The Coronavirus Stimulus Package: How large is the transfer multiplier?*

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Abstract

In response to the COVID-19 pandemic, large parts of the economy have been locked down and, as a result, households' income risk has risen sharply. At the same time, policy makers have put forward the largest stimulus package in history. In the U.S., it amounts to $2 trillion, a quarter of which are transfers to households. To the extent that these transfers are conditional on being unemployed, they mitigate income risk and the adverse impact of the lockdown ex ante. Unconditional transfers, in contrast, stabilize income ex post only. The conditional and unconditional transfer component of the Coronavirus stimulus package are of equal size. We quantify their effect in an estimated HANK model. For unconditional transfers, the multiplier ranges between 0.1 and 0.5, for conditional transfers between 1 and 2. The actual transfers of the stimulus reduce the output loss due to the lockdown by about 50 percent.

Keywords: COVID-19, Coronavirus, CARES Act, fiscal policy, stimulus, targeted transfer, transfer multiplier, lockdown, quarantine

JEL-Codes: E62, E32

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1 Introduction

The economic fallout of the COVID-19 pandemic is unprecedented. Because many businesses and industries are being locked down in an effort to limit infections, unemployment is on the rise. In the three weeks since mid-March 2020, 17 million initial claims to unemployment benefits have been filed in the U.S. In the period before, a typical week saw some 250,000 new filings. The left panel of Figure 1 shows time-series data, illustrating that the recent increase is rather exceptional. In light of this, some observers suggest that the unemployment rate may reach 30% in the second quarter of 2020.[1] The COVID-19 pandemic—by necessitating quarantine measures—has thus increased the income risk for U.S. households considerably. To put this into perspective, recall that the unemployment rate hit 10% in the wake of the Great Recession and 25% at the height of the Great Depression. Related, we observe that overall economic uncertainty has increased strongly. In the right panel of Figure 1 we display the VIX, a commonly used measure for uncertainty as reflected in expected stocky market volatility. By March 21, it reached an all-time high, surpassing levels previously seen during the financial crisis in 2008.

The pandemic also triggered an exceptional fiscal response.[2] On March 27, President Trump signed the "Coronavirus Aid, Relief, and Economic Security (CARES) Act" into law. As a result, \$2 trillion of federal funds are being disbursed to households and firms through various channels. The largest items on the household side include, first, a one-time payment of \$1,200 to any adult in the U.S. population with a gross income of \$75,000 or less and, second, a top up to state unemployment benefits of \$600 per week. Conditional on being unemployed, this top-up payment is lump sum and may run up to the end of July 2020. Each of these items is expected to amount to some \$250 billion of federal expenditures. To put this into perspective, recall that the American Recovery and Reinvestment Act (ARRA), legislated in 2009 in response to the financial crisis, mobilized some \$800 billion of additional federal spending in total.

In this paper, we analyze the quantitative impact of the transfer components of the CARES act and assess to what extent they may limit the economic fallout from the COVID-19 pandemic. We proceed in two steps. First, we develop the scenario of a lockdown that captures the essential economic aspect of the COVID-19 crisis. Specifically, we assume that 10% of the labor force is confined to quarantine or, more generally, "locked out" of work. This implies a dramatic increase in unemployment, but it still seems somewhat conservative

[1]See the remark by the President of the Federal Reserve Bank of St. Louis James Bullard reported, for instance, by Bloomberg on March 22, 2020, as well as Faria-e-Castro (2020a).

[2]The Fed, too, took a series of measures in response to the COVID-19 crisis, including cutting its policy rate to zero. In this paper we focus on the fiscal response to the crisis.

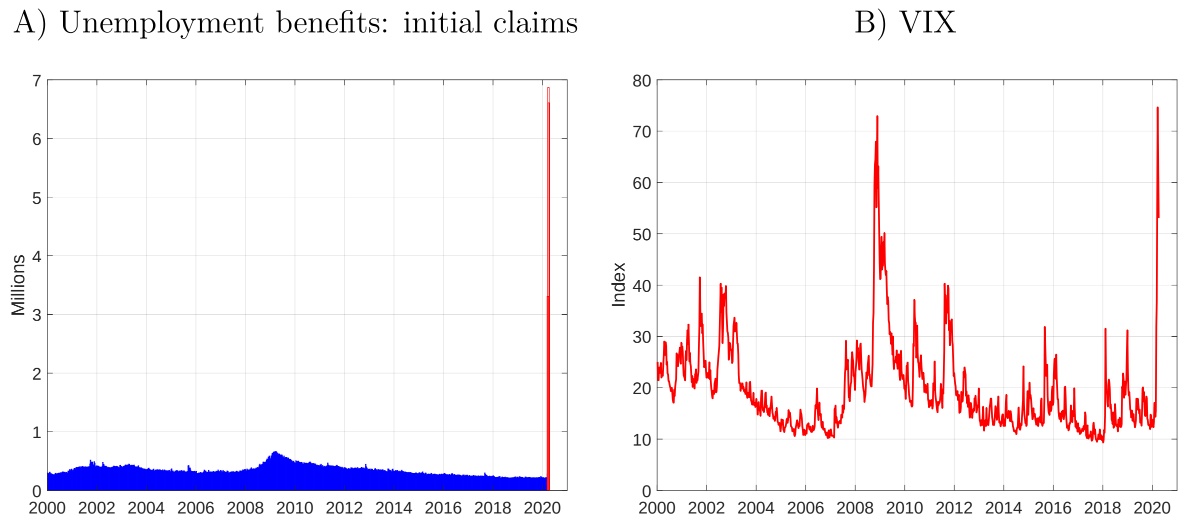


Figure 1: Unemployment and Uncertainty. Notes: Panel A) shows initial claims to unemployment benefits with observations for the three weeks since mid-March 2020 indicated by the transparent red bars, Panel B) shows CBOE Volatility Index: VIX. Weekly observations, from January 2000 to April 2020. Source: FRED Economic Data, St. Louis Fed.

in light of the scenario discussed above. We refer to this scenario as the "quarantine shock," or "Q-shock" for short.

From the aggregate perspective, the Q-shock boils down to a massive reduction of the labor force. From the household perspective it amounts to an exceptional increase of income risk because we assume, in line with the actual developments discussed above, that the lockdown is largely anticipated. People see it coming and have time to adjust their behavior in advance. In sum, the economic crisis triggered by the COVID-19 pandemic has two essential features: a) a reduction of the production potential at the aggregate level and b) an unprecedented increase in income risk at the household level. The increase in income risk, in turn, induces the private sector to increase savings. As a result, expenditures decline and economic activity collapses—well before the decline of the production potential materializes in full.

Second, given the crisis scenario, we account for key aspects of the fiscal response to the crisis. Specifically, we focus on the transfer payments to households under the CARES act and distinguish a) unconditional transfers and b) transfers that are conditional on the recipient being unemployed. There is also an element of conditionality in the $1,200-payment per person under the CARES act, but this is relevant for a small fraction of the population only.[3] Hence, we refer to it as "unconditional transfer." Unconditional transfers are part of the recession-fighting toolkit and have been deployed before. The Economic Stimulus Act passed in February 2008 under the Bush administration, for instance, was a $100-billion program under which taxpayers received a $900 payment (Broda and Parker, 2014). The economic rationale is straightforward: to the extent that households are liquidity or credit constrained, they will spend the largest part of the transfer, even if taxes may go up at some point in the future. This, in turn, may undo some of the reduction of private expenditure triggered by the recession or, more specifically in the present context, by the Q-shock. We also study how conditional transfers play out. By targeting the unemployed, the amount of funds per recipient becomes considerably larger for a fiscal package of a given size. More importantly still, it is a measure that also limits the income risk ex ante, since the employed can expect additional funds in case they are to lose their jobs. The low-income state becomes less frightful as a result.

We conduct our analysis within a quantitative model of the business cycle. It builds on earlier work by Bayer et al. (2020), who estimate a medium-scale HANK DSGE model. It is uniquely suited for the purpose at hand. First, there is a large number of households with different labor market outcomes and, because financial markets are incomplete, there is uninsurable idiosyncratic risk at the household level. As argued above, this income risk is an essential aspect of the economic fallout of the COVID-19 pandemic. Second, the model features all frictions that are necessary for a full-fledged account of actual business cycle dynamics, as shown in earlier work by Bayer et al. (2020). In our quantitative analysis we rely on the parameter estimates of this study.

Our main results can be summarized as follows. First we study our baseline scenario under which 10% of the labor force are shut off from work because of the Q-shock.[4] That there will quarantine measures becomes known already in 2020Q1, but they take effect in the next quarter only. While the quarantine itself is very short-lived, its effect on income is somewhat more persistent. This reflects the fact that some of the jobs lost because of the quarantine will be lost for good (Saez and Zucman, 2020). We study the adjustment starting from 2020Q1 onwards. Importantly, at this point idiosyncratic income risk increases strongly because ex ante (that is in 2020Q1) it is unknown which households will be quarantined and which are not. Upon impact of the Q-shock, consumption and investment thus fall sharply. In our baseline, output falls by 3.5 percent. This may appear somewhat benign. However, as we consider a more severe Q-shock as a result of which 30% of the labor force are put

[3]As explained above, there is an income limit that restricts eligibility. This limit implies that about 10 percent of the population is excluded from the program. We account for this in our model simulation below.

[4]As workers move into quarantine, we assume that their corresponding capital stock is mothballed.

under quarantine, output drops by 11 percent. Afterwards it recovers slowly, but it takes up to three years for output to recover fully from the shock. Hence, even though the Q-shock is very short-lived, there is substantial propagation in the model.

Second, given the baseline scenario, we feed the transfers into the model, both conditional and unconditional. The transfer payments interact with the Q-shock because conditional transfers reduce the income risk caused by the Q-shock. We find that transfers to households under the Coronavirus stimulus mitigate the adverse impact of the Q-shock considerably, at least in the short run. In 2020Q2, when 10% percent of the labor force is quarantined, the stimulus reduces the output loss caused by the lockdown by about 50%.

We estimate the cumulative multiplier effect of the CARES household transfers to be approximately 0.5 in 2020Q2. We obtain this value under the assumption that monetary policy operates in a conventional manner. If we assume instead a less responsive monetary policy, the multiplier doubles. We also compute the multiplier for both conditional and unconditional transfers separately and find rather stark differences. The multiplier of unconditional transfers is only 0.13, while the multiplier for conditional transfers is about eight times higher: approximately 1.1. Both of these multipliers are again twice as large if monetary policy is unresponsive. In any case, conditional transfers are much more effective in stimulating economic activity. This is for two reason. First, they lower income risk ex ante. Second, they are targeted to household with the highest marginal propensity to consume.

Our model also allows us to study the distributional consequences, both of the Q-shock and of the transfer payments under the CARES act. We find, in particular, that the Q-shock reduces income and wealth inequality because it impacts asset returns adversely. The transfer payments under the CARES act reduce inequality further because the conditional transfers are targeted to the unemployed and high-income households do not receive the "unconditional transfer".

There are relatively few estimates of the transfer multiplier, at least compared to the government spending multiplier for which there is an abundance of estimates, recently surveyed by Ramey (2019). One reason is that in standard representative agent models, Ricardian equivalence holds and hence transfers do not impact consumption and output at all. In an influential assessment of ARRA, Cogan et al. (2010) focus on the effect of government purchases rather than tranfers, even though purchases account for only a small fraction of the ARRA stimulus. Coenen et al. (2012) compare transfer multipliers in seven large-scale DSGE models. These models typically feature a fraction of agents that consumes in a "hand-to-mouth" manner in addition to agents which chose their consumption path by optimizing intertemporally. These type of models are now referred to as "two-agent New Keynesian (TANK)" models. While Ricardian equivalence fails in this model class, Coenen et al. (2012) still find moderate transfer multipliers, generally below 0.25. The transfer multiplier rises somewhat but is still well below one if the monetary policy is assumed to be unresponsive to the inflationary impact of the transfer. Giambattista and Pennings (2017) use a stylized model to provide analytical results for this case. They also simulate the transfer component of the ARRA package and find a transfer multiplier of 1.3 if the zero lower bound binds. Similarly, Mehrotra (2018) finds in a model with credit frictions that transfers at the zero lower bond generate larger transfer multipliers, but not larger than 0.5.

There is also work on the transfer multiplier in incomplete markets models of the HANK type. Oh and Reis (2012) perform a quantitative analysis of the transfers of the ARRA package in a model with household heterogeneity and sticky information. They find very small transfer multipliers on output, even though they assume that transfers are targeted to households with a high marginal propensity to consume. According to the authors this may be because their model is stylized and lacks important frictions. McKay and Reis (2016), in turn, report a tax multiplier of 0.27 in a calibrated HANK model. Hagedorn et al. (2019) assess fiscal multipliers in a HANK model under various parameterisations of monetary and fiscal rules. They find a cumulative transfer multiplier of 0.1.

Our paper is also related to a quickly growing literature studying the macroeconomic issues brought about by the COVID-19 pandemic. Like us, Guerrieri et al. (2020) and Fornaro and Wolf (2020) stress that the economic fallout from the pandemic may affect supply as well as demand. Eichenbaum et al. (2020), in turn, model the interaction between economic decisions and epidemic dynamics and study the optimal government policy in the presence of an infection externality. Most closely related to our paper is Faria-e-Castro (2020b) who analyzes fiscal policy options to counter the pandemic-induced downturn in a calibrated TANK model with a financial sector.

The remainder of this paper is organized as follows. Section 2 outlines the model structure. Section 3 explains in detail our parameter choice. Here we rely largely on an earlier estimated version of the model (Bayer et al., 2020). We present the results in Section 4. Here we also zoom in on the transmission mechanism, both of the Q-shock and the alternative transfer instruments, and analyze their distributional effects. A final section offers some conclusions.

2 Model

The model and our exposition here follows Bayer et al. (2020) closely and is extended to capture the key features of the containment measures to the global COVID-19 pandemic. We model an economy composed of a firm sector, a household sector, and a government sector.

The firm sector comprises (a) perfectly competitive intermediate goods producers who rent out labor services and capital; (b) final goods producers that face monopolistic competition, producing differentiated final goods out of homogeneous intermediate inputs; (c) producers of capital goods that turn consumption goods into capital subject to adjustment costs; (d) labor packers that produce labor services combining differentiated labor from (e) unions that differentiate raw labor rented out from households. Price setting for the final goods as well as wage setting by unions is subject to a pricing friction à la Calvo (1983).

Households earn income from supplying (raw) labor and capital and from owning the firm sector, absorbing all its rents that stem from the market power of unions and final goods producers, and decreasing returns to scale in capital goods production.

The government sector runs both a fiscal authority and a monetary authority. The fiscal authority levies taxes on labor income and distributed pure profits (monopoly rents), issues government bonds, and adjusts expenditures and tax rates to stabilize debt in the long run. The monetary authority sets the nominal interest rate on government bonds according to a Taylor rule targeting inflation and the output gap.

2.1 Households

The household sector is subdivided into two types of agents: workers and entrepreneurs. The transition between both types is stochastic. Both rent out physical capital, but only workers supply labor. The efficiency of a worker's labor evolves randomly exposing worker-households to labor-income risk. Entrepreneurs do not work, but earn all pure rents in our economy except for the rents of unions which are equally distributed across workers. All households self-insure against the income risks they face by saving in a liquid nominal asset (bonds) and a less liquid asset (capital). Trading illiquid assets is subject to random participation in the capital market.

To be specific, there is a continuum of ex-ante identical households of measure one, indexed by i. Households are infinitely lived, have time-separable preferences with time-discount factor β, and derive felicity from consumption c_{it} and leisure. They obtain income from supplying labor, n_{it}, from renting out capital, k_{it}, and from earning interest on bonds, b_{it}, and potentially from profits or union transfers. Households pay taxes on labor and profit income.

We abstract from modeling the pandemic per se through an SIER model but instead focus on the economic effects of a *successfull* suppression strategy.[5] Such strategy involves shutting down a substantial fraction of the economy where and whenever there is a local outbreak. We

[5] Berger et al. (2020) use a SIER model to analyze testing and quarantine strategies. Eichenbaum et al. (2020) nest a SIR model in a canonical general equilibrium macroeconomic model.

capture this strategy in our model by assigning zero labor market productivity to a random fraction of households – a quarantine state – from which they typically recover quickly. To model the aggregate shock to the economy, we let the probability to enter the quarantine state vary over time and calibrate it to be a very rare state in steady state. As workers move into quarantine, we assume that their corresponding capital stock is mothballed.

2.1.1 Productivity, labor supply and labor income

A household's gross labor income $w_t n_{it} h_{it}$ when not quarantined is composed of the aggregate wage rate on raw labor, w_t, the household's hours worked, n_{it}, and its idiosyncratic labor productivity, h_{it}. We assume that productivity evolves according to a log-AR(1) process and a fixed probability of transition between the worker and the entrepreneur state:

$$\tilde{h}_{it} = \begin{cases} \exp\left(\rho_h \log \tilde{h}_{it-1} + \epsilon^h_{it}\right) & \text{with probability } 1-\zeta \text{ if } h_{it-1} \neq 0, \\ 1 & \text{with probability } \iota \text{ if } h_{it-1} = 0, \\ 0 & \text{else,} \end{cases} \tag{1}$$

with individual productivity $h_{it} = \frac{\tilde{h}_{it}}{\int \tilde{h}_{it} di}$ such average productivity is normalized to one. The shocks ϵ^h_{it} to productivity are normally distributed with constant variance. A variable Q_{it} indicates that the household is quarantined, i.e., if $Q_{it} = 1$ the household is not able to work. Moving into and out of the quarantine states evolves according to a first order Markov process with time-varying entry probabilities and time-fixed exit probabilities p^{in}_t and p^{out} respectively. We denote by $1 - H_t$ the fraction of worker households in quarantine and assume that the same fraction $(1-H_t)$ of capital is quarantined, too, i.e. it is mothballed at zero utilization.

With probability ζ households become entrepreneurs ($h = 0$). With probability ι an entrepreneur returns to the labor force with median productivity. An entrepreneur obtains a fixed share of the pure rents (aside from union rents), Π^F_t, in the economy (from monopolistic competition in the goods sector and the creation of capital). We assume that the claim to the pure rent cannot be traded as an asset. Union rents, Π^U_t are distributed lump-sum across workers, leading to labor-income compression. For tractability, we assume union profits to be taxed at the average income tax rate of the economy.

With respect to leisure and consumption, households have Greenwood et al. (1988)

(GHH) preferences and maximize the discounted sum of felicity:[6]

$$\mathbb{E}_0 \max_{\{c_{it}, n_{it}\}} \sum_{t=0}^{\infty} \beta^t u \left[c_{it} - G(h_{it}, n_{it}) \right]. \tag{2}$$

The maximization is subject to the budget constraints described further below. The felicity function u exhibits a constant relative risk aversion (CRRA) with risk aversion parameter $\xi > 0$,

$$u(x_{it}) = \frac{1}{1-\xi} x_{it}^{1-\xi},$$

where $x_{it} = c_{it} - G(h_{it}, n_{it})$ is household i's composite demand for goods consumption c_{it} and leisure and G measures the disutility from work. Goods consumption bundles varieties j of differentiated goods according to a Dixit-Stiglitz aggregator:

$$c_{it} = \left(\int c_{ijt}^{\frac{\eta_t - 1}{\eta_t}} dj \right)^{\frac{\eta_t}{\eta_t - 1}}.$$

Each of these differentiated goods is offered at price p_{jt}, so that for the aggregate price level, $P_t = \left(\int p_{jt}^{1-\eta_t} dj \right)^{\frac{1}{1-\eta_t}}$, the demand for each of the varieties is given by

$$c_{ijt} = \left(\frac{p_{jt}}{P_t} \right)^{-\eta_t} c_{it}.$$

The disutility of work, $G(h_{it}, n_{it})$, determines a not-quarantined household's labor supply given the aggregate wage rate, w_t, and a labor income tax, τ_t, through the first-order condition:

$$\frac{\partial G(h_{it}, n_{it})}{\partial n_{it}} = (1 - \tau_t) w_t h_{it}. \tag{3}$$

Assuming that G has a constant elasticity w.r.t. n, $\frac{\partial G(h_{it}, n_{it})}{\partial n_{it}} = (1+\gamma) \frac{G(h_{it}, n_{it})}{n_{it}}$ with $\gamma > 0$, we can simplify the expression for the composite consumption good x_{it} making use of the first-order condition (3):

$$x_{it} = c_{it} - G(h_{it}, n_{it}) = c_{it} - \frac{(1-\tau_t) w_t h_{it} n_{it}}{1+\gamma}. \tag{4}$$

[6] The assumption of GHH preferences is mainly motivated by the fact that many estimated DSGE models of business cycles find small aggregate wealth effects in the labor supply; see, e.g., Born and Pfeifer (2014). It also simplifies the numerical analysis somewhat. Unfortunately, it is not feasible to estimate the flexible form of preference of Jaimovich and Rebelo (2009), which also encompasses King et al. (1988) preferences. This would require solving the stationary equilibrium in every likelihood evaluation, which is substantially more time consuming than solving for the dynamics around this equilibrium.

When the Frisch elasticity of labor supply is constant, the disutility of labor is always a constant fraction of labor income. Total effective labor input, $\int(1-Q_{it})n_{it}h_{it}di$, is hence equal to $N(w_t)H_t$ because $H_t := \int(1-Q_{it})h_{it}di$.

2.1.2 Consumption, savings, and portfolio choice

Given this labor income, households optimize intertemporally subject to their budget constraint:

$$\begin{aligned} c_{it} + b_{it+1} + q_t k_{it+1} = b_{it}\tfrac{R(b_{it},R_t^b)}{\pi_t} &+ (q_t + r_t)k_{it} + \mathcal{T}_t \\ &+ (1-\tau_t)[(1-Q_{it})h_{it}w_t N_t + \mathcal{R}(h)Q_{it}h_{it}w_t N_t + \mathbb{I}_{h_{it}\neq 0}\Pi_t^U + \mathbb{I}_{h_{it}=0}\Pi_t^F], \\ k_{it+1} \geq 0, \quad b_{it+1} \geq \underline{B}\ , & \end{aligned}$$

where Π_t^U is union profits, Π_t^F is firm profits, b_{it} is real bond holdings, k_{it} is the amount of illiquid assets, q_t is the price of these assets, r_t is their dividend, $\pi_t = \frac{P_t - P_{t-1}}{P_{t-1}}$ is realized inflation, and R is the nominal interest rate on bonds, which depends on the portfolio position of the household and the central bank's interest rate R_t^b, which is set one period before. All households that do not participate in the capital market ($k_{it+1} = k_{it}$) still obtain dividends and can adjust their bond holdings. Depreciated capital has to be replaced for maintenance, such that the dividend, r_t, is the net return on capital. Holdings of bonds have to be above an exogenous debt limit $\underline{B}$, and holdings of capital have to be non-negative. Households that are quarantined receive a payment replacing a fraction $\mathcal{R}(h)$ of their foregone labor income. In line with the US unemployment insurance scheme the replacement rate depends on the level of foregone income. All households potentially receive a lump-sum transfer $\mathcal{T}_t$.

Households make their savings choices and their portfolio choice between liquid bonds and illiquid capital in light of a capital market friction that renders capital illiquid because participation in the capital market is random and i.i.d. in the sense that only a fraction, λ, of households is selected to be able to adjust their capital holdings in a given period.

What is more, we assume that there is a wasted intermediation cost given by a constant, $\overline{R}$, when households resort to unsecured borrowing. This means, we specify:

$$R(b_{it}, R_t^b) = \begin{cases} R_t^b & \text{if } b_{it} \geq 0 \\ R_t^b + \overline{R} & \text{if } b_{it} < 0. \end{cases}$$

The extra wedge for unsecured borrowing creates a mass of households with zero unsecured credit but with the possibility to borrow, though at a penalty rate.

Since a household's saving decision will be some non-linear function of that household's wealth and productivity, inflation and all other prices will be functions of the joint distribution, Θ_t, of (b, k, h, Q) in t. This makes Θ a state variable of the household's planning problem and this distribution evolves as a result of the economy's reaction to aggregate shocks. For simplicity, we summarize all effects of aggregate state variables, including the distribution of wealth and income, by writing the dynamic planning problem with time-dependent continuation values.

This leaves us with three functions that characterize the household's problem: value function V^a for the case where the household adjusts its capital holdings, the function V^n for the case in which it does not adjust, and the expected envelope value, $\mathbb{E}V$, over both:

$$\begin{aligned}
V_t^a(b,k,h,Q) =& \max_{k',b'_a} u[x(b,b'_a,k,k',h,Q)] + \beta \mathbb{E}_t V_{t+1}(b'_a,k',h',Q') \\
V_t^n(b,k,h,Q) =& \max_{b'_n} u[x(b,b'_n,k,k,h,Q)] + \beta \mathbb{E}_t V_{t+1}(b'_n,k,h',Q') \\
\mathbb{E}_t V_{t+1}(b',k',h',Q') =& \mathbb{E}_t \left[\lambda V^a_{t+1}(b',k',h',Q')\right] + \mathbb{E}_t \left[(1-\lambda) V^n_{t+1}(b',k,h',Q')\right]
\end{aligned} \tag{5}$$

Expectations about the continuation value are taken with respect to all stochastic processes conditional on the current states, including time-varying income risk. Maximization is subject to the corresponding budget constraint.

2.2 Firm Sector

The firm sector consists of four sub-sectors: (a) a labor sector composed of "unions" that differentiate raw labor and labor packers who buy differentiated labor and then sell labor services to intermediate goods producers, (b) intermediate goods producers who hire labor services and rent out capital to produce goods, (c) final goods producers who differentiate intermediate goods and then sell them to goods bundlers, who finally sell them as consumption goods to households, and to (d) capital goods producers, who turn bundled final goods into capital goods.

When profit maximization decisions in the firm sector require intertemporal decisions (i.e. in price and wage setting and in producing capital goods), we assume for tractability that they are delegated to a mass-zero group of households (managers) that are risk neutral and compensated by a share in profits.[7] They do not participate in any asset market and have the same discount factor as all other households. Since managers are a mass-zero group in the economy, their consumption does not show up in any resource constraint and all but

[7]Since we solve the model by a first-order perturbation in aggregate shocks, the assumption of risk-neutrality only serves as a simplification in terms of writing down the model. With a first-order perturbation we have certainty equivalence and fluctuations in stochastic discount factors become irrelevant.

the unions' profits go to the entrepreneur households (whose $h = 0$). Union profits go lump sum to worker households.

2.2.1 Labor Packers and Unions

Worker households sell their labor services to a mass-one continuum of unions indexed by j, each of whom offers a different variety of labor to labor packers who then provide labor services to intermediate goods producers. Labor packers produce final labor services according to the production function

$$N_t = \left(\int \hat{n}_{jt}^{\frac{\zeta-1}{\zeta}} dj \right)^{\frac{\zeta}{\zeta-1}}, \tag{6}$$

out of labor varieties $\hat{n}_{jt}$. Only a fraction H_t of these workers finds themselves able to work, because $(1-H_t)$ is quarantined. Cost minimization by labor packers implies that each variety of labor, each union j, faces a downward-sloping demand curve

$$\hat{n}_{jt} = \left(\frac{W_{jt}}{W_t^F} \right)^{-\zeta} N_t,$$

where W_{jt} is the *nominal* wage set by union j and W_t^F is the nominal wage at which labor packers sell labor services to final goods producers.

Since unions have market power, they pay the households a wage lower than the price at which they sell labor to labor packers. Given the nominal wage W_t at which they buy labor from households and given the *nominal* wage index W_t^F, unions seek to maximize their discounted stream of profits. However, they face a Calvo-type (1983) of adjustment friction with indexation with the probability λ_w to keep wages constant. They therefore maximize

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \lambda_w^t \frac{W_t^F}{P_t} N_t H_t \left\{ \left(\frac{W_{jt}\bar{\pi}_W^t}{W_t^F} - \frac{W_t}{W_t^F} \right) \left(\frac{W_{jt}\bar{\pi}_W^t}{W_t^F} \right)^{-\zeta} \right\}, \tag{7}$$

by setting W_{jt} in period t and keeping it constant except for indexation to $\bar{\pi}_W$, the steady-state wage inflation rate.

Since all unions are symmetric, we focus on a symmetric equilibrium and obtain the linearized wage Phillips curve from the corresponding first-order condition as follows, leaving out all terms irrelevant at a first-order approximation around the stationary equilibrium:

$$\log\left(\tfrac{\pi_t^W}{\bar{\pi}_W}\right) = \beta \mathbb{E}_t \log\left(\tfrac{\pi_{t+1}^W}{\bar{\pi}_W}\right) + \kappa_w \left(\tfrac{w_t}{w_t^F} - \tfrac{1}{\mu^W}\right), \tag{8}$$

with $\pi_t^W := \frac{W_t^F}{W_{t-1}^F} = \frac{w_t^F}{w_{t-1}^F}\pi_t^Y$ being wage inflation, w_t and w_t^F being the respective *real* wages for households and firms, and $\frac{1}{\mu^W} = \frac{\zeta-1}{\zeta}$ being the target mark-down of wages the unions pay to households, W_t, relative to the wages charged to firms, W_t^F and $\kappa_w = \frac{(1-\lambda_w)(1-\lambda_w\beta)}{\lambda_w}$.[8]

2.2.2 Final Goods Producers

Similar to unions, final goods producers differentiate a homogeneous intermediate good and set prices. They face a downward-sloping demand curve

$$y_{jt} = (p_{jt}/P_t)^{-\eta} Y_t$$

for each good j and buy the intermediate good at the nominal price MC_t. As we do for unions, we assume price adjustment frictions à la Calvo (1983) with indexation.

Under this assumption, the firms' managers maximize the present value of real profits given this price adjustment friction, i.e., they maximize:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \lambda_Y^t (1-\tau_t) Y_t \left\{ \left(\frac{p_{jt}\bar{\pi}_Y^t}{P_t} - \frac{MC_t}{P_t} \right) \left(\frac{p_{jt}\bar{\pi}^t}{P_t} \right)^{-\eta} \right\}, \tag{9}$$

with a time constant discount factor.

The corresponding first-order condition for price setting implies a Phillips curve

$$\log\left(\frac{\pi_t}{\bar{\pi}}\right) = \beta \mathbb{E}_t \log\left(\frac{\pi_{t+1}}{\bar{\pi}}\right) + \kappa_Y \left(mc_t - \tfrac{1}{\mu^Y} \right), \tag{10}$$

where we again dropped all terms irrelevant for a first-order approximation and have $\kappa_Y = \frac{(1-\lambda_Y)(1-\lambda_Y\beta)}{\lambda_Y}$. Here, π_t is the gross inflation rate of final goods, $\pi_t := \frac{P_t}{P_{t-1}}$, $mc_t := \frac{MC_t}{P_t}$ is the real marginal costs, $\bar{\pi}$ is steady-state inflation and $\mu^Y = \frac{\eta}{\eta-1}$ is the target markup.

2.2.3 Intermediate Goods Producers

Intermediate goods are produced with a constant returns to scale production function of *not quarantined* production:

$$Y_t^F = N_t^\alpha (u_t K_t)^{(1-\alpha)},$$

[8] Including the first-order irrelevant terms, the Phillips curve reads

$$\log\left(\frac{\pi_t^W}{\bar{\pi}^W}\right) = \beta \mathbb{E}_t \left[\log\left(\frac{\pi_{t+1}^W}{\bar{\pi}^W}\right) \frac{1-\tau_{t+1}}{1-\tau_t} \frac{W_{t+1}^F P_t}{W_t^F P_{t+1}} \frac{N_{t+1} H_{t+1}}{N_t H_t} \right] + \kappa_w \left(\frac{w_t}{w_t^F} - \frac{1}{\mu^W} \right)$$

where τ_t is the average income tax.

where $u_t K_t$ is the effective capital stock taking into account utilization u_t, i.e., the intensity with which the existing capital stock is used. Using capital with an intensity higher than normal results in increased depreciation of capital according to $\delta(u_t) = \delta_0 + \delta_1 (u_t - 1) + \delta_2/2 (u_t - 1)^2$, which, assuming $\delta_1, \delta_2 > 0$, is an increasing and convex function of utilization. Without loss of generality, capital utilization in the steady state is normalized to 1, so that δ_0 denotes the steady-state depreciation rate of capital goods.

Let mc_t be the relative price at which the intermediate good is sold to final goods producers. The intermediate goods producer maximizes profits,

$$mc_t Y_t^F - w_t^F N_t - [r_t + q_t \delta(u_t)] K_t,$$

where r_t^F and q_t are the rental rate of firms and the (producer) price of capital goods respectively. The intermediate goods producer operates in perfectly competitive markets, such that the real wage and the user costs of capital are given by the marginal products of labor and effective capital:

$$w_t^F = \alpha mc_t \left(\frac{u_t K_t}{N_t} \right)^{1-\alpha}, \tag{11}$$

$$r_t^F + q_t \delta(u_t) = u_t (1-\alpha) mc_t \left(\frac{N_t}{u_t K_t} \right)^{\alpha}. \tag{12}$$

We assume that utilization is decided by the owners of the capital goods, taking the aggregate supply of capital services as given. The optimality condition for utilization is given by

$$q_t [\delta_1 + \delta_2 (u_t - 1)] = (1-\alpha) mc_t \left(\frac{N_t}{u_t K_t} \right)^{\alpha}, \tag{13}$$

i.e., capital owners increase utilization until the marginal maintenance costs equal the marginal product of capital services.

Total production $Y_t = H_t Y_t^F$ is scaled by H_t because we assume that the same fraction of capital is quarantined as are workers, e.g. when stores or plants temporarily need to close. However, this does not show up in any first order condition of active production units – the easiest way to think about this is that production units make their factor demand decisions and only afterwards find out whether they can produce. If the production unit is quarantined, workers receive zero wages and quarantined capital receives zero user cost compensation but is still depreciated at rate $\delta_0 - \delta_1 + \delta_2/2$. This means capital owners receive as average dividend payment on their capital

$$r_t = r_t^F H_t - (1 - H_t) \delta(0). \tag{14}$$

2.2.4 Capital Goods Producers

Capital goods producers take the relative price of capital goods, q_t, as given in deciding about their output, i.e., they maximize

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t I_t \left\{ q_t \left[1 - \frac{\phi}{2} \left(\log \frac{I_t}{I_{t-1}} \right)^2 \right] - 1 \right\}. \tag{15}$$

Optimality of the capital goods production requires (again dropping all terms irrelevant up to first order)

$$q_t \left[1 - \phi \log \frac{I_t}{I_{t-1}} \right] = 1 - \beta \mathbb{E}_t \left[q_{t+1} \phi \log \left(\frac{I_{t+1}}{I_t} \right) \right], \tag{16}$$

and each capital goods producer will adjust its production until (16) is fulfilled.

Since all capital goods producers are symmetric, we obtain as the law of motion for aggregate capital

$$K_t - (1 - \delta(u_t)) K_{t-1} = \left[1 - \frac{\phi}{2} \left(\log \frac{I_t}{I_{t-1}} \right)^2 \right] I_t \ . \tag{17}$$

The functional form assumption implies that investment adjustment costs are minimized and equal to 0 in the steady state.

2.3 Government

The government operates a monetary and a fiscal authority. The monetary authority controls the nominal interest rate on liquid assets, while the fiscal authority issues government bonds to finance deficits, chooses both the average tax rate in the economy as well as tax progressivity, and adjusts expenditures to stabilize debt in the long run and output in the short run.

We assume that monetary policy sets the nominal interest rate following a Taylor-type (1993) rule with interest rate smoothing:

$$\frac{R^b_{t+1}}{\bar{R}^b} = \left(\frac{R^b_t}{\bar{R}^b} \right)^{\rho_R} \left(\frac{\pi_t}{\bar{\pi}} \right)^{(1-\rho_R)\theta_\pi} \left(\frac{Y_t}{Y^*_t} \right)^{(1-\rho_R)\theta_Y} . \tag{18}$$

The coefficient $\bar{R}^b \geq 0$ determines the nominal interest rate in the steady state. The coefficients $\theta_\pi, \theta_Y \geq 0$ govern the extent to which the central bank attempts to stabilize inflation and the output gap, where the gap, $\frac{Y_t}{Y^*_t}$, is defined relative to what output would be at stationary equilibrium markups, Y_t^*. $\rho_R \geq 0$ captures interest rate smoothing.

The government follows a simple rule for government spending that reacts to government debt:

$$\frac{G_t}{\bar{G}} = \left(\frac{G_t}{\bar{G}}\right)^{\rho_G} \left(\frac{B_t}{\bar{B}}\right)^{(1-\rho_G)\gamma_B^G} \quad , \tag{19}$$

where γ_B^G determines the degree of debt stabilization.

The government sets the tax rate in the economy according to a similar rule:

$$\frac{\tau_t}{\bar{\tau}} = \left(\frac{\tau_t}{\bar{\tau}}\right)^{\rho_\tau} \left(\frac{B_t}{\bar{B}}\right)^{(1-\rho_\tau)\gamma_B^\tau} \quad . \tag{20}$$

Total taxes T_t are then $T_t = \tau_t \left(w_t n_{it} h_{it} + \mathbb{I}_{h_{it} \neq 0} \Pi_t^U + \mathbb{I}_{h_{it}=0} \Pi_t^F\right)$ and the government budget constraint determines government debt residually:

$$B_{t+1} = R_t^b / \pi_t B_t + G_t - T_t + \mathcal{T}_t + w_t N_t (1 - H_t) \int \mathcal{R}(h_i) h_i di. \tag{21}$$

2.4 Goods, Bonds, Capital, and Labor Market Clearing

The labor market clears at the competitive wage given in (11). The bond market clears whenever the following equation holds:

$$B_{t+1} = B^d(R_t^b, p_t^{in}, r_t, q_t, \Pi_t^F, \Pi_t^U, w_t, \pi_t, \tau_t, \Theta_t, \mathbb{E}_t V_{t+1}) := \mathbb{E}_t \left[\lambda b_{a,t}^* + (1-\lambda) b_{n,t}^*\right], \tag{22}$$

where $b_{a,t}^*, b_{n,t}^*$ are functions of the states (b, k, h, Q), and depend on how households value asset holdings in the future, $V_{t+1}(b, k, h, Q)$, and the current set of prices (and tax rates) $(R_t^b, p_t^{in}, r_t, q_t, \Pi_t^F, \Pi_t^U, w_t, \pi_t, \tau_t)$. Future prices do not show up because we can express the value functions such that they summarize all relevant information on the expected future price paths. Expectations in the right-hand-side expression are taken w.r.t. the distribution $\Theta_t(b, k, h, Q)$. Equilibrium requires the total *net* amount of bonds the household sector demands, B^d, to equal the supply of government bonds. In gross terms there are more liquid assets in circulation as some households borrow up to $\underline{B}$.

Last, the market for capital has to clear:

$$K_{t+1} \quad = \quad K^d(R_t^b, p_t^{in}, r_t, q_t, \Pi_t^F, \Pi_t^U, w_t, \pi_t, \tau_t, \Theta_t, \mathbb{E}_t V_{t+1}) := \mathbb{E}_t[\lambda k_t{}^* + (1-\lambda)k] \ , \tag{23}$$

where the first equation stems from competition in the production of capital goods, and the second equation defines the aggregate supply of funds from households – both those that trade capital, λk_t^*, and those that do not, $(1-\lambda)k$. Again k_t^* is a function of the current prices and continuation values. The goods market then clears due to Walras' law, whenever labor, bonds, and capital markets clear.

2.5 Equilibrium

A *sequential equilibrium with recursive planning* in our model is a sequence of policy functions $\{x^*_{a,t}, x^*_{n,t}, b^*_{a,t}, b^*_{n,t}, k^*_t\}$, a sequence of value functions $\{V^a_t, V^n_t\}$, a sequence of prices $\{w_t, w^F_t, \Pi^F_t, \Pi^U_t, q_t, r_t, R^b_t, \pi_t, \pi^W_t, \tau_t\}$, a sequence of stochastic states p^{in}_t and quarantine shocks ϵ^p_t, aggregate capital and labor supplies $\{K_t, N_t\}$, distributions Θ_t over individual asset holdings and productivity, and expectations Γ for the distribution of future prices, such that

1. Given the functional $\mathbb{E}_t V_{t+1}$ for the continuation value and period-t prices, policy functions $\{x^*_{a,t}, x^*_{n,t}, b^*_{a,t}, b^*_{n,t}, k^*_t\}$ solve the households' planning problem, and given the policy functions $\{x^*_{a,t}, x^*_{n,t}, b^*_{a,t}, b^*_{n,t}, k^*_t\}$, prices, and the value functions $\{V^a_t, V^n_t\}$ are a solution to the Bellman equation (5).

2. Distributions of wealth and income evolve according to households' policy functions.

3. The labor, the final goods, the bond, the capital, and the intermediate goods markets clear in every period, interest rates on bonds are set according to the central bank's Taylor rule, fiscal policies are set according to the fiscal rules, and stochastic processes evolve according to their law of motion.

4. Expectations are model consistent.

3 Parameterization

We solve the model by perturbation methods (Bayer and Luetticke, 2018) and parameterize the model in the following way. First, we calibrate or fix all parameters that affect the steady state of the model. Second, we take the parameters that govern the dynamics of the model from Bayer et al. (2020) who estimate a closely related variant of our model using Bayesian full-information methods.

We fix a number of parameters either following the literature or targeting steady-state ratios; see Table 2 (all at quarterly frequency of the model). For the household side, we set the relative risk aversion to 4, which is common in the incomplete markets literature; see Kaplan et al. (2018). We set the Frisch elasticity to 0.5; see Chetty et al. (2011). We take estimates for idiosyncratic income risk (after tax and transfers) from Storesletten et al. (2004), $\rho_h = 0.98$ and $\bar{\sigma}_h = 0.12$. Guvenen et al. (2014) provide the probability that a

Table 1: Calibrated parameters

Targets	Model	Data	Source	Parameter
Mean illiquid assets (K/Y)	11.44	11.44	NIPA	Discount factor
Mean liquidity (B/Y)	2.88	2.88	FRED	Port. adj. probability
Top10 wealth share	0.67	0.67	WID	Fraction of entrepreneurs
Fraction borrowers	0.16	0.16	SCF	Borrowing penalty

Table 2: External/calibrated parameters (quarterly frequency)

Parameter	Value	Description	Target
Households			
β	0.981	Discount factor	see Table 1
ξ	4	Relative risk aversion	Kaplan et al. (2018)
γ	2	Inverse of Frisch elasticity	Chetty et al. (2011)
λ	0.1	Portfolio adj. prob.	see Table 1
ρ_h	0.98	Persistence labor income	Storesletten et al. (2004)
σ_h	0.12	STD labor income	Storesletten et al. (2004)
ζ	1/5000	Trans. prob. from W. to E.	see Table 1
ι	1/16	Trans. prob. from E. to W.	Guvenen et al. (2014)
p_{ss}^{in}	1/5000	Trans. prob. into Q	
p^{out}	0.5	Trans. prob. out of Q	
$\bar{R}$	1.95%	Borrowing penalty	see Table 1
Firms			
α	0.68	Share of labor	62% labor income
δ_0	1.75%	Depreciation rate	Standard value
$\bar{\eta}$	11	Elasticity of substitution	Price markup 10%
$\bar{\zeta}$	11	Elasticity of substitution	Wage markup 10%
Government			
$\bar{\tau}^L$	0.2	Tax rate level	$G/Y = 15\%$
$\bar{R}^b$	1.004	Nominal rate	1.6% p.a.
$\bar{\pi}$	1.00	Inflation	0% p.a.

household will fall out of the top 1% of the income distribution in a given year, which we take as the transition probability from entrepreneur to worker, $\iota = 1/16$.

Table 1 summarizes the calibration of the remaining household parameters. We match 4 targets: 1) average illiquid assets (K/Y=11.44), 2) average liquidity (B/Y=2.88), 3) the fraction of borrowers, 16%, and 4) the average top 10% share of wealth, which is 67%. This yields a discount factor of 0.981, a portfolio adjustment probability of 10%, borrowing

Table 3: Aggregate frictions and policy rules

Real frictions				Nominal frictions			
δ_s	1.483	ϕ	0.233	κ	0.101	κ_w	0.128
Monetary policy							
ρ_R	0.800	θ_π	2.603	θ_y	0.000		
Government spending				Taxes			
ρ_G	0.900	γ_B^G	-0.100	ρ_τ	0.900	γ_B^τ	-0.100

Notes: Parameter values for real and nominal frictions and the Taylor rule (except θ_y, see text) based on the estimated HANK model in Bayer et al. (2020). Tax and government spending rules parameterized to ensure debt sustainability.

penalty of 1.95% quarterly (given a borrowing limit of two times average income), and a transition probability from worker to entrepreneur of 1/5000.[9]

We model the Q-state as a rare disaster state with almost zero mass in steady state. In that state, households receive government transfers that replace 40% of their after-tax labor income capped at 50% of median income. This mimics the generosity of the US unemployment insurance before the CARES act. The exit probability from the Q-state is 50% per quarter. In our experiments in the next section, we will increase p_t^{in}, the probability to enter Q, for one quarter.

For the firm side, we set the labor share in production, α, to 68% to match a labor income share of 62%, which corresponds to the average BLS labor share measure over 1954-2015. The depreciation rate is 1.75% per quarter. An elasticity of substitution between differentiated goods of 11 yields a markup of 10%. The elasticity of substitution between labor varieties is also set to 11, yielding a wage markup of 10%. Both are standard values in the literature.

The government taxes labor and profit income. The level of taxes in steady state, τ^L, is set to clear the government budget constraint that corresponds to a government share of $G/Y = 15\%$. The policy rate is set to an annualized rate of 1.6%. This corresponds to the average federal funds rate in real terms over 1954-2015. We set steady-state inflation to zero as we have assumed indexation to the steady-state inflation rate in the Phillips curves.[10]

The remaining parameters that only matter for the dynamics of the model, i.e., the aggregate frictions, are set to the values estimated via Bayesian methods in Bayer et al. (2020);

[9]Detailed data sources can be found in Appendix A.

[10]We subtract from both the liquid and illiquid return 1.6% annual to account for the annual growth rate of the US economy over 1954-2015.

see Table 3. These parameter estimates are broadly in line with the representative-agent literature, with the exception of the real frictions, which are up to one order of magnitude smaller than the typical representative-agent model estimates. In particular, investment adjustment costs are substantially smaller. This reflects the portfolio adjustment costs at the household level that generate inertia in aggregate investment. The parameter values for nominal frictions are standard, with price and wage stickiness being less than 4 quarters on average. The estimated Taylor rule coefficients on inflation, 2.6 and interest rate inertia 0.8 are in line with the literature. The Taylor rule coefficient on output needs some discussion, as it is not clear in the current situation whether the Fed's output target Y^* takes the lock-down into account. Given that the Fed has some room for policy discretion in this, we avoid taking a stand and set the coefficient to zero. The fiscal rules that govern spending and taxes are parameterized to ensure that public debt is slowly brought back to steady state after a debt build-up.

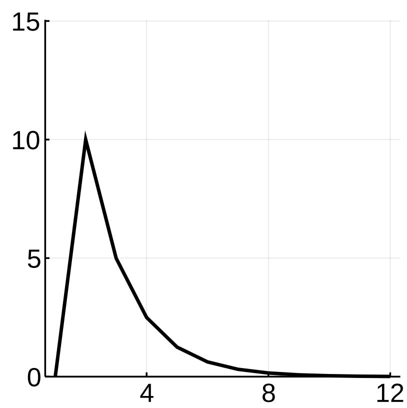
4 Results

In this section, we present our results based on model simulations. In a first step, we develop our baseline scenario for which we expose the estimated model to the quarantine shock (Q-shock). Given this scenario we assess, in a second step, how the transfer component of the CARES act plays out. Third, we zoom in on the design of the transfer payments in order to shed some light into the transmission mechanism. And last, we report results regarding the distributional effects of the Q-shock and the transfer component of the Coronavirus stimulus.

4.1 The Quarantine Shock

First, to set the stage, we develop a baseline scenario for the lockdown. We assume that households face a 10% chance of becoming quarantined. While this represents a strong increase of income risk, we consider it a conservative modelling choice in light of the outlook for near term employment as of March 2020. Below we also report results for a more severe shock in which case we assume that 30% of the labor force are put under quarantine. Figure 2 shows the quarantine shock. Here and in what follows the horizontal axis measures time in quarters, while the vertical axis measures the deviation from steady state. In the initial period, say, in 2020Q1, nobody is yet put under quarantine, but the risk of becoming quarantined in 2020Q2 increases to 10% (from effectively zero). Figure 2 plots the fraction of the labor force that is actually quarantined. In 2020Q2, quarantine peaks with 10% of the labor force being quarantined. The quarantine state is short lived with an exit probability of

Figure 2: Quarantine shock: Fraction of quarantined households



Notes: Impulse responses to the quarantine shock. X-axis: Quarters.

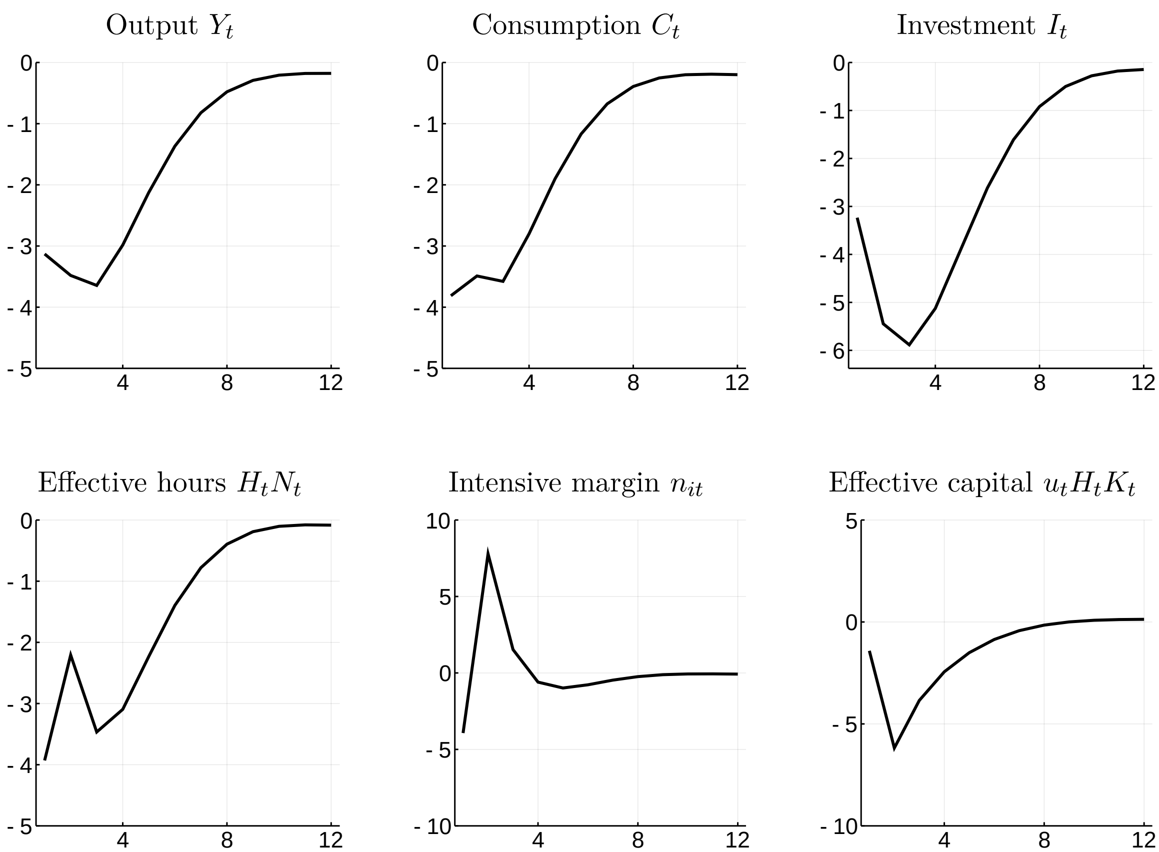
50% each quarter. Four quarters after it has started, only about 2.5% of the labor force are still under quarantine. While actual quarantine measures are likely to be even shorter, the income loss from quarantine measures may extend somewhat beyond the quarantine state. And the income loss is what matters for our analysis.

The quarantine shock reduces the effective labor force and the effective capital stock in the economy and thus lowers its production potential. However, it also adversely impacts aggregate demand to the extent that it is anticipated and that it increases idiosyncratic income risk. Households try to self-insure against this risk by increasing their liquid savings.[11]

Figure 3 shows the response of aggregate quantities to the Q-shock. Although quarantine starts in 2020Q2 only, output, consumption, and investment already decline strongly due the immediate negative impact on expectations—the anticipation brings forward in time the adverse impact of the shock. In each panel we measure the deviation of a variable in percentage deviations from steady state. On impact, that is, as soon as the shock becomes known, consumption (upper row, middle panel) drops by 4%, investment (upper row, right panel) collapses as well. As a result, output (upper row, left panel) declines by about 3%. At this point, hours worked (lower row, left panel) drop sharply, even though the labor force has not been decimated by quarantine, yet. In fact, this is a response to the collapse in aggregate demand and comes about through a reduction of hours worked per person. We show the adjustment of the intensive margin in the lower-middle panel of the figure. On

[11]In terms of aggregate dynamics this looks like a “risk premium shock”, a driving force of business cycles in standard macro models (see, for instance, Smets and Wouters, 2007).

Figure 3: Quarantine shock: Aggregate quantities



Notes: Impulse responses to the quarantine shock. Y-axis: Percent deviation from steady state. X-axis: Quarters.

impact it declines sharply. The utilization of capital, that is, the effective capital stock, (lower-right panel) declines likewise.

Over time, the nature of the adjustment changes fundamentally. Investment and output decline further, but now this decline is due to the quarantine which becomes effective in the second period. In fact, some of the reduction of the labor force is now compensated by an increase of hours worked by those people which are still employed.[12] This does not, however, fully compensate for the shortfall of labor supply: Effective hours remain depressed relative to the steady-state level. As a result, the contraction gets more severe. We observe

[12]Practical examples would be workers in the health sector, in delivery services, in grocery stores and supermarkets because cooking at home replaces eating out, in the production of medical equipment or IT equipment for remote work, etc.

a maximum output effect of 3.5% in the third period after impact, that is, in 2020Q3. At this point investment has declined by about 6% relative to its steady-state level. As a result the Q-shock is having a lasting effect: even though the quarantine itself is fairly short-lived, it takes more than 3 years for output to recover.

Overall, the recession triggered by the Q-shock is relatively mild—not compared to a garden-variety recession—but compared to household expectations regarding the impact of the COVID-19 pandemic (Dietrich et al., 2020). Note, however, that the assumptions underlying our Q-shock scenario for the baseline are relatively benign. As we consider a more adverse scenario below for which we assume that 30% of the labor force is put under quarantine, the effect of the shock on the economy also increases by a factor of 3 compared to the baseline.[13]

4.2 The Coronavirus Stimulus

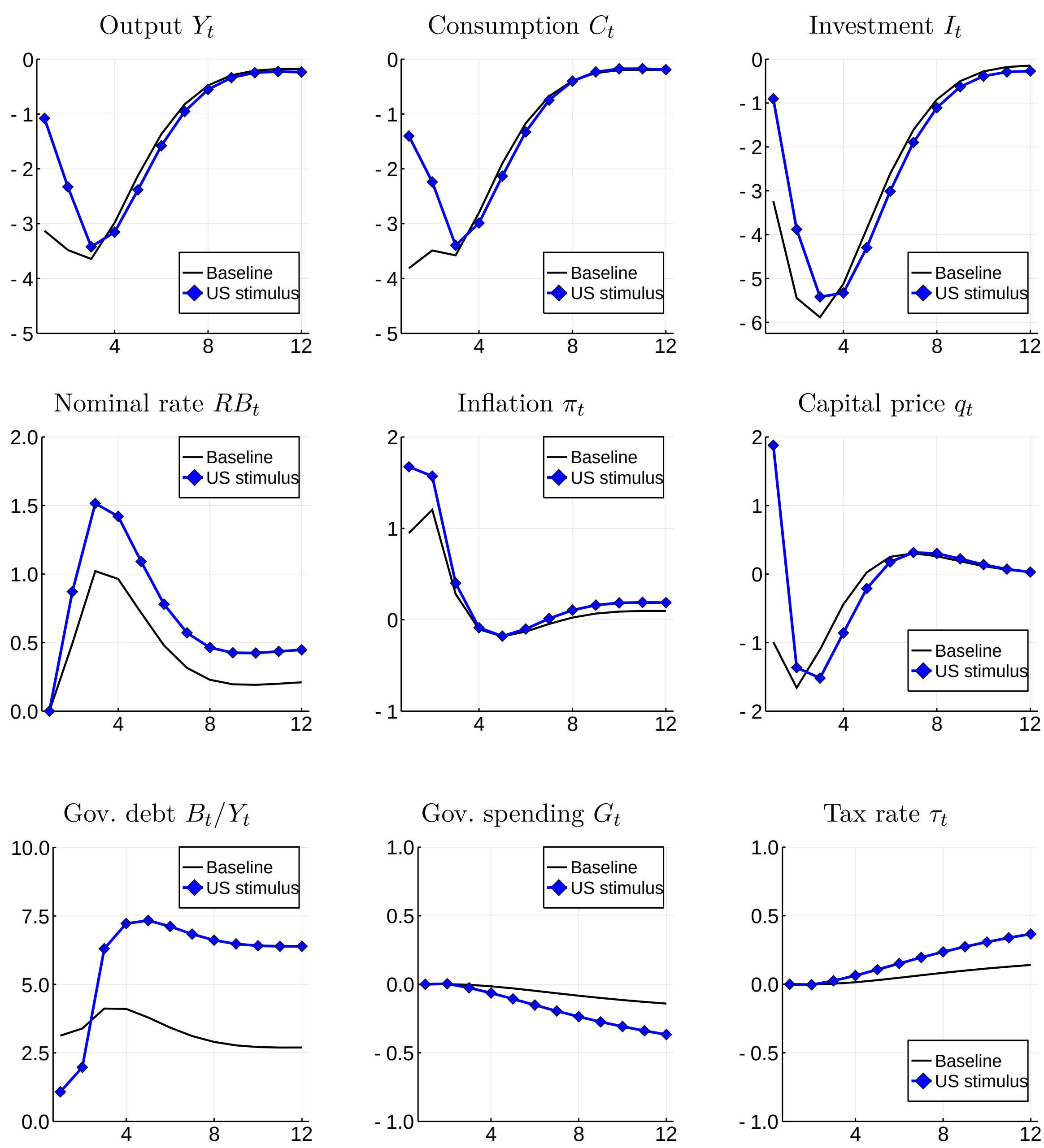
The CARES act provides for substantial transfer payments to households in response to the economic fallout from the pandemic. We are now in position to quantify its effect on the aggregate economy. In doing so, we seek to account for the circumstances under which the transfer payments take place, namely in an economy that has been exposed to the Q-shock. As we will see shortly, this matters for the effects of the stimulus package.

The reason is that part of the transfers are paid conditional on the recipient being unemployed. In this way, the transfer payment partly undoes the increase of income risk due to the Q-shock. In our model simulations, we capture this conditional transfer by paying a lump-sum transfer equivalent to $600 per week to those households that lose income because they are put under quarantine. For the baseline, we assume unemployment to rise to 10%. In this case the CARES-act transfer payments to the unemployed amounts to $250 billion, which happens to be sum currently earmarked under the CARES act for this purpose. Importantly, by being conditional on being unemployed, the transfer operates like an unemployment insurance, thereby reducing the costs associated with the quarantine state from an ex-ante perspective.

The other transfer component under the CARES act, instead, is basically unconditional: a one-time payment of $1,200 to any adult in the U.S. population, except for households in the top 10% of the income distribution. This form of conditionality is moderate and for the ease of exposition we refer to this transfer as "unconditional transfer". We model these transfers as lump-sum payments to households, where the unconditional transfer is a one-off event in period 2 (2020Q2). Consistent with the actual provisions in the CARES act, we

[13] See Appendix B.

Figure 4: Adjustment to the Q-shock: w and w/o stimulus



Notes: Y-axis: All quantities are reported in percent deviations from steady state. All prices are reported in annualized percentage points from steady state. X-axis: Quarters.

exclude households above the 90th percentile of the income distribution from the transfer payment.

Figure 4 contrasts the adjustment to the Q-shock with and without the transfer payments under the CARES act. The black solid lines serve as a benchmark: they reproduce the results shown in Figure 3 above, namely the adjustment that would take place in the absence of the CARES-act transfer. The blue dashed lines show the response of the economy to the same shock under the assumption that the transfers are put in place. They clearly make a big difference in the short run. With transfers to households, the decline in consumption in the short run is reduced by more than half. On impact consumption drops only by 1.5% rather than by 4%, and similarly in the second period when most of the transfers are actually paid out. The sizable transfer to households counteracts the effect of the recessionary Q-shock by stimulating demand and increasing insurance. From 2020Q3 onward, however, the path of consumption basically follows the baseline. Hence, the effect of the stimulus is limited to the first two quarters after impact. This is perhaps unsurprising, given that it is rather short-lived. During 2020Q1-Q2, we observe that output drops by 50% less as a result of the transfer payments.

The transfer payment is no free lunch: it raises the debt-to-GDP ratio persistently by about 5 percentage points. The adjustment of the debt-to-GDP ratio with and without transfers is shown in the lower-left panel of Figure 4. Without the transfers under the CARES act, the debt ratio increases by about 2-3 percentage points because of higher outlays under the conventional unemployment insurance scheme. On impact, the debt ratio increases less under the stimulus because it generates additional tax revenues by boosting economic activity ahead of the actual disbursement of the transfer payment. In the second period the stimulus bill comes due and at the beginning of the third period debt exceeds its counterfactual no-stimulus level by some 5 percentage points. This difference is rather lasting because we assume that debt is paid back over many years—by gradually increasing taxes and reducing government spending in equal proportions.

The middle row of Figure 4 shows the response of prices and returns (in annualized percentage points). The price of capital immediately reacts and falls by 1% in 2020Q1 when quarantine is announced. The Q-shock, by restricting the supply of labor and capital, increases marginal costs and hence inflation. Inflation peaks in 2020Q2 with an increase of 1 percentage points, absent the transfer payment. The transfer adds to the inflationary impact, pushing up the inflation response to close to 2 percentage points in 2020Q2. Higher inflation, in turn, induces monetary policy to raise nominal rates sharply (middle-left panel) under our interest rate rule. We consider an alternative, more accommodating specification for monetary policy below.

4.3 The Transfer Multiplier

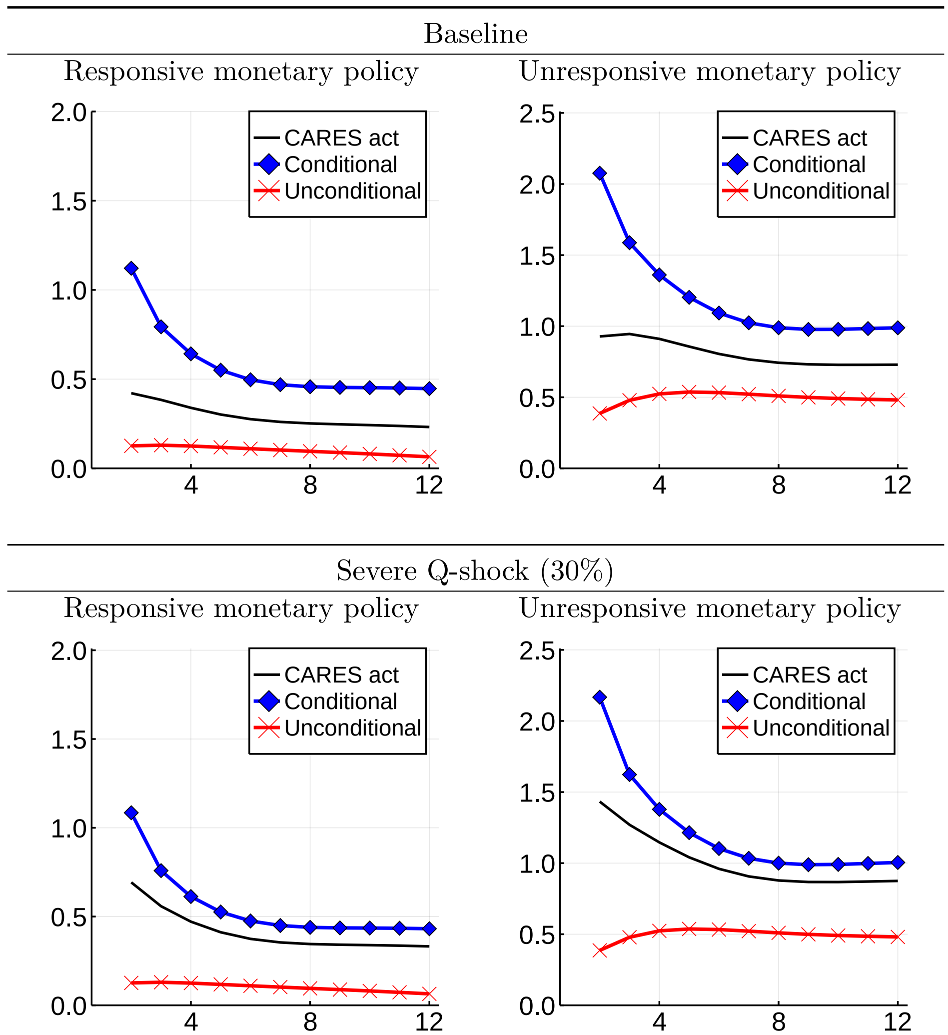
We finally turn to the question that motivates our analysis: How large is the transfer multiplier? As our discussion above made clear, the answer depends crucially on whether the transfer is conditional or unconditional. The upper part of Figure 5 presents transfer multipliers for two alternative specifications of monetary policy. In the left panel, we assume the conventional monetary policy rule as parameterized in Section 3. For the results shown in the right panel, we assume that monetary policy is less responsive than usual; we discuss this scenario below. In all instances, we show the cumulative multiplier: the cumulative output change in all periods up to horizon k that are due to the transfer, divided by the cumulative transfer payments up to the same horizon. In the figure, we show the cumulative transfer multiplier from period 2 onward because no transfers are disbursed in the first period.

The (black) solid line without markers captures the overall transfer multiplier of the CARES act. In period 2, that is, in 2020Q2, the cumulative multiplier is 0.42. This means that for every dollar that is disbursed to households in 2020Q2, total income in the first half of 2020 increases by 42 cents on average. This within the range reported in the existing literature, albeit at the higher end (Coenen et al., 2012; McKay and Reis, 2016; Giambattista and Pennings, 2017). To shed more light on this result, we decompose the multiplier: the (blue) line with diamonds and the (red) line with crosses in Figure 5 represent the multiplier for the conditional and the unconditional transfer under the CARES act. Here we obtain values of 0.13 and 1.12 for 2020Q2. The overall multiplier is a weighted average of the two.

The conditional transfer multiplier is about 8 times the unconditional transfer multiplier for three reasons. First, the conditional transfer is directed to the unemployed which have a high marginal propensity to consume. Second, this matters already in the impact period. As shown by Auclert et al. (2018), in HANK models such as ours, anticipated income changes impact current spending via the "intertemporal marginal propensity to consume". Specifically, households that operate near their liquidity constraint may raise expenditures in response to an expected income increase in the near future. This effect is not present in TANK models since there the borrowing constraint of non-optimizing households is always binding. Third, the conditional transfer boosts aggregate demand already in period 1 because it reduces income risk. The cumulative multiplier captures this effect since it measures the total effect on output since the transfer is announced in the first period.

To illustrate this in more detail, Figure 6 shows the responses of aggregate quantities to the quarantine shock for the baseline and for both transfer payments. The unconditional transfer, worth 5% of quarterly GDP, is paid out lump-sum to all households in quarter 2 (plotted in red with crosses). This policy stabilizes aggregate consumption by only so much. However, also in this case we observe the strongest impact in the first period, that is when

Figure 5: Cumulative transfer multipliers

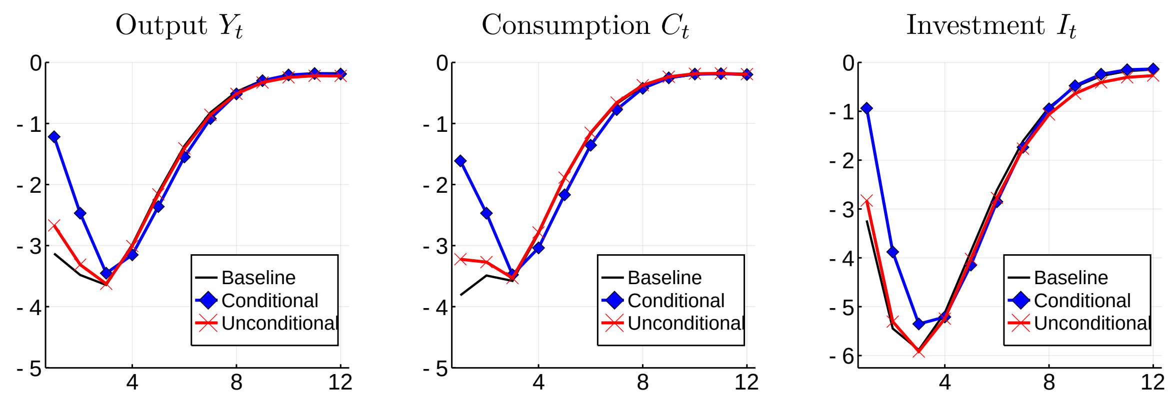


Notes: Cumulative multiplier is computed as $\sum_{j=1}^{k} y_i / \sum_{j=1}^{k} t_i$, where y_i is the deviation of output from baseline, t_i is the transfer payment (both measured in percentage points of steady-state output), and k is the time since announcement in period 2020Q1, measured along the horizontal axis. We report multipliers from period $t = 2$ onward, since transfers are zero in the first period.

the transfer is announced, rather than when it is coming online. The conditional transfer, while having much larger effects, exerts its maximum impact also in period 1. In this case, it is particularly sizable for the reasons given above.

Monetary policy plays a key role for the transmission of fiscal policy measures. This point has been emphasized by a number of contributions which have mostly focused on government

Figure 6: Aggregate quantities: Conditional vs unconditional transfers



Notes: Y-axis: Percent deviation from steady state. X-axis: Quarters.

purchases (Christiano et al., 2011; Leeper et al., 2017; Woodford, 2011). We now zoom in on how monetary policy matters for the effect of the transfers under the CARES act. Specifically, we compare the results for the baseline to an alternative specification for which we assume that monetary policy is less responsive to inflation. We do so by introducing substantial interest rate smoothing: we set $\rho_R = 0.99$ in the interest rate rule above and refer to this case as "unresponsive" monetary policy.[14]

We report the cumulative multiplier under the unresponsive monetary policy in the upper right panel of Figure 5. We find that relative to the baseline results shown in the left panel, multipliers are shifted upwards. We find values for the cumulative multiplier in 2020Q2 that are now about unity (overall), 2.1 (conditional transfers) and 0.4 (unconditional transfers). This is because monetary policy now raises the interest rate less in the short run as the inflationary pressure of the fiscal stimulus mounts. Real interest rates increase less and this amplifies the effect of the fiscal stimulus. At the time of writing, it is unclear to what extent central banks will be ready to accommodate the inflationary impulse of the stimulus or not.

Likewise there is considerably uncertainty about the size of the contraction due the COVID-19 pandemic. Our baseline scenario is conservative as we assume that only 10% of the labor force is quarantined. We now report results for a more extreme scenario in which the lockdown shuts off 30% of the labor force. While this scenario is extreme, it cannot be ruled out at the time of writing, see also the discussion in the Section 1. We show results

[14] We leave a full-fledged analysis of the zero-lower-bound constraint or a passive monetary policy regime for further research.

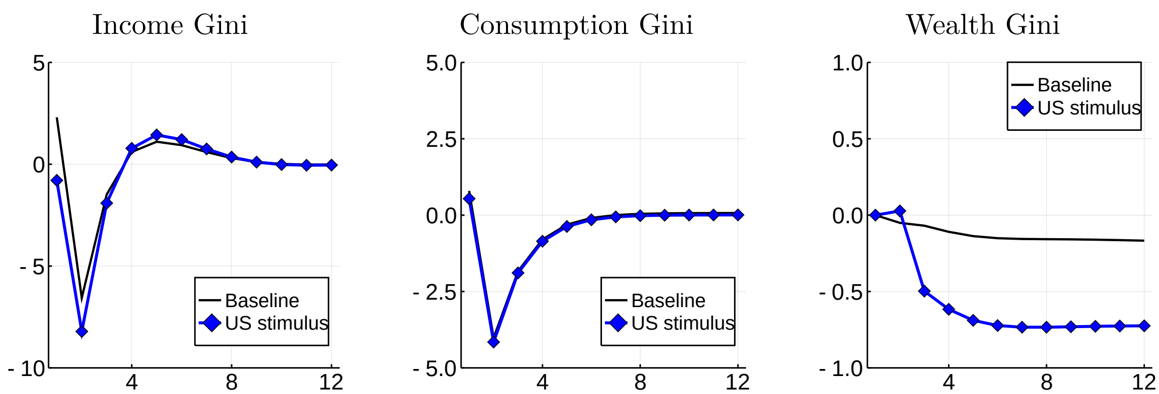
for this scenario in Figure 9 in the Appendix. The figure is organized in the same way as Figure 4 above and the results are comparable, but scaled up relative to the smaller Q-shock by factor 3. Note, however, that in this case the conditional transfer is much larger than in our baseline, too. It amounts now to some $750 billion, rather than $250 billion in the baseline. Hence, if this more adverse scenario were to materialize, the Coronavirus stimulus would necessarily increase in size. We show the effect on the multipliers in the lower part of Figure 5. The key difference relative to the baseline scenario is that only the multiplier for the total transfers under the CARES act increase, simply because the relative weight of conditional transfers goes up.

4.4 Distributional Effects

Since the Q-shock reduces the supply of production factors drastically, it drives up marginal costs and thus – despite our estimated Phillips curve being relatively flat – it lowers markups considerably. This has a strong impact on the income distribution and especially the income richest households, the entrepreneurs, lose heavily from the Q-shock. What is more, also returns to capital fall drastically and more than wage income because the quarantined capital still depreciates. In addition, initially low real returns on liquid assets also hit those rich in these assets.

As a consequence of all of this, consumption and income inequality, measured by the Gini coefficient decline after the Q-shock, see Figure 7. The stimulus package amplifies the movements in marginal costs further by stabilizing demand. The stimulus also is highly progressive in its distributional consequences such that the income Gini falls even further. Since real interest rates on liquid assets rise further under the stimulus package because government debt shows a stronger upward movement, the wealth Gini falls stronger under the stimulus package than without (cf. Bayer et al., 2020). But it also falls under the baseline as a result of the very rich entrepreneur households strongly losing income during the crisis.

Figure 7: Distributional effects



Notes: Y-axis: Quarterly percent deviation from steady state. X-axis: Quarters.

5 Conclusion

We analyze the economic effects of a *successfull* suppression strategy of COVID-19. Such strategy involves shutting down a substantial fraction of the economy where and whenever there is a local outbreak. We capture this strategy in our model by introducing a quarantine state for households that reduces the effective amount of labor and capital in aggregate production. Under the assumption that 10% of households are in quarantine in 2020Q2, we show that output declines by 3.5% in 2020. The recession follows from depressed supply but also from depressed demand because quarantine increases household income risk.

Given this scenario, we show that the transfer component of the CARES act stabilizes output and consumption by almost 50% in 2020. There is already a substantial effect on output and consumption in 2020Q1 by affecting households' expectations of the costs of quarantine. We estimate a transfer multipliers of the CARES act between 0.4 and 1.2 in 2020, depending on the responsiveness of monetary policy to inflation and the share of transfers to unemployed households. Key for this high multiplier are transfers directly paid to the unemployed/quarantined households because these transfers are targeted to high MPC households and reduce income risk ex ante.

References

Auclert, A., Rognlie, M., and Straub, L. (2018). The intertemporal Keynesian Cross. NBER Working Papers 25020.

Bayer, C., Born, B., and Luetticke, R. (2020). Shocks, frictions, and inequality in us business cycles. *CEPR Discussion Paper No. DP14364*.

Bayer, C. and Luetticke, R. (2018). Solving heterogeneous agent models in discrete time with many idiosyncratic states by perturbation methods. CEPR Discussion Papers 13071.

Bayer, C., Luetticke, R., Pham-Dao, L., and Tjaden, V. (2019). Precautionary savings, illiquid assets, and the aggregate consequences of shocks to household income risk. *Econometrica*, 87(1):255–290.

Berger, D., Herkenhoff, K., and Mongey, S. (2020). An SEIR infectious disease model with testing and conditional quarantine. NBER Working Paper 26901.

Born, B. and Pfeifer, J. (2014). Policy risk and the business cycle. *Journal of Monetary Economics*, 68:68–85.

Broda, C. and Parker, J. A. (2014). The economic stimulus payments of 2008 and the aggregate demand for consumption. *Journal of Monetary Economics*, 68:S20 – S36.

Calvo, G. A. (1983). Staggered prices in a utility-maximizing framework. *Journal of Monetary Economics*, 12(3):383–398.

Chetty, R., Guren, A., Manoli, D., and Weber, A. (2011). Are micro and macro labor supply elasticities consistent? A review of evidence on the intensive and extensive margins. *The American Economic Review*, 101(3):471–475.

Christiano, L., Eichenbaum, M., and Rebelo, S. (2011). When is the government spending multiplier large? *Journal of Political Economy*, 119(1):78–121.

Coenen, G., Erceg, C. J., Freedman, C., Furceri, D., Kumhof, M., Lalonde, R., Laxton, D., Lindé, J., Mourougane, A., Muir, D., Mursula, S., de Resende, C., Roberts, J., Roeger, W., Snudden, S., Trabandt, M., and in't Veld, J. (2012). Effects of fiscal stimulus in structural models. *American Economic Journal: Macroeconomics*, 4(1):22–68.

Cogan, J. F., Cwik, T., Taylor, J. B., and Wieland, V. (2010). New Keynesian versus old Keynesian government spending multipliers. *Journal of Economic Dynamics and Control*, 34(3):281–295.

Dietrich, A., Kuester, K., Müller, G. J., and Schoenle, R. (2020). News and uncertainty about covid-19: Survey evidence and short-run economic impact. Technical report. Mimeo.

Eichenbaum, M. S., Rebelo, S., and Trabandt, M. (2020). The macroeconomics of epidemics. NBER Working Paper 26882.

Faria-e-Castro, M. (2020a). Back-of-the-envelope estimates of next quarter's unemployment rate. On the economy blog, Federal Reserve Bank of St. Louis.

Faria-e-Castro, M. (2020b). Fiscal policy during a pandemic. Working Paper 2020-006D, Federal Reserve Bank of St. Louis.

Fornaro, L. and Wolf, M. (2020). Covid-19 Coronavirus and macroeconomic policy. CEPR Discussion Paper 14529.

Giambattista, E. and Pennings, S. (2017). When is the government transfer multiplier large? *European Economic Review*, 100:525 – 543.

Greenwood, J., Hercowitz, Z., and Huffman, G. W. (1988). Investment, capacity utilization, and the real business cycle. *American Economic Review*, 78(3):402–417.

Guerrieri, V., Lorenzoni, G., Straub, L., and Werning, I. (2020). Macroeconomic implications of COVID-19: Can negative supply shocks cause demand shortages? Mimeo, MIT.

Guvenen, F., Kaplan, G., and Song, J. (2014). How risky are recessions for top earners? *The American Economic Review*, 104(5):148–153.

Hagedorn, M., Manovskii, I., and Mitman, K. (2019). The fiscal multiplier. *NBER Working Paper*, No. 25571.

Jaimovich, N. and Rebelo, S. (2009). Can news about the future drive the business cycle? *American Economic Review*, 99(4):1097–1118.

Kaplan, G., Moll, B., and Violante, G. L. (2018). Monetary policy according to HANK. *American Economic Review*, 108(3):697–743.

King, R. G., Plosser, C. I., and Rebelo, S. T. (1988). Production, growth and business cycles: I. The basic neoclassical model. *Journal of Monetary Economics*, 21(2):195 – 232.

Leeper, E. M., Traum, N., and Walker, T. B. (2017). Clearing up the fiscal multiplier morass. *American Economic Review*, 107(8):2409–54.

McKay, A. and Reis, R. (2016). The role of automatic stabilizers in the u.s. business cycle. *Econometrica*, 84(1):141–194.

Mehrotra, N. R. (2018). Fiscal Policy Stabilization: Purchases or Transfers? *International Journal of Central Banking*, 14(2):1–50.

Oh, H. and Reis, R. (2012). Targeted transfers and the fiscal response to the great recession. *Journal of Monetary Economics*, 59:S50 – S64. Supplement issue:October 15-16 2010 Research Conference on 'Directions for Macroeconomics: What did we Learn from the Economic Crises' Sponsored by the Swiss National Bank (http://www.snb.ch).

Ramey, V. A. (2019). Ten years after the financial crisis: What have we learned from the renaissance in fiscal research? *Journal of Economic Perspectives*, 33(2):89–114.

Saez, E. and Zucman, G. (2020). Jobs Aren't Being Destroyed This Fast Elsewhere. Why Is That? Technical report. New York Times.

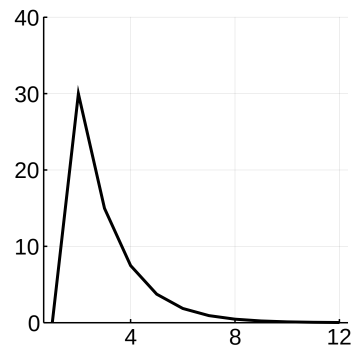
Smets, F. and Wouters, R. (2007). Shocks and frictions in US business cycles: A Bayesian DSGE approach. *American Economic Review*, 97(3):586–606.

Storesletten, K., Telmer, C. I., and Yaron, A. (2004). Cyclical dynamics in idiosyncratic labor market risk. *Journal of Political Economy*, 112(3):695–717.

Taylor, J. B. (1993). Discretion versus policy rules in practice. In *Carnegie-Rochester Conference Series on Public Policy*, volume 39, pages 195–214. Elsevier.

Woodford, M. (2011). Simple analytics of the government expenditure multiplier. *American Economic Journal: Macroeconomics*, 3(1):1–35.

Figure 8: Severe Quarantine Shock: Fraction of quarantined households



Notes: Impulse responses to the quarantine shock. X-axis: Quarters.

A Data for Calibration

Mean illiquid assets. Fixed assets (NIPA table 1.1) over quarterly GDP (excluding net exports; see below), averaged over 1954-2015.

Mean liquidity. Gross federal debt held by the public as percent of GDP (FYPUGDA188S). Available from 1954-2015.

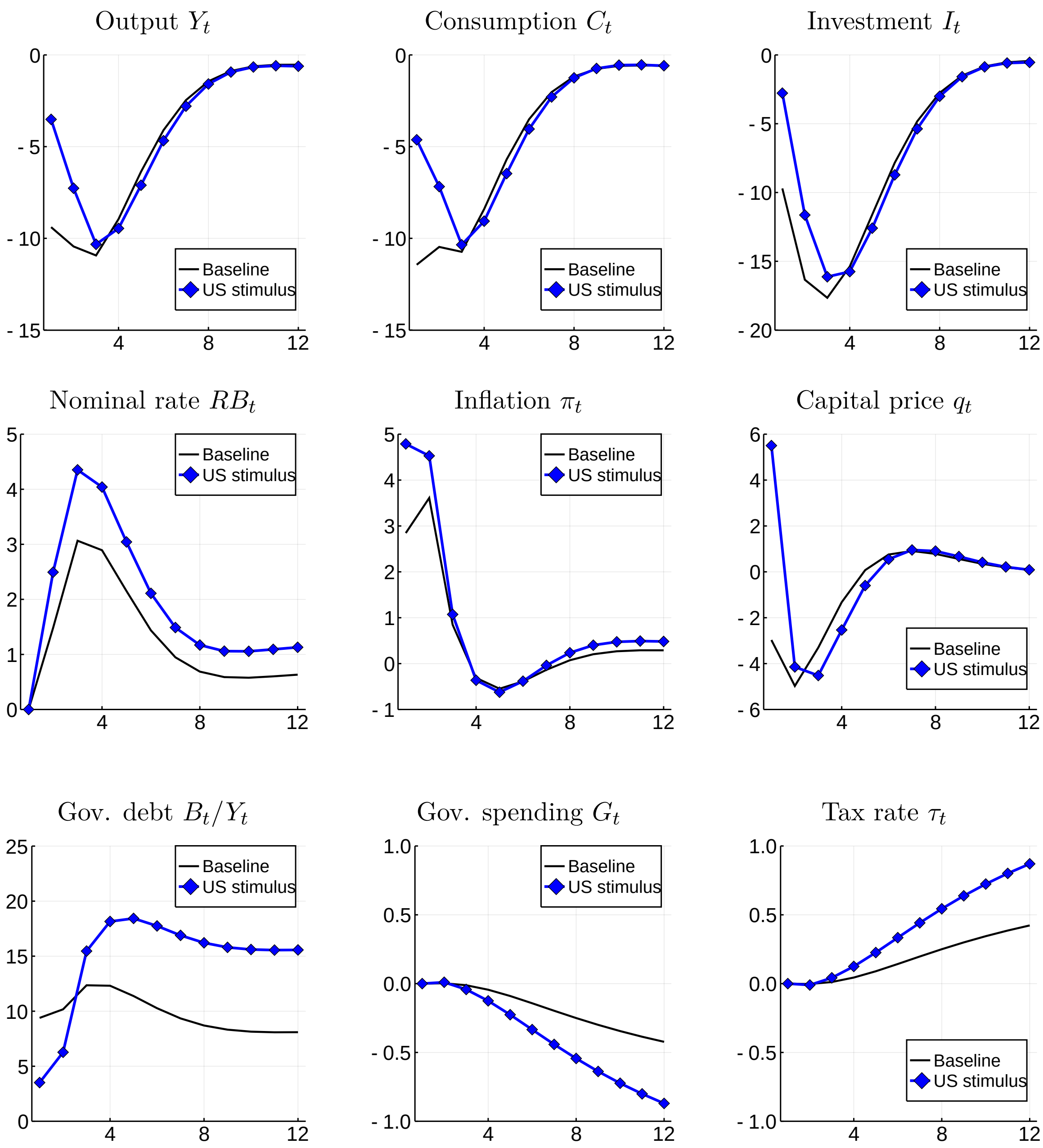
Fraction of borrowers. Taken from the Survey of Consumer Finances (1983-2013); see Bayer et al. (2019) for more details.

Average top 10% share of wealth. Source is the World Inequality Database (1954-2015).

B Severe Quarantine

Figure 9 shows the aggregate consequences for the scenario when 30% of households are in quarantine in 2020Q2.

Figure 9: The Adjustment to 30% Q-shock: w and w/o Stimulus



Notes: Y-axis: All quantities are reported in percent deviations from steady state. All prices are reported in annualized percentage points from steady state. X-axis: Quarters.