provides individuals who switch sectors with higher consumption than workers who are in the open sector throughout. That is, there's in effect a "moving bonus" to workers who switch sectors in a pandemic. The reason is that higher consumption of switchers, but not higher consumption of workers who stay in the open sector, increases the incentive to switch sectors.[4]

[4] This discussion presumes the government can do this. If it can't treat employed workers differently depending on which sector they were in originally (because of either limited information or fairness considerations), labor mobility still mitigates the fall in output, and the employed still consume more than the unemployed. This case is broadly similar to our baseline case of incentives and fairness, where allocations are characterized by just the two variables C^E and C^U.

C. High-Risk Essential Workers and Hazard Pay

Assumptions. As described in the text, we introduce high-risk essential workers by assuming there are three sectors rather than two, and that in the event of a pandemic both the utility of consuming one sector's output and the disutility of working in that sector rise. Let $U^H(C)$ be the utility of consuming the output of the high-risk essential sector in a pandemic, and $V^H(L)$ be the disutility of working in that sector in a pandemic. We assume $U^{H\prime}(C) > U'(C)$ for all $C \geq 0$, and $V^H(1) > V(1)$; we normalize $U^H(0)$ and $V^H(0)$ to 0. ($U(\bullet)$ continues to denote the utility from consuming the output of a sector that's not high-risk, and $V(\bullet)$ the disutility of working in such a sector.) As in our baseline case, ex ante the sectors are identical: each is equally likely to be the one that's shut by a pandemic, and equally likely to be the one that's essential in a pandemic. Individuals are again mobile ex ante but immobile ex post.

High-risk essential workers in the baseline case. If there aren't incentive or fairness considerations, adding an essential hazardous sector has little effect on the complete-markets outcome, and hence correspondingly little effect on optimal social insurance. As in the baseline case without a high-risk essential sector, the symmetry of the sectors causes individuals to be allocated equally among them. In the event of a pandemic, there's full employment in the two sectors that continue to operate (recall that we assume preferences are such that in equilibrium individuals always work unless prevented by a pandemic); and it's again straightforward to check that all individuals have equal consumption of the outputs of those sectors (for the same reasons as in the baseline case). As before, the complete-markets allocation can be replicated by the straightforward tax-and-transfer scheme of taxing individuals who remain employed what they would have spent on the output of the sector that is shut and giving the proceeds to the individuals who had been employed in that sector.

Adding incentive or fairness considerations. If allocations that make employed workers worse off than the unemployed aren't feasible or are viewed as undesirable, the implications of adding an essential high-risk sector are different. Denote the three sectors in a pandemic by S ("shut down"), H ("high-risk essential"), and L ("lower-risk"), and the consumption of an individual in sector j of the output of sector i by C_i^j.). For workers in the high-risk sector, the condition that the employed must be at least as well off as the unemployed is

$$\text{(A4)} \qquad U^H(C_H^H) + U(C_L^H) - V^H(1) \geq U^H\left(C_H^S\right) + U\left(C_L^S\right).$$

And for those in the lower-risk sector, it is

$$\text{(A5)} \qquad U^H(C_H^L) + U(C_L^L) - V(1) \geq U^H\left(C_H^S\right) + U\left(C_L^S\right).$$

As in the case without a high-risk essential sector, the optimal allocation satisfies the constraints with equality. Since $V^H(1) > V(1) > 0$, it follows that individuals in the high-risk sector have higher consumption than individuals in the lower-risk sector, who in turn have higher consumption than individuals in the sector that shuts down.

As discussed in the text, the implication that individuals in the high-risk essential sector consume more than individuals in the lower-risk sector can be interpreted as hazard pay. (Note, however, that in the efficient allocation in the absence of incentive or fairness considerations, workers in both the high-risk sector and the open sector that's lower risk are taxed. As a result, hazard "pay" for individuals in the high-risk essential sector could take the form of reduced taxes rather than actual transfers.)

***Does the government need to provide the hazard pay*?** Suppose there aren't insurance markets or markets in Arrow-Debreu commodities, that prices and wages are determined after the state of the world is realized, and that there's potentially social insurance. In a pandemic, the outputs of the two sectors that remain open are equal, but the marginal utility of the output of the high-risk essential sector is greater than that of the output of the lower-risk sector. Thus if prices and wages are flexible, the price of the high-risk sector's output must be greater than that of the lower-risk sector's. This implies that the marginal revenue product of a worker in the high-risk essential sector is greater than that of a worker in the lower-risk sector, and hence that the wage in the high-risk sector is higher. Thus an element of hazard pay (in the sense of higher wages for high-risk essential workers) would arise endogenously.

There's no reason, however, for the rise in the wage in the high-risk essential sector to make individuals in the two sectors that are open exactly equally well off, which is what's required under the optimal social insurance policy. At a general level, since the economy involves taxes and transfers and features incentive or fairness constraints, there's no presumption that it will yield the efficient outcome. Specifically, if the difference in marginal utility between the outputs of the high-risk and lower-risk sectors is small and the gap in the disutility of working is large, the rise in the wage isn't enough to make high-risk workers as well off as lower-risk workers; and if the opposite pattern holds, the rise in the wage makes high-risk workers strictly better off than lower-risk workers. Thus government intervention is almost certainly necessary to ensure that high-risk essential workers receive the optimal amount of hazard pay. Finally, in actuality prices and wages appear to have been quite sticky in the pandemic, suggesting that in practice the amount of endogenously generated hazard pay was minimal.

D. Heterogeneous Incomes and Self-Insurance

***Heterogeneous incomes in the static case*.** The most natural way to introduce income heterogeneity is to assume workers differ in their productivities. Concretely, consider the baseline case with the change that if individual j works in a sector, they produce $\alpha_j > 0$ units of the sector's output (rather than producing 1 unit), with α varying across individuals. It's straightforward to show that in this case, each individual's consumption under complete markets scales with their α. That is, if there's no pandemic, individual j consumes $\alpha_j/2$ units of the output of each sector, and if there's a pandemic, they consume $\alpha_j/2$ units of the output of the sector that remains open. (The equilibrium also features the sum of the α's of the workers in each sector being equal, rather than the number of workers in each sector being equal.) Thus, social insurance that replicates the complete-markets outcome features payments to the unemployed proportional to their non-pandemic earnings.

The proportionality result continues to hold when there are incentive or fairness considerations. To see this, recall that in the absence of such considerations, optimal social insurance makes the ratio of any two individuals' marginal utilities constant across states of the world. Although that property no longer holds for all pairs of individuals when there incentive or fairness constraints, it still holds for any pair of individuals who are in the same sector. If we assume that utility takes the usual constant relative risk aversion form, $U(C) = C^{1-\theta}/(1-\theta), \theta > 0$, this result implies that the ratio of the consumptions of any two individuals in the same sector is constant across states. And this in turn implies that the consumption that optimal social insurance provides to the unemployed in a pandemic is proportional to their non-pandemic earnings.

***Introducing costs of social insurance and possibilities for self-insurance*.** Although the proportionality result holds both with and without incentive and fairness considerations, for simplicity we focus on the case without them in the remainder of this section. As discussed in the text, the result that optimal social insurance is strongly increasing in individuals' non-pandemic earnings is unlikely to hold if social insurance is costly and there are realistic possibilities for self-insurance. To investigate the implications of these factors, it's not necessary to specify and solve a general equilibrium model with less than actuarially fair insurance and some self-insurance through saving and borrowing. A partial equilibrium approach is sufficient to see the main points.

For concreteness, consider an individual who is in sector A. Let C^A_{NO} be their consumption of sector-A output in the event of a sector-B pandemic in the case of no insurance (other than self-insurance), and let C^B_{NO} be their consumption of sector-B output in the event of a sector-A pandemic in the no-insurance case. In the background, we think of there being a dynamic economy where individuals have some ability to use saving and borrowing to smooth their consumption in the face of shocks. C^A_{NO} and C^B_{NO} reflect what comes out of that setting in the absence of any possibilities for insurance beyond self-insurance. Here, however, we take them as given, and make no assumptions about them other than $C_{NO}^{A} \geq C_{NO}^{B}$—that is, that in the no-insurance case, the individual has higher consumption if a pandemic shuts the other sector than if a pandemic shuts their own sector.

Now suppose costly insurance is introduced: the individual can give up some consumption in the event of a pandemic in the other sector in exchange for greater consumption in the event of a pandemic in their own sector (where in each case consumption is of the output of the sector that stays open). Specifically, then can choose a quantity $X \geq 0$ by which to increase their consumption in the event of a sector-A pandemic, at the cost of reducing their consumption in the event of a sector-B pandemic by $(1+\lambda)X$, where $\lambda \geq 0$. λ reflects the various costs of providing the insurance—what's typically called the "loading factor" of the insurance.

To see the effects of introducing costly insurance, it's useful to start by relating the situation we're considering to our baseline model (where there are no prospects for self-insurance, and where insurance is frictionless if it's present). In that case, $C_{NO}^{A} = 1$ (in the absence of insurance, in the event of a sector-B pandemic the individual spends their entire income on the output of sector A); $C_{NO}^{B} = 0$ (in the absence of insurance, in the event of a sector-A pandemic the individual earns nothing and consumes nothing); and $\lambda = 0$ (the pricing of insurance is actuarially fair). With the individual able to trade off consumption in the two pandemic states one-for-one, they buy insurance until their marginal utilities in the two pandemic states are equal. Given our assumptions about utility, this implies they have equal consumption in the two states. Thus they choose $X = 1/2$.

Now return to the case we're interested in. The individual chooses the amount of insurance, X, to solve

(A6) $$\max_{X \geq 0} U(C_{NO}^{B} + X) + U(C_{NO}^{A} - [1+\lambda]X).$$

The solution satisfies

(A7)
$$\begin{cases} X = 0 & \text{if } \frac{U'(C_{NO}^B)}{U'(C_{NO}^A)} \leq 1 + \lambda \\ \frac{U'(C_{NO}^B + X)}{U'(C_{NO}^A - [1+\lambda]X)} = 1 + \lambda & \text{if } \frac{U'(C_{NO}^B)}{U'(C_{NO}^A)} > 1 + \lambda. \end{cases}$$

That is, if the marginal utilities in the absence of insurance in the two states are sufficiently close—specifically, if the ratio of the marginal utility the individual would have if a pandemic shut their sector to the marginal utility they would have if a pandemic shut the other sector is less than $1 + \lambda$—the individual buys no insurance. Otherwise, they buy until the ratio of marginal utilities is $1 + \lambda$. In this case, assuming the loading factor is strictly positive, it follows that they stop buying at a point where their consumption in a pandemic that hits their own sector ($C_{NO}^B + X$) is strictly less than their consumption in a pandemic that hits the other sector ($C_{NO}^A - [1 + \lambda]X$).

***Implications for social insurance*.** When insurance takes the form of government-provided social insurance, λ reflects three factors. First, there's the cost of administering the program, verifying eligibility, making payments, suffering some losses from error and fraud, and so on. Second, the program causes distortions in individuals' behavior (most notably, in unemployed individuals' efforts to find jobs). And third, satisfying the government's intertemporal budget constraint requires raising more revenue at some point, which involves distortion costs.

Most discussions of the costs of providing unemployment insurance focus on the second factor—the distortionary effects on individuals' incentives. And as we discuss in the text, during much of the pandemic, unemployment insurance replacement rates were very high. However, multiple studies, using both individual and state-level data, find no evidence of any substantial negative effect of the high replacement rates on employment during the pandemic through their incentive effects on job-finding efforts (Altonji et al., 2020; Dube, 2021; Marinescu, Skandalis, and Zhao, 2021; and Ganong et al., 2021). One reason is that, because workers didn't expect the high benefits to last, it appears they often preferred employment to unemployment even when the replacement rate exceeded 100 percent. A second reason is that because the main constraint on overall employment during the pandemic was from labor demand rather than supply, a modest negative effect of the high replacement rates on individuals' job-seeking had little impact on overall hiring.

The fact that the distortionary effects of unemployment insurance in a pandemic appear small (coupled with the fact that the program does not appear to involve large administrative and related costs relative to the scale of its spending) suggests that the main costs of providing unemployment insurance in a pandemic are likely to come from the third factor—the distortions associated with raising the additional revenue at some point to offset the unemployment insurance payments. Thus, λ is likely to be slightly higher than the marginal distortion costs of raising revenue, which are typically thought to be about 0.3 or 0.4.

If utility is constant relative risk aversion ($U(C) = C^{1-\theta}/(1-\theta), \theta > 0$), equation (A7) becomes

(A8)
$$\begin{cases} X = 0 & \text{if } \frac{C_{NO}^{B}}{C_{NO}^{A}} \geq \frac{1}{(1+\lambda)^{1/\theta}} \\ \frac{C_{NO}^{B}+X}{C_{NO}^{A}-(1+\lambda)X} = \frac{1}{(1+\lambda)^{1/\theta}} & \text{if } \frac{C_{NO}^{B}}{C_{NO}^{A}} < \frac{1}{(1+\lambda)^{1/\theta}}. \end{cases}$$

Gandelman and Hernández-Murillo (2015) report that "[p]robably the most widely accepted" estimates of θ "lie between 1 and 3." A recent study by Calvet et al. (2021), however, suggests an average value around 5. And Chetty and Szeidl (2007) show that because there are substantial costs to changing some types of consumption quickly, the effective value of θ for the short run (which is what's relevant to unemployment insurance) may be much larger (see their equation [7] and Figure IV).

If the costs of unemployment insurance are large and risk aversion is low, the gap between the consumption of the unemployed and the employed under optimal insurance may be large. For example, if λ = 0.6 and θ = 2 and the solution is interior, the individual would buy insurance to the point where their consumption if a pandemic shuts their sector is 21 percent less than their consumption if a pandemic shuts the other sector (since $1/1.6^{1/2} \approx 0.79$). Equivalently, under optimal but costly social insurance with these parameter values, in a pandemic the consumption of an individual in the sector that's shut is 21 percent lower than that of a comparable individual in the sector that's open. And if the gap would be smaller than 21 percent in the absence of any insurance other than self-insurance, it's optimal not to provide the individual with any social insurance at all. On the other hand, low costs of insurance and high risk aversion imply a small gap in consumption. For example, if $\lambda = 0.4$ and $\theta = 6$ (and again, if the solution is interior), in a pandemic the consumption of an individual in the sector that's shut is only 5 percent lower than that of a comparable individual in the sector that's open. Since the assumptions needed to obtain the 21 percent and 5 percent figures are somewhat extreme, this analysis suggests that 10 to 15 percent is a reasonable figure for the gap between the consumption of the unemployed and the employed under optimal but costly social insurance.

If the ability to self-insure is increasing in income, these results have two important implications for the progressivity of optimal social insurance. First, they tend to make optimal insurance payments rise less than proportionately with income. Second, they imply that if individuals with sufficiently high incomes have enough ability to self-insure that in the absence of social insurance, the ratio of their consumption if a pandemic shuts their sector to their consumption if a pandemic shuts the other sector is greater than the critical threshold, they shouldn't be provided with any social insurance.

Although our partial equilibrium analysis is enough to show these implications, a limitation of this approach is that it doesn't provide exact expressions for the amount of insurance individuals would choose to buy if the loading factor were λ—and thus, in our framework, for optimal social insurance payments. If an individual's self-insurance is sufficiently large that the consumption ratio we've been discussing is above the critical threshold (that is, if $C_{NO}^{B}/C_{NO}^{A} \geq 1/(1+\lambda)^{1/\theta}$), the optimal social insurance payment to the individual if a pandemic shuts their sector is indeed zero. But suppose that condition fails. In that situation, the individual won't necessarily devote social insurance payments solely to current consumption: because it's more efficient for the government to provide insurance than for individuals to self-insure, social insurance may in effect crowd out self-insurance. As a result, knowing only what the individual's consumption would be without social insurance isn't enough to determine the optimal insurance payment—the optimal payment also depends on the extent of crowding out. If self-insurance comes from borrowing and that borrowing is associated with a cost or wedge analogous to the loading factor of the social insurance, then the extent of the crowding out depends on the specifics of the wedge. For example, if the individual can borrow freely up to some limit but can't borrow more than that at any interest rate (so the wedge is zero up to the limit and then becomes infinite), there may be no crowding out. But if the individual faces a constant cost of borrowing that's larger than λ, there may be substantial crowding out.

E. The Possibility of an Aggregate Demand Shortfall and a Need for Stimulus

As described in the text, our analysis of the aggregate demand effects of a pandemic is closely related to the analysis of Guerrieri et al. (2020). Specifically, consider a multi-period version of our baseline case where each period is described by the static version. Individual j's lifetime utility is given by the natural extension of the utility function of the static model:

(A9) $$\mathcal{U}_j = \sum_t \beta^t \left[U\left(C_{jt}^A\right) + U\left(C_{jt}^B\right) - V(L_{jt})\right], \quad 0 < \beta < 1,$$

where t's denote time periods. Since we assume there's no capital in the economy (recall that each period is described by the static version of the model, with labor as the only input into production), net wealth is zero. However, we allow for the possibility of saving and borrowing at the individual level (that is, for trades among individuals of claims on future output). We assume all individuals are able to save, but some may be unable to borrow. Aside from whether they're able to borrow (and, as usual, which sector they're in), individuals are identical. Finally, for simplicity we assume that each individual starts with zero wealth, that a pandemic is only possible in the first period, and, again, that utility is constant relative risk aversion, $U(C) = C^{1-\theta}/(1-\theta), \theta > 0$.

In the absence of a pandemic, consumption is constant. The intertemporal Euler equation of individuals who can both borrow and save implies that the real interest rate, r, must satisfy $\beta(1+r)=1$, or

(A10) $$r=\frac{1-\beta}{\beta}.$$

At that interest rate, individuals who cannot borrow don't want to, and so the borrowing constraint doesn't bind.

Now suppose there's a pandemic in period 1; for concreteness, assume it's in sector A. As we've seen, in the optimal allocation in our baseline case, each individual's consumption of the output of sector B remains at its steady state level. Thus in this case, all individuals continue to satisfy their intertemporal Euler equation at the steady state interest rate given by (A10). That is, with optimal social insurance, aggregate demand falls by exactly as much as aggregate supply.

But suppose that because of incentive or fairness considerations or costly insurance, the optimal allocation in a pandemic involves greater consumption by the individuals who stay employed than by those who become unemployed. Since the efficient level of output in sector B is unaffected, employed workers' consumption of the output of sector B is above its steady state level, and unemployed workers' is below. At the steady state real interest rate, employed workers therefore want to save and unemployed workers want to borrow. In the absence of any borrowing constraints, there's no reason to expect an imbalance between the two in one direction rather than the other at that interest rate, and in fact the assumption of constant relative risk aversion utility implies they exactly balance.[5] But if some unemployed individuals cannot borrow, borrowing at a given interest rate is lower. As a result, at the optimal level of output and the steady state real interest rate, saving now exceeds borrowing. Thus for the economy to attain that output, there

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[5] To see this, note that individual j's Euler equation relating their consumption of the output of sector B in periods 1 and 2 is $C_{j2}^B/C_{j1}^B=[\beta(1+r)]^{1/\theta}$, which implies that total consumptions in the two periods satisfy $C_2^B=[\beta(1+r)]^{1/\theta}C_1^B$. Since the efficient levels of sector-B output in the two periods are the same and the steady state interest rate satisfies $\beta(1+r)=1$, the condition $C_2^B=[\beta(1+r)]^{1/\theta}C_1^B$ holds at the efficient level of output and the steady state interest rate.

must be some source of additional aggregate demand, which could come from a reduction in the real interest rate or from fiscal policy.[6]

F. Debt and Payment Forgiveness

Assumptions. To address the possibility of forgiveness of payment obligations or outstanding debts, we return to our baseline model, but we suppose individual j has to make a fixed payment of F_j that doesn't generate any current consumption. As in the baseline case, individuals are otherwise identical (other than, as usual, their choice of sector). Thus if there were no possibility of a pandemic, individual j's total consumption of all outputs would be $1 - F_j$ rather than 1. We take the sizes of the payments that individuals make as given, although realistically they would reflect past shocks and decisions that leave individuals in different financial situations.

We also make several smaller changes to the model. First, to avoid having to introduce any additional actors into the economy, we assume the sum of the F_j's across individuals is zero—that is, some individuals receive fixed payments rather than making them. Second, to get results that are particularly easy to interpret, we again assume utility is constant relative risk aversion. Third, to be able to gauge the implied scale of any forgiveness, we assume that rather than two sectors there are many, and that a pandemic shuts down fraction f of them chosen at random, where $0 < f < 1$. With N sectors rather than two, individual's j's utility is $\sum_{i=1}^{N} U(C_{ji}) - V(L_j)$, where C_{ji} is their consumption of the output of sector i. In equilibrium, $1/N$ individuals are in each sector. Finally, we start by assuming that the probability of a pandemic is close to zero.

Qualitative implications. In our baseline case without the fixed payment obligations (and with no income heterogeneity), optimal social insurance causes everyone's after-tax-and-

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[6] Guerrieri et al. (2020) consider these issues in much more generality. One result that's particularly relevant to our analysis is that the fact that the fall in aggregate demand exactly equals the fall in aggregate supply in the absence of borrowing constraints depends on our assumption that utility is additively separable both over sectors and over time, which implies that the *intra*temporal elasticity of substitution between the outputs of the two sectors in a given period equals the *inter*temporal elasticity of substitution between a given sector's output in two periods. With a more general utility function, if the intratemporal elasticity is less than the intertemporal elasticity, aggregate demand falls more than aggregate supply even without borrowing constraints.

transfer income to fall by the same amount in a pandemic, and hence everyone's consumption to fall by the same amount. In the presence of fixed payment obligations, if a pandemic reduces output from 1 to $1 - f$, a policy that causes everyone's consumption to fall by the same amount causes individual j's consumption to fall from $1 - F_j$ to $1 - F_j - f$.

This policy doesn't replicate the complete-markets outcome, however. To see this, note that in the complete-markets allocation, for any two individuals the ratio of their marginal utilities is the same across states. With constant relative risk aversion utility, this requires that the ratio of their consumptions is the same across states. Thus optimal social insurance causes each individual's consumption to fall by the same *proportion* in a pandemic rather than by the same *amount*. When a pandemic causes aggregate consumption to fall by fraction f, the complete-markets allocation therefore has individual j's consumption fall from $1 - F_j$ to $(1 - f)(1 - F_j)$, or $1 - f - (1 - f)F_j$. This expression differs from $1 - f - F_j$ (what their consumption would be if each individual's consumption fell by amount f) by fF_j. Thus the complete-markets allocation—or the corresponding allocation achieved through social insurance—reduces individuals' fixed payment obligations by the same proportion that aggregate consumption falls. And in a multi-period version of the model where the pandemic is temporary, with complete markets individual j's consumption reverts to $1 - F_j$ after the end of the pandemic. That is, the model points to partial payment forgiveness during the pandemic, not to permanent forgiveness of the underlying obligation that gives rise to the payments.

Relaxing the assumption that the probability of a pandemic is close to zero has little impact on these results. The place where this assumption enters the analysis is in the statement that if individual j has a fixed payment obligation of F_j, their non-pandemic consumption is $1 - F_j$. This claim implicitly leaves out the individual's spending on insurance against a pandemic; this is appropriate when the chances of a pandemic are negligible, but not otherwise. When the probability of a pandemic isn't negligible, neither is spending on insurance against a pandemic.

As a result, in the general case the fact that individuals with larger F_j's buy more insurance causes individual j's non-pandemic consumption to take the form $1-\gamma(p)F_j$, where p is the probability of a pandemic and where $\gamma(0)=1, \gamma'(\bullet)>0$. In this case, individual j's consumption in a pandemic is $(1-f)(1-\gamma(p)F_j)$.

***<u>Quantitative implications</u>*.** At its low in April 2020, real personal consumption expenditures (PCE) in the U.S. were 18 percent below their peak level. And with the exception of April and May 2020, they were never more than 7 percent below their peak.[7] Thus a baseline model of optimal social insurance would have called for forgiving roughly 10 percent of fixed payment obligations during the pandemic. And it wouldn't have suggested a reason for forgiving outstanding debt balances. Thus someone with, for example, student debt would have had their payments reduced by roughly 10 percent during the pandemic and then returned to their pre-pandemic level when the pandemic ended.

***<u>The size of the welfare gains</u>*.** It's natural to wonder whether the welfare gains from the optimal forgiveness policy are large. Under no forgiveness but otherwise optimal social insurance (so each individual's consumption falls by amount f in a pandemic), individual j's expected utility is

(A11) $$\mathcal{U}_{NO,j}=(1-p)\left[NU\left(\frac{1-F_j}{N}\right)-V(1)\right]+p\left[(1-f)NU\left(\frac{1-f-F_j}{(1-f)N}\right)-(1-f)V(1)\right].$$

Under the complete-markets allocation, which includes reductions in fixed payment obligations in a pandemic, it's

(A12) $$\mathcal{U}_{FORG,j}=(1-p)\left[NU\left(\frac{1-\gamma(p)F_j}{N}\right)-V(1)\right]+p\left[(1-f)NU\left(\frac{(1-f)(1-\gamma(p)F_j)}{(1-f)N}\right)-(1-f)V(1)\right].$$

As discussed above, $\gamma(p)$ reflects the fact that with complete markets, individuals with higher fixed payments buy more insurance against a pandemic. Recall that in the complete-markets

[7] Looking at real PCE on nondurables and services, which are probably more relevant to current utility than real total PCE, yields a similar picture. The decline in real GDP (which is the same as the decline in real consumption in the model, since all output is consumed) was smaller than the decline in real PCE.

allocation, each individual's marginal utility is no different in a pandemic than in normal times, and so the pricing of pandemic insurance is actuarially fair. It follows that the expected shortfall of individual *j*'s spending on consumption from their income must equal their payment obligation, F_j. That is, the individual can use insurance to shift payments between the non-pandemic and pandemic states, but can't change their expected value. In the non-pandemic state, the individual's fixed payment is $\gamma(p)F_j$, and in the pandemic state, it's $\gamma(p)(1-f)F_j$. Thus their expected payment is $\gamma(p)[(1-p)+(1-f)p]F_j$, or $\gamma(p)(1-fp)F_j$. Since this must equal F_j, it follows that

(A13) $$\gamma(p)=\frac{1}{1-fp}.$$

The change in individual *j*'s expected utility due to the optimal forgiveness policy is $\Delta\mathcal{W}_j \equiv \mathcal{U}_{FORG,j}-\mathcal{U}_{NO,j}$. To convert this from units of utility to units of consumption, we can divide it by the individual's expected marginal utility of consumption in the absence of forgiveness, which we denote $\mathcal{U}'_{NO,j}$. A natural measure of the overall welfare benefit of the optimal forgiveness policy is the average of this measure across individuals.[8] Thus our measure of the benefit is

(A14) $$\Delta\mathcal{W} \equiv \int_{j=0}^{1}[(\mathcal{U}_{FORG,j}-\mathcal{U}_{NO,j})/\,\mathcal{U}'_{NO,j}]dj.$$

We take a second-order Taylor approximation of (A14) around the point where all the F_j's are zero. The result is:

(A15) $$\Delta\mathcal{W} \cong \frac{1}{2}\theta\frac{f^2p(1-p)}{(1-f)(1-fp)}Var(F_j),$$

where θ is the coefficient of relative risk aversion. Dividing this expression by the probability of a

[8] An alternative is to compute the average gain in expected utility across individuals, and then normalize by average expected marginal utility across individuals. For the second-order approximation that we consider, this approach yields the same expression for the welfare benefit of optimal forgiveness as what we find below. A disadvantage of using the measure based on average expected utility, however, is that it implies that the optimal policy is simply to forgive all fixed payment obligations entirely, even in the non-pandemic state. Thus using this welfare measure raises issues unrelated to the appropriate response to a pandemic.

pandemic gives the welfare gain per pandemic (that is, loosely speaking, the welfare gain if a pandemic occurs):

(A16) $$\Delta \mathcal{W}/p \cong \frac{1}{2}\theta \frac{f^2(1-p)}{(1-f)(1-fp)} Var(F_j).$$

As we describe above, f = 0.1 is a generous estimate of the fraction of the economy that was shut in most of the pandemic. Similarly, 20 percent of normal consumption is probably a generous estimate of the standard deviation of fixed payment obligations across individuals. If, in addition, we assume p = 0.01 (which has little impact on the results over a reasonable range) and θ = 4, we obtain $\Delta \mathcal{W}/p \cong 0.00088$. Since normal consumption is 1, this means that the welfare benefit, per pandemic, of the optimal forgiveness policy is roughly 0.09 percent of normal consumption, which is very small.

This discussion assumes there are no frictions or administrative costs to providing partial forgiveness. In practice, determining precisely what constitutes a fixed payment obligation, measuring each individual's obligations, and implementing a program of temporary partial forgiveness would be challenging. Given the small welfare gains from forgiveness under the optimal policy in the absence of administrative costs, with plausible costs the welfare gains might well be negative. In short, a social insurance perspective suggests at most relatively little forgiveness in a pandemic, and under realistic assumptions it might point to no forgiveness at all.

***Forbearance*.** An alternative to forgiveness is forbearance—allowing individuals to not make their fixed payment obligations during the pandemic, and instead make them, together with the accrued interest, when conditions return to normal. Thus forbearance effectively gives individuals with fixed payment obligations a way to borrow. (A third possibility, forbearance without having to pay interest, amounts to forbearance plus partial forgiveness.)

With fixed payment obligations and the optimal forgiveness policy, each individual's marginal utility in a pandemic is the same as in non-pandemic times. As a result, the marginal benefit (if any) to borrowing during a pandemic for individuals with large fixed payment obligations is no greater than in non-pandemic times. Thus there's no more reason to provide forbearance in a pandemic than in other times.

To see this concretely, consider a multi-period version of our baseline case where each period is the same as the static version, and individual j's fixed payment obligation is F_j every period (except in a pandemic, when it's $(1-f)F_j$). Then—along the lines of Section E—each individual's marginal utility under optimal policy is constant over time, no one wants to borrow or save, and so there are no benefits to forbearance.

As usual, however, the situation is different if incentive or fairness considerations cause the unemployed to have lower consumption than the employed in a pandemic. In a multi-period setting, if the unemployed face borrowing constraints, there might be scope for Pareto improvements by using forbearance to allow unemployed workers with fixed payment obligations to shift consumption from the future to the present. Thus there might be a case for forbearance in this situation. There are two important caveats, however. First, the fixed payment obligations have no direct role in these potential welfare benefits—there could be welfare benefits from allowing all unemployed individuals, regardless of the size of their fixed payment obligations, to in effect borrow against their future income. Second, the same logic that points to forbearance in a pandemic also points to policies that would allow the unemployed to borrow in normal times. Thus, a full analysis of forbearance would require addressing the issues of why the unemployed face borrowing constraints in private markets, and why there aren't currently large-scale policies of government-provided loans to the unemployed in normal times.

G. Aid to State and Local Governments

A natural extension of our social insurance framework can help us understand a somewhat different issue than aid to individuals in a pandemic—the possibility of federal aid to state and local governments. To consider the treatment of state and local governments (which we refer to as "local governments" for simplicity), we again start from our baseline case. We introduce a local government sector by assuming individuals obtain utility from the outputs of the two sectors, A and B, and from the output of local governments. We continue to assume that utility is additively separable. Thus an individual's utility is $U(C_A) + U(C_B) + H(G) - V(L)$, where G is the output of the local government sector, where we assume $H'(\bullet) > 0$ and $H''(\bullet) < 0$, and where we normalize $H(0)$ to 0. We think of G as a public good. Its production function is $G = L_G$, where L_G is the number of workers in the local government sector. As before, we assume workers are fully mobile across sectors ex ante but fully immobile ex post, and we assume sectors A and B are equally likely to be shut by a pandemic. In addition, we allow for the possibility that a pandemic makes the output of local governments more valuable, so that $H(\bullet)$ is replaced by $H^p(\bullet)$ in a pandemic, with $H^{p\prime}(\bullet) \geq H'(\bullet)$ for all G (and with $H^p(0)$ again normalized to 0). Finally, for simplicity we assume the probability of a pandemic is small.

Under these assumptions, the efficient outcome is for workers to be allocated across sectors so that the marginal utility of output of each sector if there isn't a pandemic is the same. This obviously requires equal numbers of workers in sectors A and B. Since L_A, L_B, and L_G must sum to 1, L_A and L_B must therefore each equal $(1 - L_G)/2$. It follows that the condition for the optimal number of workers in the government sector is[9]

$$H'(L_G) = U'\left(\frac{1-L_G}{2}\right). \tag{A17}$$

A pandemic has no effect on the utility cost of the marginal worker continuing to work in the government sector, and either raises or has no effect on the utility benefit. Thus the efficient allocation involves continued full employment in the local government sector.[10] Thus if

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[9] This is the only place where the assumption that the probability of a pandemic is small enters this analysis. In the case of a general p, the condition for the optimal allocation of workers to the local government sector is more complicated than (A17), but approaches (A17) as p approaches 0. This has no substantive implications.

[10] The reason we refer to this outcome as "efficient" rather than "complete-markets" is that because government output is a public good, obtaining it requires not just complete markets but also some appropriate political process. Since individuals are ex ante identical, the allocation we describe is preferred unanimously to any other allocation that doesn't provide higher expected utility to some individuals than others. Thus it seems reasonable to assume that if there's a political process for determining state-contingent outcomes ex ante, that allocation would be the outcome.

individuals contemplated the possibility of a pandemic, they would likely agree to have their local governments purchase pandemic insurance, or to have automatic tax increases on workers who stay employed in a pandemic.

In the absence of fully specified ex ante agreements about allocations, however, implementing the efficient outcome may not be feasible. In practice, local governments are subject to balanced budget requirements that must be satisfied conditional on the realized state of the world. And local governments don't have policies that make taxes rise automatically in a pandemic. Further, although raising taxes ex post in the face of a pandemic could implement the efficient allocation, an across-the-board tax increase wouldn't be a Pareto improvement conditional on the realized state. For example, local government workers who would remain employed even without the tax increase would be worse off. Thus under realistic political assumptions, taxes might not change immediately, in which case a pandemic would lead to a fall in tax revenues, and so through the balanced budget requirement to an inefficient fall in *G*. This points to the potential for a government that can borrow—in the U.S. case, the federal government—to step in and prevent the inefficient fall in local government output.

H. Incentives and Fairness with Partial Information

The analysis of incentive and fairness considerations in the text and in Section B of this appendix considers the extreme case where the government has no information at all about who should optimally be working in a pandemic. An intermediate possibility is that it has some but less than full information. For example, the government may know that the optimal allocation involves a smaller fraction of older individuals than younger individuals working in a pandemic, but not know precisely which older and younger individuals should work. This section therefore provides a brief discussion of such cases.

A straightforward way to allow for partial information is to extend the analysis in the first part of Section B to the case of multiple groups. The government knows which group each person is in and the fraction of each group that will work in a pandemic in the optimal allocation, but not who within each group should be working. In contrast to our analysis of partial labor mobility and paralleling what we do in the first part of Section B, we assume that those who should be working face no cost of doing so other than the usual disutility of work, and that working is prohibitively costly for those who shouldn't be working.

To get a sense of the implications of these assumptions, we consider a simple case with three types of individuals. The first type are all individuals who should work in a pandemic, and the other two types are all individuals who shouldn't be working in a pandemic. The government, however, cannot distinguish between the first two types, and so from its point of view individuals fall into two groups: one (the first two types) consists of a mix of individuals who should and shouldn't be working, and one (the third type) consists entirely of individuals who shouldn't be working. For concreteness, imagine that whether an individual should work in a pandemic depends only on whether they have health risks (and not what sector they were in originally), but that some health risks are observable (those of individuals of the third type) and some are not (those of individuals of the second type).

We denote the three types by "E" ("employed"), "U" ("unobservable risk"), and "O" ("observable risk"). Paralleling our assumptions in the baseline case, we assume that ex ante all individuals have the same chances as one another of being in each category. C^i denotes the consumption of a representative individual of type i, and f_i denotes the probability of being of type i. We assume the f_i's (which must sum to 1) are all strictly positive.

These assumptions imply that everyone's expected utility in a pandemic ex ante (that is, before they know which type they are) is

(A17) $$\mathcal{U} = f_E[U(C^E) - V(1)] + f_U U(C^U) + f_O U(C^O).$$

The optimal allocation involves choosing the C's to maximize $\mathcal{U}$ subject to two constraints. The first is that, since the government cannot distinguish individuals of the first two types, for individuals of the first type working must be at least as attractive as not working and having the consumption of individuals of the second type. This condition is

(A18) $$U(C^E) - V(1) \geq U(C^U).$$

As before, the optimal allocation satisfies the incentive constraint with equality. The second constraint is the economy's resource constraint:

(A19) $$f_E C^E + f_U C^U + f_O C^O = f_E.$$

The main message that comes out of analyzing this case is that the optimal allocation has $C^E > C^O > C^U$. That is, individuals who the government knows for sure shouldn't be working (the "*O*" type) receive larger transfers than the individuals in the group the government is unsure about but who in fact shouldn't be working (the "*U*" type); but these transfers aren't enough to raise the consumption of the "*O*" type to that of the employed (the "*E*" type). This result is broadly similar to our finding in the second part of Section B that with some labor mobility and imperfect information, individuals who the government knows for sure should be working obtain consumption between that of those who are induced to switch sectors and those who are unemployed.

One can also show that the optimal C^O doesn't necessarily equal f_E, the consumption that everyone would obtain in the baseline case where the government has full information about who should and shouldn't be working. It turns out that if the utility function, $U(\cdot)$, is logarithmic, the optimal C^O is exactly f_E, but that in the general case it can be either more or less than f_E.

It's conceptually straightforward to extend this analysis to *N* groups of potentially different sizes, with different fractions of individuals who should optimally be working in a pandemic.

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