

Modeling the Consumption Response to the CARES Act

Forthcoming, *International Journal of Central Banking*

Christopher D. Carroll¹

JHU

Edmund Crawley²

FRB

Jiri Slacalek³

ECB

Matthew N. White⁴

UDel

Live Dashboard

econ-ark.github.io/Pandemic

github.com/econ-ark/Pandemic

zip file: [root of repo](#) ↑

LaTeX directory in repo ↑

LaTeX directory in repo

LaTeX directory in repo

See effect of modifying main assumptions

HTML version of paper

Full codebase: Modify combos of assumptions

contains full replication files (code+text)

PDF version of paper

Presentation slides

Preferred BibTeX citation

Abstract

To predict the effects of the 2020 U.S. CARES Act on consumption, we extend a model that matches responses to past consumption stimulus packages. The extension allows us to account for two novel features of the coronavirus crisis. First, during lockdowns, many types of spending are undesirable or impossible. Second, some of the jobs that disappear during the lockdown will not reappear. We estimate that, if the lockdown is short-lived (the median point of view as we are writing in April 2020), the combination of expanded unemployment insurance benefits and stimulus payments should be sufficient to allow a swift recovery in consumer spending to pre-crisis levels. If the lockdown lasts longer (or there is a ‘second wave’), an extension of enhanced unemployment benefits will likely be necessary for consumption spending to recover quickly.

Keywords Consumption, COVID-19, Stimulus, Fiscal Policy

JEL codes D83, D84, E21, E32

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¹Carroll: Department of Economics, Johns Hopkins University, <http://econ.jhu.edu/people/ccarroll/>, ccarroll@jhu.edu ²Crawley: Federal Reserve Board, edmund.s.crawley@frb.gov ³Slacalek: DG Research, European Central Bank, <http://www.slacalek.com/>, jiri.slacalek@ecb.europa.eu ⁴White: Department of Economics, University of Delaware, mwcon@udel.edu

“Economic booms are all alike; each recession contracts output in its own way.” — with apologies to Leo Tolstoy

I Introduction

In the decade since the Great Recession, macroeconomics has made great progress by insisting that models be consistent with microeconomic evidence (see Krueger, Mitman, and Perri (2016) in the *Handbook of Macroeconomics* for a survey). To predict the effects of the 2020 CARES Act (Coronavirus Aid, Relief, and Economic Security) on consumption, we take, from this new generation, *one model* that is specifically focused on reconciling apparent conflicts between micro and macro evidence about consumption dynamics,¹ and adapt it to incorporate two aspects of the coronavirus crisis.

First, because the tidal wave of layoffs for employees of shuttered businesses will have a large impact on their income and spending, assumptions must be made about the employment dynamics of laid off workers. Specifically, the unemployed in our model consist of two categories: normal unemployed and deeply unemployed. Similar to a normal recession, the normal unemployed will be able to quickly return to their old jobs (or similar ones). However, in addition, some people become deeply unemployed, facing a more persistent unemployment shock. This feature reflects the

¹As articulated long ago by Deaton (1992) and documented recently Havranek, Rusnak, and Sokolova (2017).

Centre for Economic Policy Research pre-print journal *Covid Economics* on April 27, 2020 (as a pre-print journal, *Covid Economics* does not obtain copyright claims to its content, which is why the finished version of the paper can be published in a peer-reviewed journal which *does* obtain the copyright).

Thanks to the Consumer Financial Protection Bureau for funding the original creation of the *Econ-ARK* toolkit, whose latest version we used to produce all the results in this paper; and to the *Sloan Foundation* for funding *Econ-ARK*’s extensive further development that brought it to the point where it could be used for this project. The toolkit can be cited with its digital object identifier, [10.5281/zenodo.1001067](https://doi.org/10.5281/zenodo.1001067), as is done in the paper’s own references as Carroll, Kaufman, Kazil, Palmer, and White (2018). We are grateful to Kiichi Tokuoka, who provided valuable feedback and input as this project progressed, Mridul Seth, who created the dashboard and configurator, and to Luc Laeven, who swiftly handled our submission to IJCB. The views presented in this paper are those of the authors, and should not be attributed to the Federal Reserve Board or the European Central Bank.

fact that some kinds of jobs will not come back quickly after the lockdown, and that people who worked in these sectors will have more difficulty finding a new job.²

On the second count, we model the restricted spending options by assuming that during the lockdown spending is less enjoyable (there is a negative shock to the ‘marginal utility of consumption.’) Based on a tally of sectors that we judge to be substantially shuttered during the ‘lockdown,’ we calibrate an 11 percent reduction to spending. Thus households will prefer to defer some of their consumption into the future, when it will yield them greater utility. (See Cox, Ganong, Noel, Vavra, Wong, Farrell, and Greig (2020), Carvalho, Garcia, Hansen, Ortiz, Rodrigo, Rodriguez, and Ruiz (2020) and Andersen, Hansen, Johannesen, and Sheridan (2020) showing a strong effect of this kind in US, Spanish and Danish data, respectively).³

Our model captures the two primary features of the CARES Act that aim to bolster consumer spending:

1. The boost to unemployment insurance benefits, amounting to \$7,800 if unemployment lasts for 13 weeks.
2. The direct stimulus payments to most households, up to \$1,200 per adult.

We estimate that the combination of expanded unemployment insurance benefits and stimulus payments should be sufficient to expect a swift recovery in consumer spending to its pre-crisis levels under our default description of the pandemic, in which the lockdown ends after two quarters on average. Overall, unemployment benefits account for about 30 percent of the total aggregate consumption response and stimulus payments explain the remainder.

²The cruise industry, for example, is likely to take a long time to recover. Demand for airline travel is expected to remain depressed, with the International Air Traffic Association **projecting** that passenger travel will not return to pre-pandemic levels until 2024.

³A shock to marginal utility may not perfectly capture the essence of what depresses consumption spending, but it accomplishes our purposes and is a kind of shock commonly studied in the literature. Any analysis of the welfare consequences of the lockdown would probably need a richer treatment to be credible.

Our analysis partitions households into three groups based on their employment state when the pandemic strikes and the lockdown begins.

First, households in our model who do not lose their jobs initially build up their savings, both because of the lockdown-induced suppression of spending and because most of these households will receive a significant stimulus check, much of which the model says will be saved. Even without the lockdown, we estimate that only about 20 percent of the stimulus money would be spent immediately upon receipt, consistent with evidence from prior stimulus packages about spending on nondurable goods and services. Once the lockdown ends, the spending of the households that remained employed at the onset of the pandemic rebounds strongly thanks to their healthy household finances.

The second category of households are the ‘normal unemployed,’ job losers who perceive that it is likely they will be able to resume their old job (or get a similar new job) when the lockdown is over. Our model predicts that the CARES Act will be particularly effective in stimulating their consumption, given the perception that their income shock will be largely transitory. Our model predicts that by the end of 2021, the spending of this group recovers to the level it would have achieved in the absence of the pandemic (‘baseline’); without the CARES Act, this recovery would take more than a year longer.

Finally, for households in the ‘deeply unemployed’ category, our model says that the marginal propensity to consume (MPC) from the checks will be considerably smaller, because they know they must stretch that money for longer. Even with the stimulus from the CARES Act, we predict that consumption spending for these households will not fully recover until the middle of 2023. Even so, the Act makes a big difference to their spending, particularly in the first six quarters after the crisis. For both groups of

unemployed households, the effect of the stimulus checks is dwarfed by the increased unemployment benefits, which arrive earlier and are much larger (per recipient).

Perhaps surprisingly, we find the effectiveness of the combined stimulus checks and unemployment benefits package for aggregate consumption is not substantially different from a package that distributed the same quantity of money equally among households. The reason for this is twofold: first, the extra unemployment benefits in the CARES Act are generous enough that many of the ‘normally unemployed’ remain financially sound and can afford to save a good portion of those benefits; second, the deeply unemployed expect their income to remain depressed for some time and therefore save more of the stimulus for the future. In the model, the fact that they do *not* spend immediately is actually a reflection of how desperately they anticipate these funds will be needed to make it through a long period of low income. While unemployment benefits do not strongly stimulate current consumption of the deeply unemployed, they do provide important disaster relief for those who may not be able to return to work for several quarters (see [Krugman \(2020\)](#) for an informal discussion).

In addition to our primary scenario’s relatively short lockdown period, we also consider a more severe scenario in which the lockdown is expected to last for four quarters and the unemployment rate increases to 20 percent. In this case, we find that the return of spending toward its no-pandemic path takes roughly three years. Moreover, the spending of deeply unemployed households falls steeply unless the temporary unemployment benefits in the CARES Act are extended for the duration of the lockdown.

Our modeling assumptions — about who will become unemployed, how long it will take them to return to employment, and the direct effect of the lockdown on consumption utility — could prove to be off, in either direction. Reasonable analysts

may differ on all of these points and prefer a different calibration. To encourage such exploration, we have made available our modeling and prediction software, with the goal of making it easy for fellow researchers to test alternative assumptions. Instructions for installing and running our code can be found [here](#); alternatively, adjustments to our parametrization can be explored with an interactive dashboard [here](#).

There is a potentially important reason our model may underpredict the bounce-back in consumer spending when the lockdown ends: ‘pent up demand.’ This term captures the fact that purchases of ‘durable’ goods can be easily postponed, but that when the reason for postponement abates some portion of the missing demand is made up for.⁴ For simplicity, our model does not include durable goods, because modeling spending on durables is a formidable challenge. But it is plausible that, when the lockdown ends, people may want to spend *more* than usual on memorable or durable goods to make up for earlier missing spending.

Many papers have recently appeared on the economic effects of the pandemic and policies to manage it. Several papers combine the classic susceptible–infected–recovered (SIR) epidemiology model with dynamic economic models to study the interactions between health and economic policies (Eichenbaum, Rebelo, and Trabandt (2020) and Alvarez, Argente, and Lippi (2020), among others). Guerrieri, Lorenzoni, Straub, and Werning (2020) shows how an initial supply shock (such as a pandemic) can be amplified by the reaction of aggregate demand. The ongoing work of Kaplan, Moll, and Violante (2020) allows for realistic household heterogeneity in how household income and consumption are affected by the pandemic. Glover, Heathcote, Krueger, and Ríos-Rull (2020) studies distributional effects of optimal

⁴We put ‘durable’ in quotes because ‘memorable’ goods (Hai, Krueger, and Postlewaite (2013)) have effectively the same characteristics.

health and economic policies. Closest to our paper is some work analyzing the effects of the fiscal response to the pandemic, including Faria-e-Castro (2020b) in a two-agent DSGE model, and Bayer, Born, Luetticke, and Müller (2020) in a HANK model.

All of this work accounts for general equilibrium effects on consumption and employment, which we omit, but none of it is based on a modeling framework explicitly constructed to match micro and macroeconomic effects of past stimulus policies, as ours is.

A separate strand of work focuses on empirical studies of how the economy reacts to pandemics; see, e.g., Baker, Farrokhnia, Meyer, Pagel, and Yannelis (2020), Jorda, Singh, and Taylor (2020), Correia, Luck, and Verner (2020), Chetty, Friedman, Hendren, Stepner, and Team (2020), Garner, Safir, and Schild (2020), Casado, Glennon, Lane, McQuown, Rich, and Weinberg (2020) and Coibion, Gorodnichenko, and Weber (2020).

II Modeling Setup

A The Baseline Model

Our model extends a class of models explicitly designed to capture the rich empirical evidence on heterogeneity in the marginal propensity to consume (MPC) across different types of household (employed, unemployed; young, old; rich, poor). This is motivated by the fact that the act distributes money unevenly across households, particularly targeting unemployed households. A model that does not appropriately capture both the degree to which the stimulus money is targeted, and the differentials in responses across differently targeted groups, is unlikely to produce believable answers about the spending effects of the stimulus.

Specifically, we use a **lifecycle model** calibrated to match the income paths of high school dropouts, high school graduates, and college graduates.⁵ Households are subject to permanent and transitory income shocks, as well as unemployment spells.⁶ Within each of these groups, we calibrate the distribution of discount factors to match their distribution of liquid assets. Matching the distributions of liquid assets allows us to achieve a realistic distribution of marginal propensities to consume according to education group, age, and unemployment status, and thus to assess the impact of the act for these different groups.⁷

B Adaptations to Capture the Pandemic

To model the pandemic, we add two new features to the model.

First, our new category of ‘deeply unemployed’ households was created to capture the likelihood that the pandemic will have long-lasting effects on some kinds of businesses and jobs (e.g., the cruise and airline industries), even if the CARES Act manages to successfully cushion much of the initial financial hit to total household income. Moreover, evidence in Yagan (2019) indicates that unemployment shocks from the Great Recession had long-lasting impacts on individuals’ employment.

Each quarter, our ‘deeply unemployed’ households have a two-thirds chance of remaining deeply unemployed, and a one-third chance of becoming ‘normal unemployed.’ The expected time to re-employment for a ‘deeply unemployed’ household is four and a half quarters, much longer than the historical average length of a typical unemployment spell. Reflecting recent literature on the ‘scarring effects’ of unemployment spells (e.g., Oreopoulos, von Wachter, and Heisz (2012) and Heathcote, Perri,

⁵The baseline model is very close to the lifecycle model in Carroll, Slacalek, Tokunaka, and White (2017).

⁶Households exit unemployment with a fixed probability each quarter — the expected length of an unemployment spell is one and a half quarters.

⁷For a detailed description of the model and its calibration see Appendix A.

and Violante (2020)), permanent income of both ‘normal’ and ‘deeply’ households declines by 0.5 percent each year due to ‘skill rot’ (relative to following the default age profile that would have been followed if the consumer had remained employed).

Second, a temporary negative shock to the **marginal utility of consumption** captures the idea that, during the period of the pandemic, many forms of consumption are undesirable or even impossible.⁸

The pandemic is modeled as an unexpected (MIT) shock, sending many households into normal or deep unemployment, as well as activating the negative shock to marginal utility. Households understand and respond in a forward-looking way to their new circumstances (according to their beliefs about its duration), but their decisions prior to the pandemic did not account for any probability that it would occur. For simplicity, we assume that each household correctly recognizes whether it is ‘deeply’ or ‘normal’ unemployed and react accordingly.

Calibration

The calibration choices for the pandemic scenario are very much open for debate. We have tried to capture something like median expectations from early analyses, but there is considerable variation in points of view around those medians. Section **III.B** below presents a more adverse scenario with a longer lockdown and a larger increase in unemployment.

Unemployment forecasts for Q2 2020 range widely, from less than 10 percent to over 30 percent, but all point to an unprecedented sudden increase in unemployment.⁹

⁸For the purposes of our paper, with log utility, modeling lockdowns as a shock to marginal utility is essentially equivalent to not allowing consumers to buy a subset of goods (which are combined into composite consumption by a Cobb–Douglas aggregator). However, the two approaches would yield different implications for normative evaluations of economic policies.

⁹As of April 16, about 22 million new unemployment claims have been filed in four weeks, representing a loss of over 14 percent of total jobs. JP Morgan Global Research forecast 8.5 percent unemployment (JPMorgan (2020), from March 27); Treasury Secretary Steven Mnuchin predicted unemployment could rise to 20 percent without a significant fiscal response (Bloomberg (2020a)); St. Louis Fed president James Bullard said the unemployment rate

We choose a total unemployment rate in Q2 2020 of just over 15 percent, consisting of five percent ‘deeply unemployed’ and ten percent ‘normal unemployed’ households.

Our model assumes that the unemployment shock from the pandemic is a singular event, with no change in the longer run job separation rate for employed households (calibrated to generate a steady state unemployment rate of 5%). Consequently, agents in our model who remain employed in Q2 2020 have no additional precautionary saving motive against a heightened risk of unemployment, and any change in their consumption behavior arises from the marginal utility shock.

We calibrate the likelihood of becoming unemployed to match empirical facts about the relationship of unemployment to education level, permanent income and age, which is likely to matter because the hardest hit sectors skew young and unskilled.¹⁰ Figure 1 shows our assumptions on unemployment along these dimensions. In each education category, the solid or dashed line represents the probability of unemployment type (‘normal’ or ‘deep’) for a household with the median permanent income at each age, while the dotted lines represent the probability of unemployment type for a household at the 5th and 95th percentile of permanent income at each age; Appendix A with Table A2 detail the parametrization and calibration we used.

To calibrate the drop in marginal utility, we estimate that 10.9 percent of the goods that make up the consumer price index become highly undesirable, or simply unavailable, during the pandemic: food away from home, public transportation including airlines, and motor fuel. As we use a coefficient of risk aversion equal to one, we simply multiply utility from consumption during the period of the epidemic by a

may hit 30 percent (Bloomberg (2020b) — see Faria-e-Castro (2020a) for the analysis behind this claim). Based on a survey that closely follows the CPS, Bick and Blandin (2020) calculate a 20.2 percent unemployment rate at the beginning of April.

¹⁰See Gascon (2020), Leibovici and Santacreu (2020) and Adams-Prassl, Boneva, Golin, and Rauh (2020) for breakdowns of which workers are at most risk of unemployment from the crisis. See additional evidence in Kaplan, Moll, and Violante (2020) and modeling of implications for optimal policies in Glover, Heathcote, Krueger, and Ríos-Rull (2020).

factor of 0.891.¹¹ This calibration is in line with recent evidence in Cox, Ganong, Noel, Vavra, Wong, Farrell, and Greig (2020) and Chetty, Friedman, Hendren, Stepner, and Team (2020). Furthermore, we choose a one-half probability of exiting the period of lower marginal utility each quarter, accounting for the possibility of a ‘second wave’ if restrictions are lifted too early — see Cyranoski (2020).¹²

The CARES Act

We model the two elements of the CARES Act that directly affect the income of households:

- The stimulus check of \$1,200 for every adult taxpayer, means tested for previous years’ income.¹³
- The extra unemployment benefits of \$600 for up to 13 weeks, a total of \$7,800. For normal unemployed, we assume they receive only \$5,200 to reflect the idea that they may not be unemployed the entire 13 weeks.

We model the stimulus checks as being announced at the same time as the crisis hits. However, only a quarter of households change their behavior immediately at the time of announcement, as calibrated to past experience. The remainder do not respond until their stimulus check arrives, which we assume happens in the following quarter. The households that pay close attention to the announcement of the policy are assumed to be so forward looking that they act as though the payment will

¹¹See the Cobb-Douglas interpretation in Appendix C.

¹²The CBO expects social distancing to last for three months, and predicts it to have diminished, on average and in line with our calibration, by three-quarters in the second half of the year; see Swagel (2020).

¹³The act also includes \$500 for every child. In the model, an agent is somewhere between a household and an individual. While we do not model the \$500 payments to children, we also do not account for the fact that some adults will not receive a check. In aggregate we are close to the Joint Committee on Taxation’s estimate of the total cost of the stimulus checks.

arrive with certainty next period; the model even allows them to borrow against it if desired.¹⁴

The extra unemployment benefits are assumed to both be announced and arrive at the beginning of the second quarter of 2020, and we assume that there is no delay in the response of unemployed households' consumption to these benefits.

Figure 2 shows the path of labor income — exogenous in our model — in the baseline and in the pandemic, both with and without the CARES Act. Income in quarters Q2 and Q3 2020 is substantially boosted (by around 10 percent) by the extra unemployment benefits and the stimulus checks. After two years, aggregate labor income is almost fully recovered. See below for a brief discussion of analyses that attempt to endogenize labor supply and other equilibrium variables.

III Results

This section presents our simulation results for the scenario described above. In addition, we then model a more pessimistic scenario with a longer lockdown and higher initial unemployment rate.

A Short-lived Pandemic

Figure 3 shows three scenarios for quarterly aggregate consumption: (i) the baseline with no pandemic; (ii) the pandemic with no fiscal response; (iii) the pandemic with both the stimulus checks and extended unemployment benefits in the CARES Act.

¹⁴See Carroll, Crawley, Slacalek, Tokuoka, and White (2020) for a detailed discussion of the motivations behind this way of modeling stimulus payments, and a demonstration that this model matches the empirical evidence of how and when households have responded to stimulus checks in the past — see Parker, Souleles, Johnson, and McClelland (2013), Broda and Parker (2014) and Parker (2017), among others. See also Fagereng, Holm, and Natvik (2017) for a natural experiment measured using national registry data.

The pandemic reduces consumption by ten percentage points in Q2 2020 relative to the baseline.

Without the CARES Act, consumption remains depressed through to the second half of 2021, at which point spending returns to the baseline level as a result of the buildup of liquid assets during the pandemic by households that do not lose their income. We capture the limited spending options during the lockdown period by a reduction in the utility of consumption, which makes households save more during the pandemic than they otherwise would have, with the result that they build up liquid assets. When the lockdown ends, the pent up savings of the always-employed become available to finance a resurgence in their spending, but the depressed spending of the two groups of unemployed people keeps total spending below the baseline until most of them are reemployed, at which point their spending (mostly) recovers while the always-employed are still spending down their extra savings built up during the lockdown.

Figure 4 decomposes the effect of the pandemic on aggregate consumption (with no fiscal policy response), separating the drop in marginal utility from the reduction in income due to mass layoffs. The figure illustrates that the constrained consumption choices are quantitatively key in capturing the expected depth in the slump of spending, which is already under way; see Baker, Farrokhnia, Meyer, Pagel, and Yannelis (2020) and Armantier, Kosar, Pomerantz, Skandalis, Smith, Topa, and van der Klaauw (2020) for early evidence. The marginal utility shock hits all households, and directly affects their spending decisions in the early quarters after the pandemic; its effect cannot be mitigated by fiscal stimulus. The loss of income from unemployment is large, but affects only a fraction of households, who are disproportionately low income and thus account for a smaller share of aggregate consumption. Moreover, most households hold at least some liquid assets, allowing them to smooth their

consumption drop — the 5 percent decrease in labor income in Figure 2 induces only a 1.5 percent decrease in consumption in Figure 4.

Figure 5 shows how the consumption response varies depending on the employment status of households in Q2 2020. For each employment category (employed, unemployed, and deeply unemployed), the figure shows consumption relative to the same households' consumption in the baseline scenario with no pandemic (dotted lines).¹⁵ The upper panel shows consumption without any policy response, while the lower panel includes the CARES Act. The figure illustrates an important feature of the unemployment benefits that is lost at the aggregate level: the response provides the most relief to households whose consumption is most affected by the pandemic. For the unemployed — and especially for the deeply unemployed — the consumption drop when the pandemic hits is much shallower and returns faster toward the baseline when the fiscal stimulus is in place.

Indeed, this targeted response is again seen in Figure 6, showing the extra consumption relative to the pandemic scenario without the CARES Act. The short-dashed and dotted lines show the effect of the stimulus check in isolation (for employed workers this is the same as the total fiscal response). For unemployed households, this is dwarfed by the increased unemployment benefits. These benefits both arrive earlier and are much larger. Specifically, in Q3 2020, when households receive the stimulus checks, the effect of unemployment benefits on consumption makes up about 70 percent and 85 percent of the total effect for the normally and deeply unemployed, respectively.

Figure 7 aggregates the decomposition of the CARES Act in Figure 6 across all households. In our model economy, the extra unemployment benefits amount to

¹⁵Households that become unemployed during the pandemic might or might not have been unemployed otherwise. We assume that all households that would have been unemployed otherwise are either unemployed or deeply unemployed in the pandemic scenario. However, there are many more households that are unemployed in the pandemic scenario than in the baseline.

\$544 per household, while the stimulus checks amount to \$1,054 per household (as means testing reduces or eliminates the stimulus checks for high income households). Aggregated, stimulus checks amount to \$267 billion, while the extended unemployment benefits amount to just over half that, \$137 billion.¹⁶ The figure shows that during the peak consumption response in Q3 2020, the stimulus checks account for about 70 percent of the total effect on consumption for the average household and the unemployment benefits for about 30 percent. Thus, although the unemployment benefits make a much larger difference to the spending of the individual recipients than the stimulus checks, a small enough proportion of households becomes unemployed that the total extra spending coming from these people is less than the total extra spending from the more widely distributed stimulus checks.

The previous graphs show the importance of the targeted unemployment benefits at the individual level, but the aggregate effect is less striking. Figure 8 compares the effect of the CARES Act (both unemployment insurance and stimulus checks) to a policy of the same absolute size that distributes checks to everybody. While unemployment benefits arrive sooner, resulting in higher aggregate consumption in Q2 2020, the un-targeted policy leads to higher aggregate consumption in the following quarters.

The interesting conclusion is that, while the net spending response is similar for alternative ways of distributing the funds, the choice to extend unemployment benefits means that much more of the extra spending is coming from the people who will be worst hurt by the crisis. This has obvious implications for the design of any further stimulus packages that might be necessary if the crisis lasts longer than our baseline scenario assumes.

¹⁶See Appendix B for details on how we aggregate households.

B Alternative Scenario: Long, Deep Pandemic

Given the uncertainty about how long and deep the current recession will be, we investigate a more pessimistic scenario in which the lockdown is expected to last for four quarters. In addition, the unemployment rate increases to 20 percent in Q2 2020, consisting of 15 percent of deeply unemployed and 5 percent of normal unemployed. In this scenario we compare how effectively the CARES package stimulates consumption, also considering a more generous plan in which the unemployment benefits continue until the lockdown is over. We model the receipt of unemployment benefits each quarter as an unexpected shock, representing a series of policy renewals.

Figure 9 compares the effects of the two fiscal stimulus policies on income. The persistently high unemployment results in a substantial and long drop in aggregate income (long-dashed) as compared to the no pandemic scenario. The CARES stimulus (medium-dashed) provides only a short term support to income for the first two quarters. In contrast, the scenario with unemployment benefits extended as long as the lockdown lasts (dotted) keeps aggregate income elevated through the recession.

Figure 10 shows the implications of the two stimulus packages for aggregate consumption. The long lockdown causes a much longer decline in spending than the shorter lockdown in our primary scenario. In the shorter pandemic scenario (Figure 3) consumption returns to the baseline path after roughly one year, while in the long lockdown shown here the recovery takes around three years; the CARES stimulus shortens the consumption drop to about two years. The scenario with extended unemployment benefits ensures that aggregate spending returns to near the baseline path after just over one year, and does so by targeting the funds to the people who are worst hurt by the crisis and to whom the cash will make the most difference.

IV Conclusions

Our model suggests that there may be a strong consumption recovery when the social-distancing requirements of the pandemic begin to subside. We invite readers to test the robustness of this conclusion by using the associated software toolkit to choose their own preferred assumptions on the path of the pandemic, and of unemployment, to understand better how consumption will respond.

One important limitation of our analysis is that it does not incorporate Keynesian demand effects or other general equilibrium responses to the consumption fluctuations we predict. In practice, Keynesian effects are likely to cause movements in aggregate income in the same direction as consumption; in that sense, our estimates can be thought of as a “first round” analysis of the dynamics of the crisis, which will be amplified by any Keynesian response. (See [Bayer, Born, Luetticke, and Müller \(2020\)](#) for estimates of the multiplier for transfer payments). These considerations further strengthen the case that the CARES Act will make a substantial difference to the economic outcome. A particularly important consideration is that forward-looking firms that expect consumer demand to return forcefully in the third and fourth quarters of 2020 are more likely to maintain relations with their employees so that they can restart production quickly.

The ability to incorporate Keynesian demand effects is one of the most impressive achievements of the generation of heterogeneous agent macroeconomic models that have been constructed in the last few years. But the technical challenges of constructing those models are such that they cannot yet incorporate realistic treatments of features that our model says are quantitatively important, particularly differing risks of (and types of) unemployment, for different kinds of people (young, old; rich, poor; high- and low-education). This rich heterogeneity is important both to the

overall response to the CARES Act, and to making judgments about the extent to which it has been successfully targeted to provide benefits to those who need them most. A fuller analysis that incorporates such heterogeneity, which is of intrinsic interest to policymakers, as well as a satisfying treatment of general equilibrium will have to wait for another day, but that day is likely not far off.

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Figure 1 Unemployment Probability in Q2 2020 by Demographics

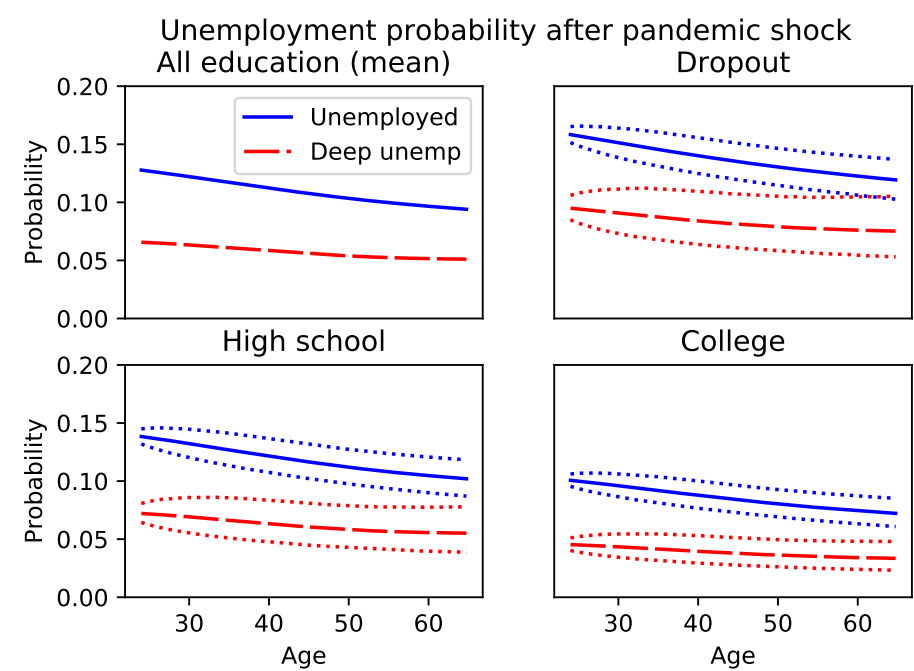


Figure 2 Labor and Transfer Income

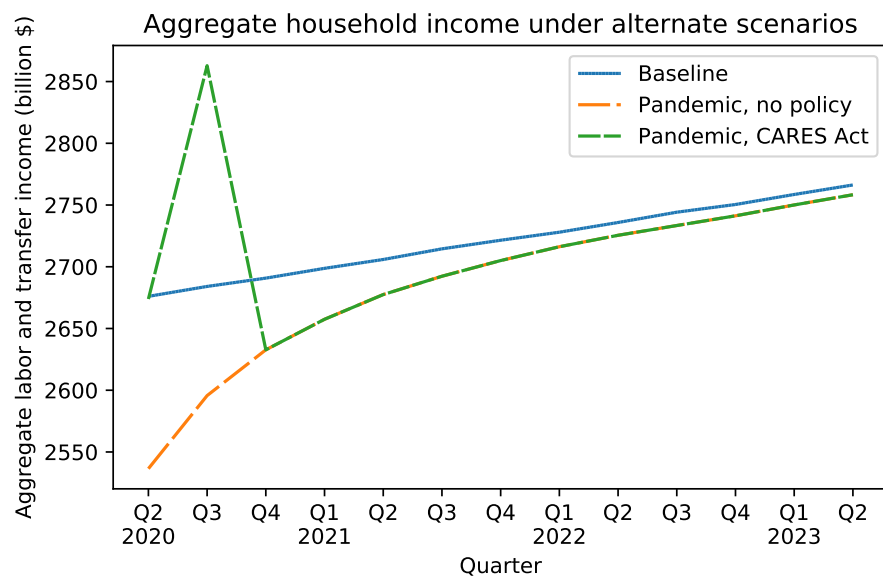


Figure 3 Consumption Response to the Pandemic and the Fiscal Stimulus

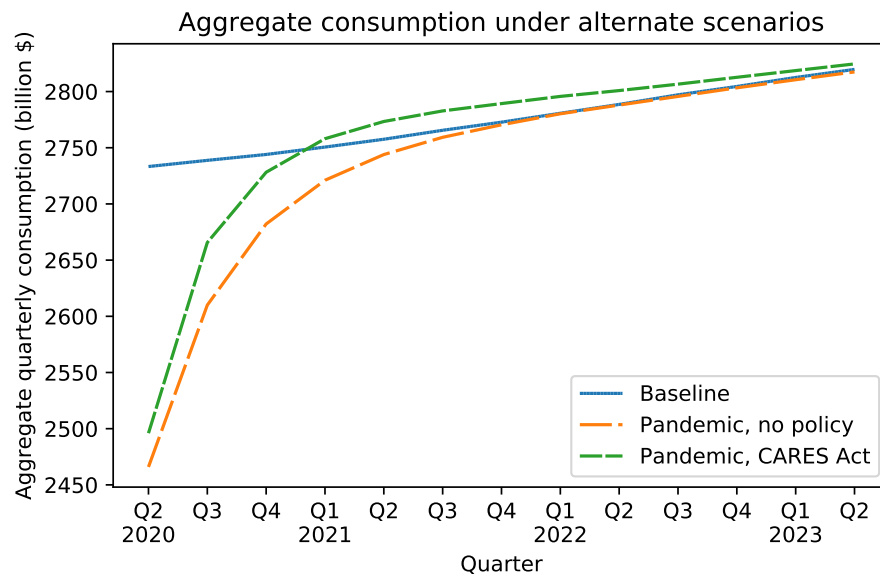


Figure 4 Decomposition of Effect of the Pandemic on Aggregate Consumption (No Policy Response)

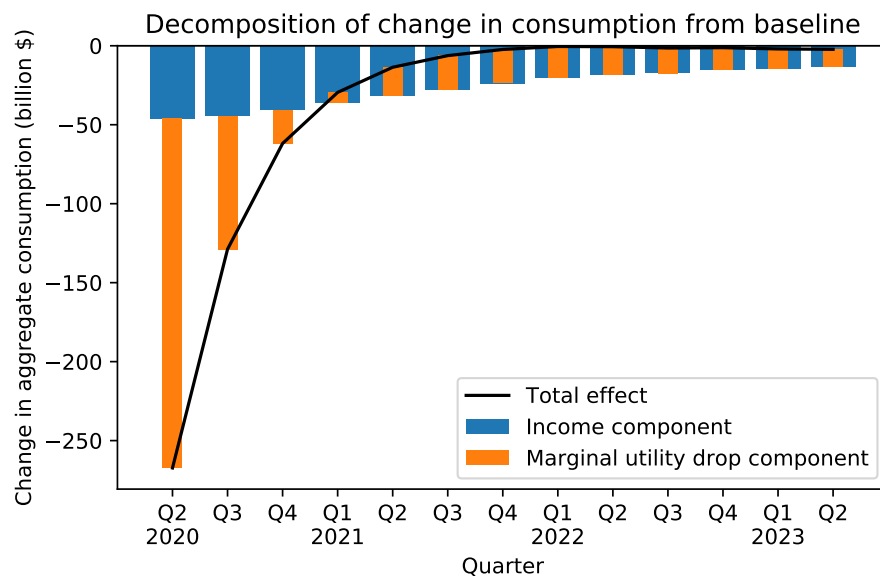


Figure 5 Consumption Response by Employment Status

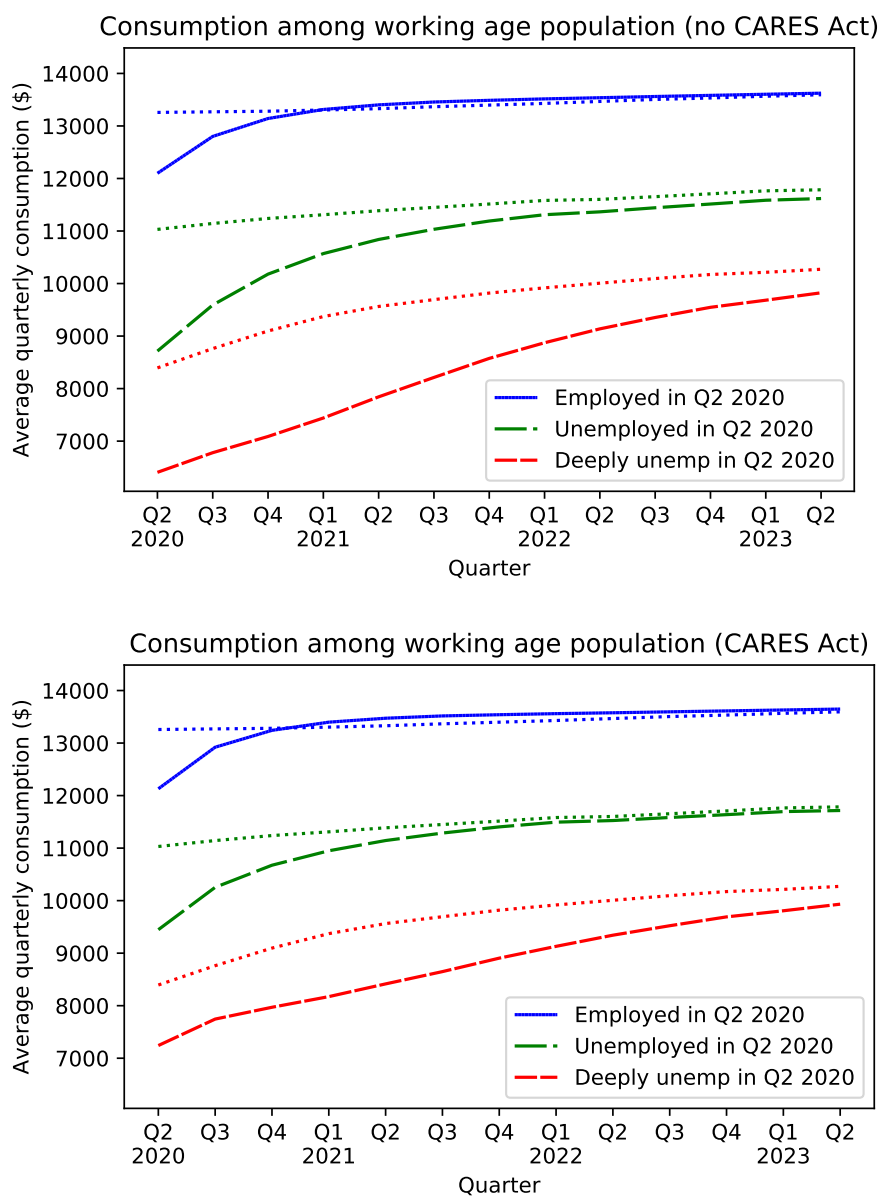


Figure 6 Effect of CARES Act by Employment Status

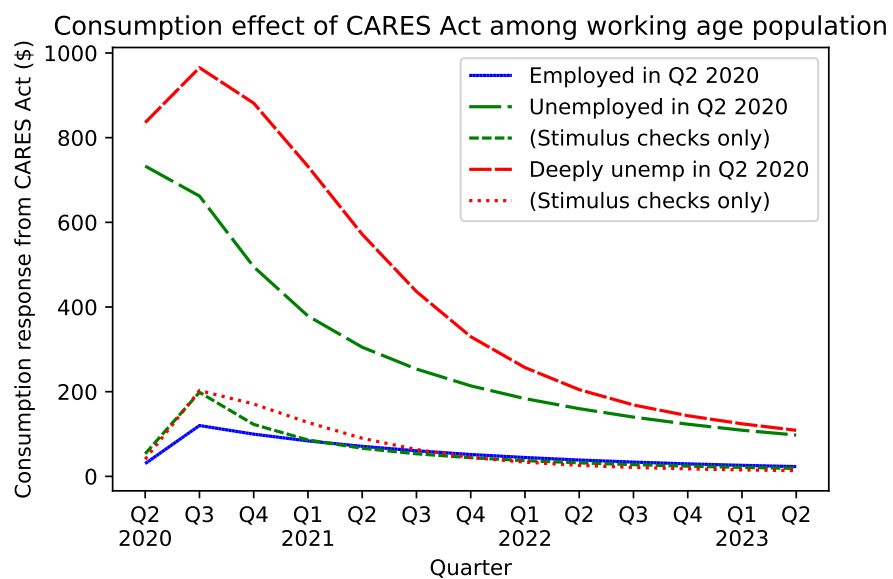


Figure 7 Aggregate Consumption Effect of Stimulus Checks vs Unemployment Benefits

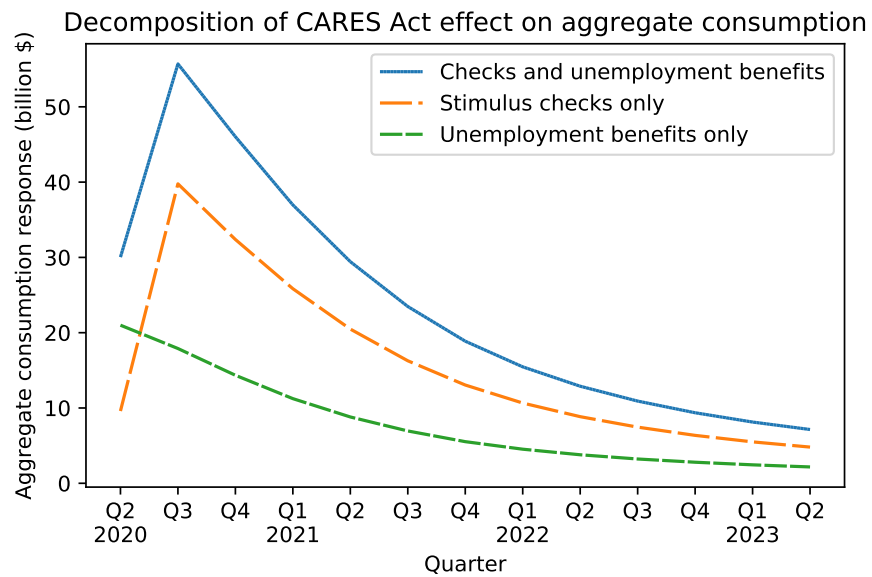


Figure 8 Effect of Targeting the CARES Act Consumption Stimulus

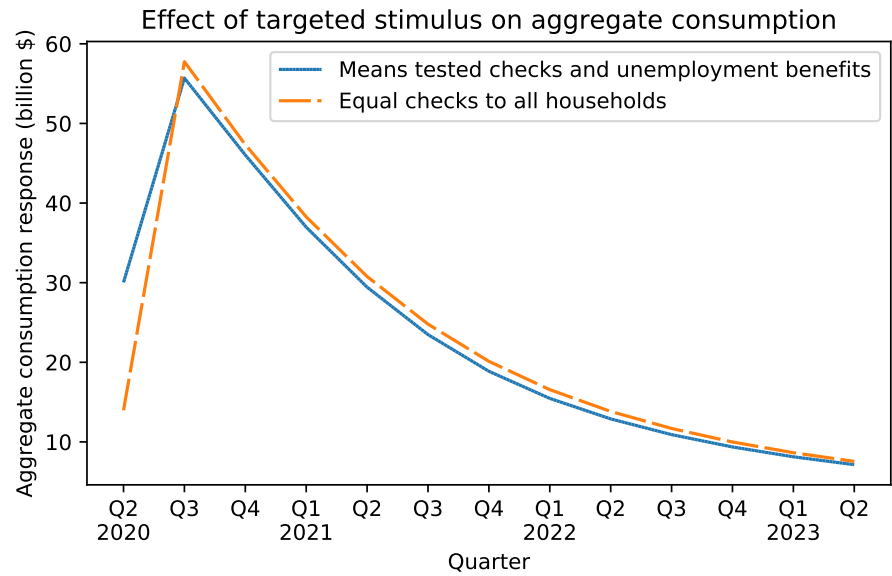


Figure 9 Labor and Transfer Income During the Long, Four-Quarter Pandemic

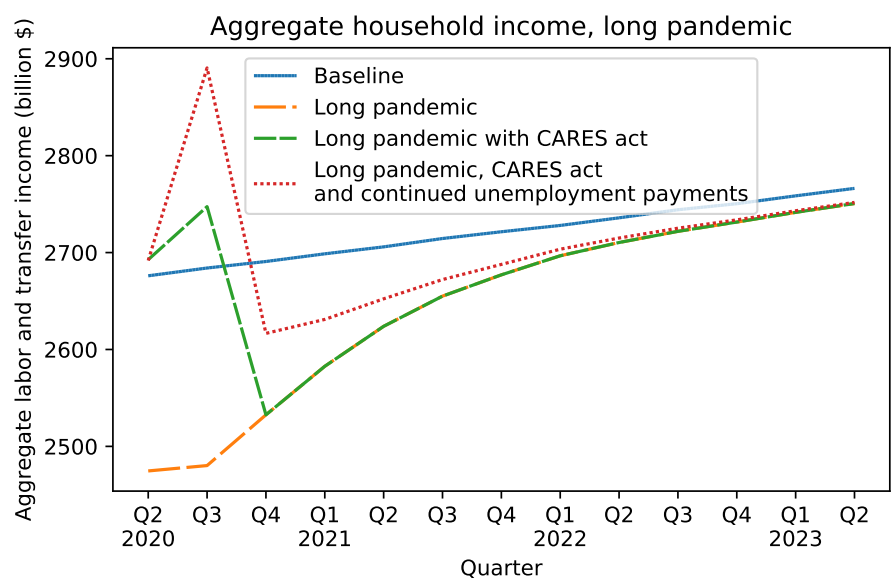
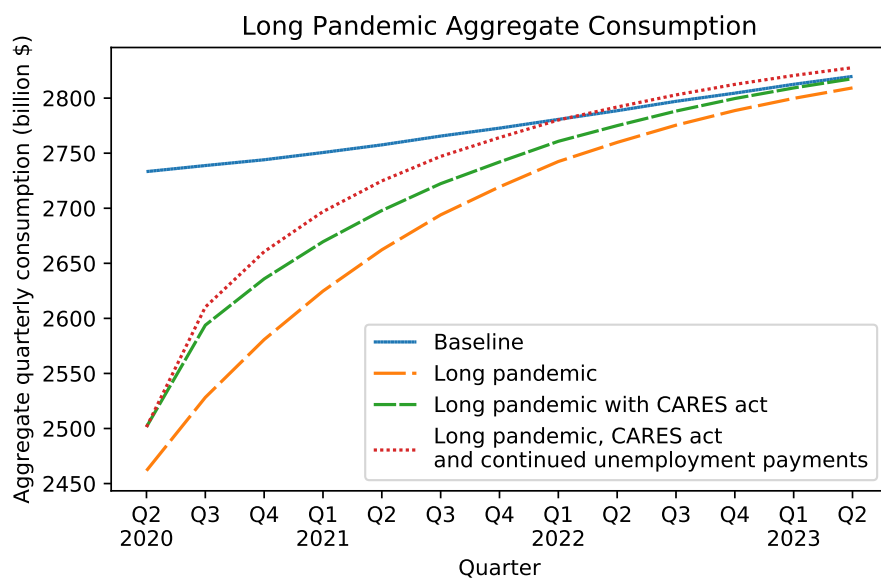


Figure 10 Consumption Response to the Long, Four-Quarter Pandemic



Appendices

A Model Details

The baseline model is adapted and expanded from Carroll, Slacalek, Tokuoka, and White (2017). The economy consists of a continuum of expected utility maximizing households with a common CRRA utility function over consumption, $u(\mathbf{c}, \eta) = \eta \mathbf{c}^{1-\rho} / (1-\rho)$, where η is a marginal utility shifter. Households are *ex ante* heterogeneous: household i has a quarterly time discount factor $\beta_i \leq 1$ and an education level $e_i \in \{D, HS, C\}$ (for dropout, high school, and college, respectively). Each quarter, the household receives (after tax) income, chooses how much of their market resources \mathbf{m}_{it} to consume \mathbf{c}_{it} and how much to retain as assets \mathbf{a}_{it} ; they then transition to the next quarter by receiving shocks to mortality, income, their employment state, and their marginal utility of consumption.

For each education group e , we assign a uniform distribution of time preference factors between $\hat{\beta}_e - \nabla$ and $\hat{\beta}_e + \nabla$, chosen to match the distribution of liquid wealth and retirement assets. Specifically, the calibrated values in Table A1 fit the ratio of liquid wealth to permanent income in aggregate for each education level, as computed from the 2004 Survey of Consumer Finance. The width of the distribution of discount factors was calibrated to minimize the difference between simulated and empirical Lorenz shares of liquid wealth for the bottom 20%, 40%, 60%, and 80% of households, as in Carroll, Slacalek, Tokuoka, and White (2017).

When transitioning from one period to the next, a household with education e that has already lived for j periods faces a D_{ej} probability of death. The quarterly mortality probabilities are calculated from the Social Security Administration’s actuarial table (for annual mortality probability) and adjusted for education using Brown,

Liebman, and Pollett (2002); a household dies with certainty if it (improbably) reaches the age of 120 years. The assets of a household that dies are completely taxed by the government to fund activities outside the model. Households who survive to period $t + 1$ experience a return factor of R on their assets, assumed constant.

Household i 's state in period t , at the time it makes its consumption–saving decision, is characterized by its age j ,¹⁷ a level of market resources $\mathbf{m}_{it} \in \mathbb{R}_+$, a permanent income level $\mathbf{p}_{it} \in \mathbb{R}_{++}$, a discrete employment state $\ell_{it} \in \{0, 1, 2\}$ (indicating whether the individual is employed, normal unemployed, or deeply unemployed), and a discrete state $\eta_{it} \in \{1, \underline{\eta}\}$ that represents whether its marginal utility of consumption has been temporarily reduced ($\underline{\eta} < 1$). Denote the joint discrete state as $n_{it} = (\ell_{it}, \eta_{it})$.

Each household inelastically participates in the labor market when it is younger than 65 years ($j < 164$) and retires with certainty at age 65. The transition from working life to retirement is captured in the model by a one time large decrease in permanent income at age $j = 164$.¹⁸ Retired households face essentially no income risk: they receive Social Security benefits equal to their permanent income with 99.99% probability and miss their check otherwise; their permanent income very slowly degrades as they age. The discrete employment state ℓ_{it} is irrelevant for retired households.

Labor income for working age households is subject to three risks: unemployment, permanent income shocks, and transitory income shocks. Employed ($\ell_{it} = 0$) households' permanent income grows by age-education-conditional factor Γ_{ej} on average, subject to a mean one lognormal permanent income shock ψ_{it} with age-conditional underlying standard deviation of $\sigma_{\psi j}$. The household's labor income \mathbf{y}_{it} is also subject to a mean one lognormal transitory shock ξ_{it} with age-conditional underlying standard

¹⁷Households enter the model aged 24 years, so model age $j = 0$ corresponds to being 24 years, 0 quarters old.

¹⁸The size of the decrease depends on education level, very roughly approximating the progressive structure of Social Security: $\Gamma_{D164} \approx 0.56$, $\Gamma_{HS164} \approx 0.44$, $\Gamma_{C164} \approx 0.31$.

deviation of $\sigma_{\xi j}$. The age profiles of permanent and transitory income shock standard deviations are approximated from the results of [Sabelhaus and Song \(2010\)](#), and the expected permanent income growth factors are adapted from [Cagetti \(2003\)](#). Normal unemployed and deeply unemployed households receive unemployment benefits equal to a fraction $\underline{\xi} = 0.3$ of their permanent income, $\mathbf{y}_{it} = \underline{\xi}\mathbf{p}_{it}$; they are not subject to permanent nor transitory income risk, but their permanent income grows at rate χ less than if employed, representing “skill rot”.¹⁹

The income process for a household can be represented mathematically as:

$$\mathbf{p}_{it} = \begin{cases} \psi_{it}\Gamma_{ej}\mathbf{p}_{it-1} & \text{if } \ell_{it} = 0, j < 164 & \text{Employed, working age} \\ (\Gamma_{ej} - \chi)\mathbf{p}_{it-1} & \text{if } \ell_{it} > 0, j < 164 & \text{Unemployed, working age} \\ \Gamma_{ret}\mathbf{p}_{it-1} & \text{if } j \geq 164 & \text{Retired} \end{cases}$$

$$\mathbf{y}_{it} = \begin{cases} \xi_{it}\mathbf{p}_{it} & \text{if } \ell_{it} = 0, j < 164 & \text{Employed, working age} \\ \underline{\xi}\mathbf{p}_{it} & \text{if } \ell_{it} > 0, j < 164 & \text{Unemployed, working age} \\ \mathbf{p}_{it} & \text{if } j \geq 164 & \text{Retired} \end{cases}$$

A working-age household’s employment state ℓ_{it} evolves as a Markov process described by the matrix Ξ , where element k, k' of Ξ is the probability of transitioning from $\ell_{it} = k$ to $\ell_{it+1} = k'$. During retirement, all households have $\ell_{it} = 0$ (or any other trivializing assumption about the “employment” state of the retired). We assume that households treat $\Xi_{0,2}$ and $\Xi_{1,2}$ as zero: they do not consider the possibility of ever attaining the deep unemployment state $\ell_{it} = 2$ from “normal” employment or unemployment, and thus it does not affect their consumption decision in those employment states.

¹⁹Unemployment is somewhat persistent in our model, so the utility risk from receiving 15% of permanent income for one quarter (as in [Carroll, Slacalek, Tokunaka, and White \(2017\)](#)) is roughly the same as the risk of receiving 30% of permanent income for 1.5 quarters in expectation.

We specify the unemployment rate during normal times as $\mathcal{U} = 5\%$, and the expected duration of an unemployment spell as 1.5 quarters. The probability of transitioning from unemployment back to employment is thus $\Xi_{1,0} = \frac{2}{3}$, and the probability of becoming unemployed is determined as the flow rate that offsets this to generate 5% unemployment (about 3.5%). The deeply unemployed expect to be unemployed for *much* longer: we specify $\Xi_{2,0} = 0$ and $\Xi_{2,1} = \frac{1}{3}$, so that a deeply unemployed person remains so for three quarters on average before becoming “normal” unemployed (they cannot transition directly back to employment). Thus the unemployment spell for a deeply unemployed worker is 2 quarters at a minimum and 4.5 quarters on average.²⁰

Like the prospect of deep unemployment, the possibility that consumption might become less appealing (via marginal utility scaling factor $\eta_{it} < 1$) does not affect the decision-making process of a household in the normal $\eta_{it} = 1$ state. If a household does find itself with $\eta_{it} = \underline{\eta}$, this condition is removed (returning to the normal state) with probability 0.5 each quarter; the evolution of the marginal utility scaling factor is represented by the Markov matrix H . In this way, the consequences of a pandemic are fully unanticipated by households, a so-called “MIT shock”; households act optimally once in these states, but did not account for them in their consumption–saving problem during “normal” times.²¹

The household’s permanent income level can be normalized out of the problem, dividing all boldface variables (absolute levels) by the individual’s permanent income \mathbf{p}_{it} , yielding non-bold normalized variables, e.g., $m_{it} = \mathbf{m}_{it}/\mathbf{p}_{it}$. Thus the only

²⁰Our computational model allows for workers’ *beliefs* about the average duration of deep unemployment to differ from the *true* probability. However, we do not present results based on this feature and thus will not further clutter the notation by formalizing it here.

²¹Our computational model also allows households’ beliefs about the duration of the reduced marginal utility state (via social distancing) to deviate from the true probability. The code also permits the possibility that the reduction in marginal utility is lifted as an aggregate or shared outcome, rather than idiosyncratically. We do not present results utilizing these features here, but invite the reader to investigate their predicted consequences using our public repository.

state variables that affect the choice of optimal consumption are normalized market resources m_{it} and the discrete Markov states n_{it} . After this normalization, the household consumption functions $c_{e,j}$ satisfy:

$$\begin{aligned}
v_{e,j}(m_{it}, n_{it}) &= \max_{c_{e,j}} u(c_{e,j}(m_{it}, n_{it}), \eta_{it}) + \beta_i(1 - D_{e,j}) \mathbb{E}_t \left[\hat{\Gamma}_{it+1}^{1-\rho} v_{e,j+1}(m_{it+1}, n_{it+1}) \right] \\
&\text{s.t.} \\
a_{it} &= m_{it} - c_{e,j}(m_{it}, n_{it}), \\
m_{it+1} &= (R/\hat{\Gamma}_{it+1})a_{it} + y_{it}, \\
n_{it+1} &\sim (\Xi, H), \\
a_{it} &\geq 0,
\end{aligned}$$

where $\hat{\Gamma}_{it+1} = \mathbf{p}_{it+1}/\mathbf{p}_{it}$, the realized growth rate of permanent income from period t to $t+1$. Consumption function $c_{e,j}$ yields optimal *normalized* consumption, the ratio of consumption to the household's permanent income level; the actual consumption level is simply $\mathbf{c}_{it} = \mathbf{p}_{it}c_{e,j}(m_{it}, n_{it})$.

Starting from the terminal model age of $j = 384$, representing being 120 years old (when the optimal choice is to consume all market resources, as death is certain), we solve the model by backward induction using the endogenous grid method, originally presented in [Carroll \(2006\)](#). Substituting the definition of next period's market resources into the maximand, the household's problem can be rewritten as:

$$\begin{aligned}
v_{e,j}(m_{it}, n_{it}) &= \max_{c_{it} \in \mathbb{R}_+} u(c_{it}, \eta_{it}) + \beta_i(1 - D_{e,j}) \mathbb{E}_t \left[\hat{\Gamma}_{it+1}^{1-\rho} v_{e,j+1}((R/\hat{\Gamma}_{it+1})a_{it} + y_{it}, n_{it+1}) \right] \\
&\text{s.t. } a_{it} = m_{it} - c_{it}, \quad a_{it} \geq 0, \quad n_{it+1} \sim (\Xi, H).
\end{aligned}$$

This problem has one first order condition, which is both necessary and sufficient for optimality. It can be solved to yield optimal consumption as a function of

(normalized) end-of-period assets and the Markov state:

$$\underbrace{\eta_{it} c_{it}^{-\rho}}_{=\frac{\partial u}{\partial c}} - \underbrace{\beta_i R(1 - D_{e,j}) \mathbb{E}_t \left[\widehat{\Gamma}_{it+1}^{-\rho} v_{e,j+1}^m ((R/\widehat{\Gamma}_{it+1}) a_{it} + y_{it}, n_{it+1}) \right]}_{\equiv v_{e,j}^a(a_{it}, n_{it})} = 0 \implies c_{it} = \left(\frac{v_{e,j}^a(a_{it}, n_{it})}{\eta_{it}} \right)^{-\frac{1}{\rho}}.$$

To solve the age- j problem numerically, we specify an exogenous grid of end-of-period asset values $a \geq 0$, compute end-of-period marginal value of assets at each gridpoint (and each discrete Markov state), then calculate the unique (normalized) consumption that is consistent with ending the period with this quantity of assets while acting optimally. The beginning-of-period (normalized) market resources from which this consumption was taken is then simply $m_{it} = a_{it} + c_{it}$, the *endogenous gridpoint*. We then linearly interpolate on this set of market resources–consumption pairs, adding an additional bottom gridpoint at $(m_{it}, c_{it}) = (0, 0)$ to represent the liquidity-constrained portion of the consumption function $c_{e,j}(m_{it}, n_{it})$.

The standard envelope condition applies in this model, so that the marginal value of market resources equals the marginal utility of consumption when consuming optimally:

$$v_{e,j}^m(m_{it}, n_{it}) = \eta_{it} c_{e,j}(m_{it}, n_{it})^{-\rho}.$$

The marginal value function for age j can then be used to solve the age $j - 1$ problem, iterating backward until the initial age $j = 0$ problem has been solved.

When the pandemic strikes, we draw a new employment state (employed, unemployed, deeply unemployed) for each working age household using a logistic distribution. For each household i at $t = 0$ (the beginning of the pandemic and lockdown), we compute logistic weights for the employment states as:

$$\mathbb{P}_{i,\ell} = \alpha_{\ell,e} + \alpha_{\ell,p} \mathbf{p}_{i0} + \alpha_{\ell,j} j_{i0} \quad \text{for } \ell \in \{1, 2\}, \quad \mathbb{P}_{i,0} = 0,$$

where $e \in \{D, H, C\}$ for dropouts, high school graduates, and college graduates and

j is the household’s age. The probability that household i draws employment state $\ell \in \{0, 1, 2\}$ is then calculated as:

$$\Pr(\ell_{it} = \ell) = \exp(\mathbb{P}_{i,\ell}) / \sum_{k=0}^2 \exp(\mathbb{P}_{i,k}).$$

Our chosen logistic parameters are presented in Table A2.

B Aggregation

Households are modeled as individuals and incomes sized accordingly. We completely abstract from family dynamics. To get our aggregate predictions for income and consumption, we take the mean from our simulation and multiply by 253 million, the number of adults (over 18) in the United States in 2019. To size the unemployment benefits correctly, we multiply the benefits per worker by 0.8 to account for the fact that 20 percent of the working-age population is out of the labor force, so the average working-age household consists of 0.8 workers and 0.2 non-workers. With this adjustment, there are 151 million workers eligible for unemployment benefits in the model. Aggregate consumption in our baseline for 2020 is just over \$11 trillion, a little less than total personal consumption expenditure, accounting for the fact that some consumption does not fit in the usual budget constraint.²² Aggregating in this way underweights the young, as our model excludes those under the age of 24.

Our model estimates the aggregate size of the stimulus checks to be \$267 billion, matching the the Joint Committee on Taxation’s estimate of disbursements in 2020.²³ This is somewhat of a coincidence: we overestimate the number of adults who will actually receive the stimulus, while excluding the \$500 payment to children.

²²PCE consumption in Q4 2019, from the NIPA tables, was \$14.8 trillion. Market based PCE, a measure that excludes expenditures without an observable price was \$12.9 trillion. Health care, much of which is paid by employers and not in the household’s budget constraint, was \$2.5 trillion.

²³The JCT’s 26 March 2020 publication JCX-11-20 predicts disbursements of \$267 billion in 2020, followed by \$24 billion in 2021.

The aggregate cost of the extra unemployment benefits depends on the expected level of unemployment. Our estimate is \$137 billion, much less than the \$260 billion mentioned in several press reports, but in line with the extent of unemployment in our pandemic scenario.²⁴ We do not account for the extension of unemployment benefits to the self-employed and gig workers.

Households enter the model at age $j = 0$ with zero liquid assets. A ‘newborn’ household has its initial permanent income drawn lognormally with underlying standard deviation of 0.4 and an education-conditional mean. The initial employment state of households matches the steady state unemployment rate of 5%.²⁵

We assume annual population growth of 1%, so older simulated households are appropriately down-weighted when we aggregate idiosyncratic values. Likewise, each successive cohort is slightly more productive than the last, with aggregate productivity growing at a rate of 1% per year. The profile of average income by age in the population at any moment in time thus has more of an inverted-U shape than implied by the permanent income profiles from Cagetti (2003).

C Marginal Utility Equivalence

We model the ‘lockdown’ as a reduction in the marginal utility of consumption. This can be interpreted as an increase in the quality-adjusted price of goods, where the quality of basic goods such as shelter and housing has not decreased, but more discretionary goods such as vacations and restaurants have decreased in quality.

Figure 11 shows how this works. In normal times, the cost of a consumption unit is equal to one, represented by the blue line. During the lockdown, the cost of a unit of

²⁴While \$260 billion was widely reported in the press, back-of-the-envelope calculations show this to be an extreme number. Furthermore, the origin of this reported number is unclear.

²⁵This is the case even during the pandemic and lockdown, so the death and replacement of simulated agents is a second order contribution to the profile of the unemployment rate.

consumption is increasing in the number of units bought. As shown here, the number of consumption units that can be bought follows the lower envelope of the blue and orange lines, where the orange line is equal to Cost^α . As long as the household is consuming above the kink, their utility is $\log(\text{Cost}^\alpha) = \alpha \log(\text{Cost})$, exactly equivalent to the reduction in marginal utility we apply. Taking this interpretation seriously, the drop in marginal utility should not be applied to households with very low levels of consumption, below the kink. Our implementation abstracts from this, taking the marginal utility factor to be the same for all agents.

An alternative interpretation is that consumption is made up of a Cobb-Douglass aggregation of two goods:

$$C = c_1^\alpha c_2^{1-\alpha}$$

During the lockdown, the second good is replaced by home production at a fixed level \bar{c}_2 . A log-utility function gives $\log(C) = \alpha \log(c_1) + (1 - \alpha) \log(\bar{c}_2)$, equivalent to our model in which we reduce marginal utility by a factor α .

Figure 11 Concave Cost of Consumption Units

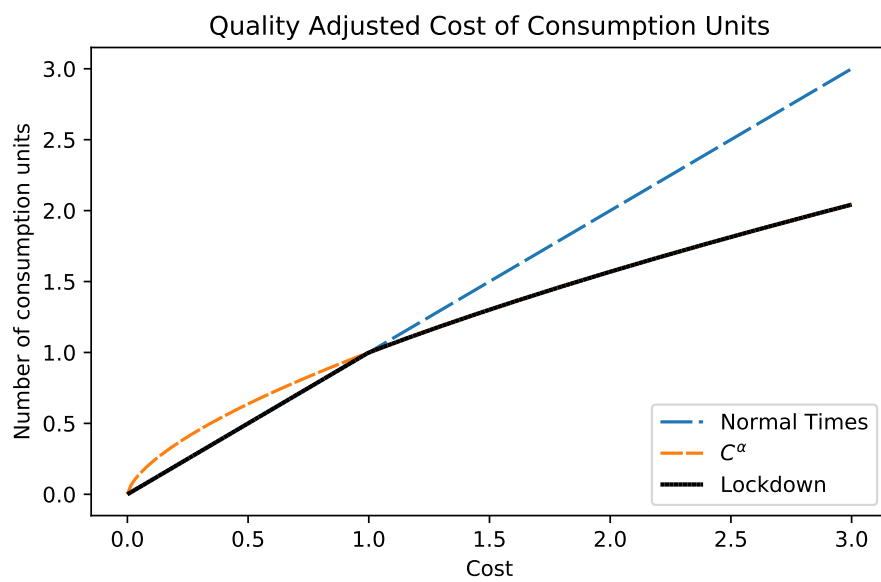


Table A1 Parameter Values in the Baseline Model

Description	Parameter	Value
Coefficient of relative risk aversion	ρ	1
Mean discount factor, high school dropout	β_D	0.9637
Mean discount factor, high school graduate	β_{HS}	0.9705
Mean discount factor, college graduate	β_C	0.9756
Discount factor band (half width)	∇	0.0253
Employment transition probabilities:		
– from normal unemployment to employment	$\Xi_{1,0}$	2/3
– from deep unemployment to normal unemployment	$\Xi_{2,1}$	1/3
– from deep unemployment to employment	$\Xi_{2,0}$	0
Proportion of high school dropouts	θ_D	0.11
Proportion of high school graduates	θ_{HS}	0.55
Proportion of college graduates	θ_C	0.34
Average initial permanent income, dropout	\bar{p}_{D0}	5000
Average initial permanent income, high school	\bar{p}_{HS0}	7500
Average initial permanent income, college	\bar{p}_{C0}	12000
Steady state unemployment rate	\bar{U}	0.05
Unemployment insurance replacement rate	ξ	0.30
Skill rot of all unemployed	chi	0.00125
Quarterly interest factor	R	1.01
Population growth factor	N	1.0025
Technological growth factor	\mathcal{I}	1.0025

Table A2 Pandemic Assumptions

Description	Parameter	Value
Short-lived Pandemic		
Logistic parametrization of unemployment probabilities		
Constant for dropout, regular unemployment	$\alpha_{1,D}$	-1.15
Constant for dropout, deep unemployment	$\alpha_{2,D}$	-1.5
Constant for high school, regular unemployment	$\alpha_{1,H}$	-1.3
Constant for high school, deep unemployment	$\alpha_{2,H}$	-1.75
Constant for college, regular unemployment	$\alpha_{1,C}$	-1.65
Constant for college, deep unemployment	$\alpha_{2,C}$	-2.2
Coefficient on permanent income, regular unemployment	$\alpha_{1,p}$	-0.1
Coefficient on permanent income, deep unemployment	$\alpha_{2,p}$	-0.2
Coefficient on age, regular unemployment	$\alpha_{1,j}$	-0.01
Coefficient on age, deep unemployment	$\alpha_{2,j}$	-0.01
Marginal Utility Shock		
Pandemic utility factor	$\underline{\eta}$	0.891
Prob. exiting pandemic each quarter	$\bar{H}_{1,0}$	0.5
Long, Deep Pandemic		
Logistic parametrization of unemployment probabilities		
Constant for dropout, regular unemployment	$\alpha_{1,D}$	-1.45
Constant for dropout, deep unemployment	$\alpha_{2,D}$	-0.3
Constant for high school, regular unemployment	$\alpha_{1,H}$	-1.6
Constant for high school, deep unemployment	$\alpha_{2,H}$	-0.55
Constant for college, regular unemployment	$\alpha_{1,C}$	-1.95
Constant for college, deep unemployment	$\alpha_{2,C}$	-1.00
Coefficient on permanent income, regular unemployment	$\alpha_{1,p}$	-0.2
Coefficient on permanent income, deep unemployment	$\alpha_{2,p}$	-0.2
Coefficient on age, regular unemployment	$\alpha_{1,j}$	-0.01
Coefficient on age, deep unemployment	$\alpha_{2,j}$	-0.01
Marginal Utility Shock		
Pandemic utility factor	$\underline{\eta}$	0.891
Prob. exiting pandemic each quarter	$\bar{H}_{1,0}$	0.25

Table A3 Fiscal Stimulus Assumptions, CARES Act

Description	Value
Stimulus check	\$1,200
Means test start (annual)	\$75,000
Means test end (annual)	\$99,000
Stimulus check delay	1 quarter
Fraction that react on announcement	0.25
Extra unemployment benefit for:	
Normal unemployed	\$5,200
Deeply unemployed	\$7,800

Note: The unemployment benefits are multiplied by 0.8 to account for the fact that 20 percent of the working age population is out of the labor force. See aggregation details in [Appendix B](#).