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 is earmarked for transfer payments to households. To the extent that such transfers are conditional on recipients being unemployed, they mitigate income risk and the adverse impact of the lockdown ex ante. Unconditional transfers, in contrast, stabilize income ex post. We simulate the effects of a lockdown in a medium-scale HANK model and quantify the impact of transfers. For the short run, we find large differences in the transfer multiplier: it is 0.25 for unconditional transfers and 1.5 for conditional transfers. Overall, we find that the transfers reduce the output loss due to the pandemic by up to 5 percentage points.

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

JEL-Codes: D31, E32, E62

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"The reason it doesn't feel like the Great Depression is emergency relief, which has compensated many workers for lost wages." Paul Krugman on Twitter, June 6, 2020

1 Introduction

The economic fallout of the COVID-19 pandemic is unprecedented. As many businesses and industries have been locked down in an effort to limit infections, unemployment has been rising sharply. In the ten weeks from mid-March to the end of May 2020, more than 40 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 since 2000, illustrating that the recent increase is rather exceptional. The COVID-19 pandemic—by necessitating quarantine measures—has thus increased the income risk for U.S. households considerably.[1] This happened against the backdrop of a general increase in economic uncertainty. In the right panel of Figure 1, we display the implied stock returns volatility (VIX): by late March it had reached levels previously seen only during the financial crisis in 2008.[2]

The pandemic also triggered an exceptional fiscal response.[3] 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 a lump sum and runs up to the end of July 2020. Under the CARES Act, $250 billion of federal expenditures are earmarked for each of these items. 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 limit the economic fallout from the COVID-

[1] Initially, some observers suggested that unemployment would reach 30% in the second quarter of 2020; see, for instance, the remark by the president of the Federal Reserve Bank of St. Louis James Bullard, reported by Bloomberg on March 22, 2020, or Faria-e-Castro (2020a).

[2] Economic policy uncertainty, too, reached an all time high (Baker et al., 2020). Dietrich et al. (2020) document COVID-19-induced uncertainty at the household level on the basis of a real-time survey.

[3] 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.

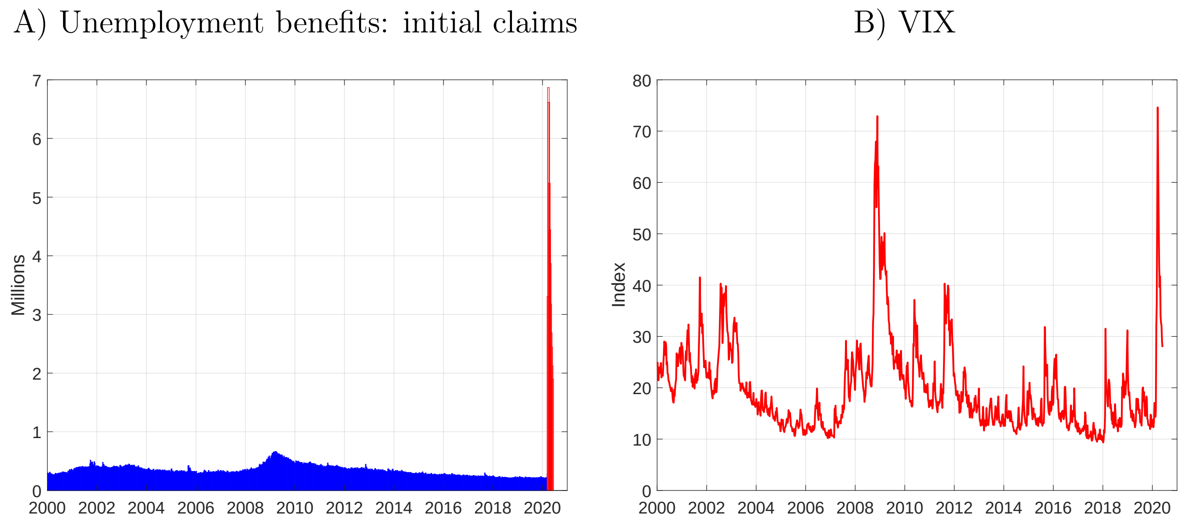

Figure 1: Unemployment and uncertainty. Notes: Panel A) shows initial claims to unemployment benefits, with observations for the weeks since mid-March 2020 indicated by the transparent red bars. Panel B) shows CBOE Volatility Index: VIX. Weekly observations: January 2000 to May 2020. Source: FRED Economic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

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 a sizeable fraction of the labor force is confined to quarantine or, more generally, "locked out" of work. In addition, capital and the goods of some sectors also become temporarily unavailable for production and consumption to the same extent that the labor force is restricted. We refer to this scenario as the "quarantine shock," or "Q-shock" for short. We remain agnostic as to whether the Q-shock is a deliberate government choice or the result of voluntary social restraint. We assume, in line with actual developments, that it is largely anticipated. As a result, the shock not only lowers the production potential of the aggregate economy, it also triggers an unprecedented increase in income risk at the household level, which, 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 Q-shock, we investigate how key aspects of the fiscal response to the crisis play out. Specifically, we focus on the transfer payments to households under the CARES Act and distinguish between a) unconditional transfers and b) transfers that are conditional on the recipient being unemployed.[4] Unconditional transfers are part of

[4] There is also an element of conditionality in the $1,200 payment per person under the CARES Act, but this concerns only a small fraction of the population. We account for this in our model simulations but refer to it as an "unconditional transfer" for simplicity.

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 in 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 deprived of income in the event of a job loss. The low-income state becomes less frightful as a result.

We conduct our analysis within a heterogeneous agent New Keynesian (HANK) model. Here we rely on earlier work by Bayer et al. (2020a,b), who estimate versions of this model. It is uniquely suited to the purpose at hand. First, there are 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.

Our main results can be summarized as follows. We assume that the quarantine measures take effect by March 2020. They are partly anticipated in February, but not to their full extent. The unemployment rate peaks in April at 16%. At this point the economy is already in a deep recession. Afterwards, the recession intensifies and reaches a trough at an almost 20% output loss relative to the pre-shock level. Yet this scenario does not feature any fiscal transfers. It merely serves as a benchmark to assess their effect. Once we account for the transfer payments under the CARES Act, we find that the recessionary effect of the Q-shock is reduced to 15%.

We zoom in on how the transfers alter the impact of the shock and find the distinction between conditional and unconditional transfers to be crucial. To see this, we compute the cumulative transfer multiplier. In the short run it is about 0.75 for the overall transfer component of the CARES Act, but 1.5 for conditional transfers and 0.25 for unconditional transfers. Hence, conditional transfers are particularly effective in stabilizing the economy. We show that this is because they reduce the income risk caused by the Q-shock. In addition, they are targeted to households with the highest marginal propensity to consume.

We also study the distributional consequences, both of the Q-shock and of the transfer payments under the CARES Act. Focusing on the Gini coefficients of total income, labor earnings, consumption, and wealth, we find that the Q-shock drives up all four measures of inequality, at least in the medium run. In the first 3-4 months, consumption and wealth inequality fall because the wealthiest households are hit by the recession-induced fall in the price of capital. But once a substantial fraction of households are in quarantine, these two measures also rise above the pre-crisis level. The transfer package under the CARES Act, through its progressive nature, is quite successful in containing the increase in inequality.

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 (Ramey, 2019). One reason is that in standard representative agent models, Ricardian equivalence holds such that transfers do not impact consumption and output at all. Hence, in their influential assessment of the ARRA, Cogan et al. (2010) focus on the effect of government purchases rather than transfers. Coenen et al. (2012) compare transfer multipliers in seven large-scale DSGE models. These models typically feature a fraction of agents who consume in a "hand-to-mouth" manner in addition to agents who choose their consumption path by optimizing intertemporally. These types of models are now referred to as "two-agent New Keynesian" (TANK) models. While Ricardian equivalence fails in this model class, transfer multipliers are still moderate and generally below 0.25. They are somewhat larger if the zero lower bound binds. Mehrotra (2018) considers a model with credit friction and obtains similar results. Bilbiie et al. (2013), Giambattista and Pennings (2017), and Bilbiie (2019) derive analytical results in TANK models.

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 parameterizations of monetary and fiscal rules. They find a cumulative transfer multiplier of 0.1.

A quickly growing literature takes up the issues related to the COVID-19 pandemic. Guerrieri et al. (2020) stress that the economic fallout from the pandemic may affect supply as well as demand. They argue that asymmetric lockdowns across sectors can create demand shortages. We quantify this channel in a medium-scale DSGE model and find that the temporary unavailability of some goods explains three-quarters of the peak output loss. However, this channel does not affect the size of the transfer multiplier.

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. Glover et al. (2020), like us, stress the importance of household heterogeneity but their focus is on age rather than income because age matters for infection risk. Most closely related to our paper is the work on the effect of the fiscal stimulus in the context of a pandemic-induced downturn. Faria-e-Castro (2020b) analyzes fiscal policy options in a calibrated TANK model with a financial sector. Auerbach et al. (2020), instead, put forward a stylized model with COVID-19-related restrictions and economic slack. They show analytically that transfers to low-income households can increase spending on unrestricted items and that targeted transfers to firms are particularly effective in stimulating the economy. Cox et al. (2020) document on the basis of household-level bank data that, after an initial drop, spending has rebounded most rapidly for low-income households since mid-April 2020. At the same time their liquid assets have increased considerably. According to the authors this suggests—in line with our model-based analysis—that the CARES stimulus program played an important role in limiting the effects of labor market disruptions on spending.

The remainder of this paper is organized as follows. Section 2 outlines the model structure. Section 3 explains in detail our parameter choice. We present the results of our model simulations in Section 4. Here we also zoom in on the transmission mechanism, of both 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 follow Bayer et al. (2020b) closely and are extended to capture the economic fallout of the global COVID-19 pandemic. We model an economy composed of a firm sector, a household sector, and a government sector. In the firm sector, we define several layers in order to maintain tractability. There is a continuum of isomorphic final-good sectors, each characterized by monopolistic competition. Sectors differ in that some are put under quarantine in response to the Q-shock, while others are not. In this case, as explained in detail by Guerrieri et al. (2020), demand spillovers across sectors depend crucially on the elasticity of substitution across the goods produced in different sectors. Hence, we allow it to differ from the elasticity of substitution within sectors.

Final good producers rely on homogeneous intermediate inputs provided by perfectly competitive intermediate goods producers. Capital goods, in turn, are produced on the basis of final goods, subject to adjustment costs. Labor services are assembled on the basis of differentiated labor types provided by unions that, in turn, differentiate the raw labor input of households. Price setting for the final goods as well as wage setting by unions is subject to nominal rigidities. Households earn income from supplying (raw) labor and capital and from owning the firm sector, absorbing all of 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.

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.

A key economic aspect of the pandemic is that a substantial fraction of workers is locked out of work. We capture this 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 of entering the quarantine state vary over time and calibrate it to be a very rare state in the 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:

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

with individual productivity $h_{it} = \frac{\tilde{h}_{it}}{\int \tilde{h}_{it} di}$ such that average productivity is normalized to one. The shocks ϵ_{it}^h 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_t^{in} and p^{out}, respectively. While in quarantine, human capital evolves as if workers were still employed, such that quarantine is effectively a layoff on recall. We denote by $1 - H_t$ the fraction of worker households in quarantine and assume that the same fraction $(1 - H_t)$ of final-good sectors and capital is quarantined, too.

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_t^F, 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_t^U, are distributed lump-sum across workers, leading to labor-income compression.

With respect to leisure and consumption, households have GHH preferences (Greenwood et al., 1988) and maximize the discounted sum of felicity:[5]

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

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

[5] 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.

$\xi > 0$,

$$u(x_{it}) = \frac{1}{1-\xi} x_{it}^{1-\xi}, \tag{3}$$

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. The consumption good is a bundle of varieties j of differentiated goods from a continuum of final-good sectors k of measure one. Formally, we rely on a nested Dixit-Stiglitz aggregator:

$$c_{it} = \left[\int \psi_{kt} \left(\int_{j \in S(k)} c_{ijkt}^{\frac{\eta_F - 1}{\eta_F}} dj \right)^{\frac{\eta_F}{\eta_F - 1} \frac{\eta_S - 1}{\eta_S}} dk \right]^{\frac{\eta_S}{\eta_S - 1}}, \tag{4}$$

where $j \in S(k)$ indicates that differentiated good j belongs to sector k. The elasticity of substitution within a final-good sector, η_F, is assumed to be larger than the substitutability across sectors, η_S. Each of the differentiated goods, j, is offered at price p_{jt}. Not all sectors are equally affected by the pandemic. We model this by the indicator ψ which determines whether sector-k goods can actually be bought ($\psi_{kt} = 1$) or become unavailable due to the pandemic ($\psi_{kt} = 0$). This means that the demand for each of the varieties is given by

$$c_{ijkt} = \psi_{kt} \left(\frac{p_{jt}}{P_{kt}} \right)^{-\eta_F} c_{ikt} \ . \tag{5}$$

Here P_{kt} is the (ideal) price index of all varieties in sector k and using these prices, we obtain the aggregate price level $P_t = \left(\int \psi_{kt} P_{kt}^{1-\eta_S} dk \right)^{\frac{1}{1-\eta_S}}$.

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

$$\frac{\partial G(h_{it}, n_{it})}{\partial n_{it}} = (1 - \tau_t) w_t h_{it}. \tag{6}$$

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 (6):

$$x_{it} = c_{it} - G(h_{it}, n_{it}) = c_{it} - \frac{(1-\tau_t) w_t h_{it} n_{it}}{1+\gamma}. \tag{7}$$

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:

$$\begin{aligned} c_{it} + b_{it+1} + q_t k_{it+1} &= b_{it} \tfrac{R(b_{it}, R^b_t)}{\pi_t} + (q_t + r_t) k_{it} + \mathcal{T}_t(h) \\ &+ (1-\tau_t)[(1-Q_{it}) h_{it} w_t N_t + \mathcal{R}(h) Q_{it} h_{it} w_t N_t + \mathbb{I}_{h_{it} \neq 0} \Pi^U_t + \mathbb{I}_{h_{it}=0} \Pi^F_t], \\ & k_{it+1} \geq 0, \quad b_{it+1} \geq \underline{B} \ , \end{aligned} \tag{8}$$

where Π^U_t is union profits, Π^F_t 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^b_t, 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 forgone labor income. In line with the U.S. unemployment insurance scheme, the replacement rate depends on the level of forgone income. Depending on their income level, households potentially receive a lump-sum transfer $\mathcal{T}_t(h)$.

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:

$$R(b_{it}, R^b_t) = \begin{cases} R^b_t & \text{if } b_{it} \geq 0 \\ R^b_t + \overline{R} & \text{if } b_{it} < 0. \end{cases} \tag{9}$$

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:

$$\begin{aligned} V_t^a(b,k,h,Q) =& \max_{k',b_a'} u[x(b,b_a',k,k',h,Q)] + \beta\mathbb{E}_t V_{t+1}(b_a',k',h',Q') \\ V_t^n(b,k,h,Q) =& \max_{b_n'} u[x(b,b_n',k,k,h,Q)] + \beta\mathbb{E}_t V_{t+1}(b_n',k,h',Q') \\ \mathbb{E}_t V_{t+1}(b',k',h',Q') =& \mathbb{E}_t\left[\lambda V_{t+1}^a(b',k',h',Q')\right] + \mathbb{E}_t\left[(1-\lambda)V_{t+1}^n(b',k,h',Q')\right] \end{aligned} \tag{10}$$

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

[6]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.

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 which 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

$$N_t = \left(\int \hat{n}_{jt}^{\frac{\zeta-1}{\zeta}} dj \right)^{\frac{\zeta}{\zeta-1}} , \tag{11}$$

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

$$\hat{n}_{jt} = \left(\frac{W_{jt}}{W_t^F} \right)^{-\zeta} N_t \ , \tag{12}$$

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

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \lambda_w^t \frac{W_t^F}{P_t} N_t H_t \left\{ \left(\frac{W_{jt}\bar{\pi}_W^t}{W_t^F} - \frac{W_t}{W_t^F} \right) \left(\frac{W_{jt}\bar{\pi}_W^t}{W_t^F} \right)^{-\zeta} \right\}, \tag{13}$$

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:

$$\log\left(\tfrac{\pi_t^W}{\bar{\pi}_W}\right) = \beta \mathbb{E}_t \log\left(\tfrac{\pi_{t+1}^W}{\bar{\pi}_W}\right) + \kappa_w \left(\tfrac{w_t}{w_t^F} - \tfrac{1}{\mu^W}\right), \tag{14}$$

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 $\kappa_w =$

$\frac{(1-\lambda_w)(1-\lambda_w\beta)}{\lambda_w}$.[7]

2.2.2 Final Goods Producers

Similar to unions, final goods producers differentiate a homogeneous intermediate good and set prices. Each reseller j in sector k faces a downward-sloping demand curve

$$y_{jt} = \psi_{kt} \left(p_{jt}/P_{kt}\right)^{-\eta_F} Y_{kt} \tag{16}$$

and buys 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. We assume for simplicity that it is i.i.d. whether a sector is active or not and that this shock realizes after price setting.

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

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \lambda_Y^t (1-\tau_t) Y_{kt} \psi_{jt} \left\{ \left(\frac{p_{jt}\bar{\pi}^t}{P_t} - \frac{MC_t}{P_t} \right) \left(\frac{p_{jt}\bar{\pi}^t}{P_t} \right)^{-\eta_F} \right\}, \tag{17}$$

with a time constant discount factor, where $1 - \lambda_Y$ is the probability of price adjustment and $\bar{\pi}$ is the steady-state inflation rate.

Since all sectors are symmetric and the fact that a sector is shut down or open is only realized after price setting lets all firms that can reset their price choose the same price. Therefore, all sectoral price levels $P_{kt} = \left(\int_{j \in S(k)} p_{jt}^{1-\eta_F} dj \right)^{\frac{1}{1-\eta_F}}$ are the same and we denote this price level by $P_{kt} = P_t^F$. Yet, the fact that only a fraction $\Psi_t = \mathbb{E}\psi_{kt}$ of sectors do actually offer their varieties implies a loss in final consumption to the households. They lose out on varieties and this introduces a wedge $\Psi_t^{\frac{1}{1-\eta_S}}$ between the average price set by all firms, P_t^F, and the effective P_t of the consumption aggregate (ideal price index): $P_t = P_t^F \Psi_t^{\frac{1}{1-\eta_S}}$. Vice versa, it implies that the real value of total output Y_t is by factor $\Psi_t^{\frac{1}{\eta_S - 1}}$ smaller than the simple quantity of intermediate goods produced.

We use this expression for the relationship between the average price of goods and the

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

$$\log\left(\frac{\pi_t^W}{\bar{\pi}^W}\right) = \beta \mathbb{E}_t \left[\log\left(\frac{\pi_{t+1}^W}{\bar{\pi}^W}\right) \frac{1-\tau_{t+1}}{1-\tau_t} \frac{W_{t+1}^F P_t}{W_t^F P_{t+1}} \frac{N_{t+1} H_{t+1}}{N_t H_t} \right] + \kappa_w \left(\frac{w_t}{w_t^F} - \frac{1}{\mu^W} \right) \tag{15}$$

where τ_t is the average income tax.

effective price level to rewrite the maximization problem of price setters as:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \lambda_Y^t (1-\tau_t) Y_t \psi_{jt} \Psi_t^{\frac{1}{\eta_S - 1}} \left\{ \left(\frac{p_{jt}\bar{\pi}^t}{P_t^F} - \frac{MC_t}{P_t} \frac{1}{\Psi_t^{\frac{1}{\eta_S-1}}} \right) \left(\frac{p_{jt}\bar{\pi}^t}{P_t^F} \right)^{-\eta_F} \right\}, \tag{18}$$

which, through its corresponding first-order condition for price setting, implies a Phillips curve for average price

$$\log\left(\frac{\pi_t^F}{\bar{\pi}}\right) = \beta \mathbb{E}_t \log\left(\frac{\pi_{t+1}^F}{\bar{\pi}}\right) + \kappa_Y \left(mc_t / \Psi_t^{\frac{1}{\eta_S-1}} - \frac{1}{\mu^Y} \right), \tag{19}$$

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^F is the gross inflation rate of the average price of final goods, $\pi_t^F := \frac{P_t^F}{P_{t-1}^F}$, which, different from π_t, does not take into account whether a sector is locked down or not. $mc_t := \frac{MC_t}{P_t}$ is the real marginal costs and $\mu^Y = \frac{\eta_F}{\eta_F - 1}$ is the target markup. The effective price P_t, the ideal price index, then exhibits an inflation rate $\pi_t = \pi_t^F \left(\frac{\Psi_{t-1}}{\Psi_t}\right)^{\frac{1}{\eta_S-1}}$.

Importantly, the love-of-variety term $\Psi_t^{\frac{1}{\eta_S-1}}$ adds an element of as-if-perfectly-flexible prices to the model. In the first period in which the quarantine shock hits, some varieties are lost and Ψ_t falls. As a consequence, the effective price level jumps up even if all individual prices remain constant because households cannot perfectly substitute the lost varieties. As households expect the quarantine to be reduced in the future, they expect varieties to return and hence a falling effective price level from the love-of-variety component. This deflationary effect of the return of varieties to the consumption basket increases the real interest rate that households face and leads them to save more. This is the key mechanism behind the "Keynesian supply shocks" in Guerrieri et al. (2020) as they explain in Section 3.1 of their paper.

2.2.3 Intermediate Goods Producers

Intermediate goods are produced with a constant returns to scale production function, taking into account that a fraction H_t of labor and capital is quarantined:

$$Y_t^F = (H_t N_t)^{\alpha} (H_t u_t K_t)^{(1-\alpha)} . \tag{20}$$

Here, $u_t K_t$ 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,

$$mc_t Y_t^F - H_t w_t^F N_t - H_t\left[r_t + q_t\delta(u_t)\right]K_t, \tag{21}$$

where r_t^F and q_t are the rental rate of firms and the (producer) price of capital goods, respectively. Only non-quarantined factors receive payments.[8] 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:

$$w_t^F = \alpha mc_t\left(\frac{u_t K_t}{N_t}\right)^{1-\alpha}, \tag{22}$$

$$r_t^F + q_t\delta(u_t) = u_t(1-\alpha)mc_t\left(\frac{N_t}{u_t K_t}\right)^{\alpha}. \tag{23}$$

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

$$q_t\left[\delta_1 + \delta_2(u_t-1)\right] = (1-\alpha)mc_t\left(\frac{N_t}{u_t K_t}\right)^{\alpha}, \tag{24}$$

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

Total production $Y_t = \Psi_t^{\frac{1}{\eta_S-1}} Y_t^F$ is scaled by an additional term $\Psi_t^{\frac{1}{\eta_S-1}}$, which reflects the fact that the loss in varieties through the quarantine decreases the effective productivity of the economy even further.

[8] None of the quarantine terms show up in any first-order conditions 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, quarantined capital is still depreciated at rate $\delta_0 - \delta_1 + \delta_2/2$. This means capital owners receive an average dividend payment on their capital $r_t = r_t^F H_t - (1-H_t)\delta(0)$.

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

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t I_t \left\{ q_t \left[1 - \frac{\phi}{2} \left(\log \frac{I_t}{I_{t-1}} \right)^2 \right] - 1 \right\}. \tag{25}$$

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

$$q_t \left[1 - \phi \log \frac{I_t}{I_{t-1}} \right] = 1 - \beta \mathbb{E}_t \left[q_{t+1} \phi \log \left(\frac{I_{t+1}}{I_t} \right) \right], \tag{26}$$

and each capital goods producer will adjust its production until (26) is fulfilled.

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

$$K_t - (1 - \delta(u_t)) K_{t-1} = \left[1 - \frac{\phi}{2} \left(\log \frac{I_t}{I_{t-1}} \right)^2 \right] I_t \; . \tag{27}$$

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 the average tax rate in the economy, and adjusts expenditures to stabilize debt in the long run.

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

$$\frac{R^b_{t+1}}{\bar{R}^b} = \left(\frac{R^b_t}{\bar{R}^b} \right)^{\rho_R} \left(\frac{\pi^F_t}{\bar{\pi}} \right)^{(1-\rho_R)\theta_\pi} . \tag{28}$$

The coefficient $\bar{R}^b \geq 0$ determines the nominal interest rate in the steady state. The coefficient $\theta_\pi \geq 0$ governs the extent to which the central bank attempts to stabilize inflation. We assume that the central bank reacts to average, i.e., measured, not effective price inflation that depends on unobserved substitution elasticities for quarantined products and services.

The parameter $\rho_R \geq 0$ captures interest rate smoothing. We leave out any reaction of the central bank to the output gap, because it is unclear whether the efficient output that the central bank should target is the one taking the quarantine measures into account or the original capacity.

The fiscal branch of the government follows two simple rules for spending and taxes that react only to the deviation of government debt from its long-run target in order to avoid fiscal dominance:

$$\frac{G_t}{\bar{G}} = \left(\frac{G_t}{\bar{G}}\right)^{\rho_G} \left(\frac{B_t}{\bar{B}}\right)^{(1-\rho_G)\gamma_B^G} , \tag{29}$$

$$\frac{\tau_t}{\bar{\tau}} = \left(\frac{\tau_t}{\bar{\tau}}\right)^{\rho_\tau} \left(\frac{B_t}{\bar{B}}\right)^{(1-\rho_\tau)\gamma_B^\tau} . \tag{30}$$

The coefficients γ_B^G and γ_B^τ determine the speed at which government debt is returned to its target level.

Total taxes T_t are then $T_t = \tau_t \left(w_t H_t N_t + \Pi_t^U + \Pi_t^F\right)$ and the government budget constraint determines government debt residually:

$$B_{t+1} = R_t^b/\pi_t B_t + G_t - T_t + \int \mathcal{T}(h_i)di + w_t N_t(1 - H_t) \int \mathcal{R}(h_i)h_i di. \tag{31}$$

2.4 Goods, Bonds, Capital, and Labor Market Clearing

The labor market clears at the competitive wage given in (22). The bond market clears whenever the following equation holds:

$$B_{t+1} = B^d(R_t^b, p_t^{in}, r_t, q_t, \Pi_t^F, \Pi_t^U, w_t, \pi_t, \tau_t, \Theta_t, \mathbb{E}_t V_{t+1}) := \mathbb{E}_t \left[\lambda b_{a,t}^* + (1-\lambda) b_{n,t}^*\right], \tag{32}$$

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:

$$K_{t+1} = K^d(R_t^b, p_t^{in}, r_t, q_t, \Pi_t^F, \Pi_t^U, w_t, \pi_t, \tau_t, \Theta_t, \mathbb{E}_t V_{t+1}) := \mathbb{E}_t[\lambda k_t{}^* + (1-\lambda)k] , \tag{33}$$

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 $\{V_t^a, V_t^n\}$, a sequence of prices $\{w_t, w_t^F, \Pi_t^F, \Pi_t^U, q_t, r_t, R_t^b, \pi_t, \pi_t^W, \tau_t\}$, a sequence of stochastic states p_t^{in} and quarantine shocks ϵ_t^p, 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 $\{x_{a,t}^*, x_{n,t}^*, b_{a,t}^*, b_{n,t}^*, k_t^*\}$ and prices, the value functions $\{V_t^a, V_t^n\}$ are a solution to the Bellman equation (10).

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 at *monthly* frequency in the following way. First, we calibrate or fix all parameters that determine the steady state of the model. Second, we specify the values of those parameters that govern the dynamics of the model in line with the estimates of Bayer et al. (2020b). They estimate a closely related variant of our model using Bayesian full-information methods.

Table 1 summarizes a first set of parameter values. On the household side, we set the relative risk aversion to 4, which is common in the incomplete markets literature; see Kaplan

Table 1: External/calibrated parameters (monthly frequency)

Parameter	Value	Description	Target
Households			
β	0.99	Discount factor	see Table 2
ξ	4.00	Relative risk aversion	Kaplan et al. (2018)
γ	2.00	Inverse of Frisch elasticity	Chetty et al. (2011)
λ	5.50%	Portfolio adj. prob.	see Table 2
ρ_h	0.99	Persistence labor income	Storesletten et al. (2004)
σ_h	0.07	STD labor income	Storesletten et al. (2004)
ζ	0.02%	Trans. prob. from W. to E.	see Table 2
ι	2.40%	Trans. prob. from E. to W.	Guvenen et al. (2014)
p_{ss}^{in}	0.02%	Trans. prob. into Q	see text
p^{out}	50.00%	Trans. prob. out of Q	see text
$\bar{R}$	0.95%	Borrowing penalty	see Table 2
Firms			
α	0.68	Share of labor	62% labor income
δ_0	7.5%/12	Depreciation rate	Standard value
η_F	11.00	Elasticity of substitution within sectors	Price markup 10%
η_S	3.00	Elasticity of substitution between sectors	see text
ζ	11.00	Elasticity of substitution	Wage markup 10%
Government			
$\bar{\tau}^L$	0.2	Tax rate level	$G/Y = 15\%$
$\bar{R}^b$	1.00	Nominal rate	see text
$\bar{\pi}$	1.00	Inflation	see text

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), $\rho_h = 0.993$ and $\bar{\sigma}_h = 0.069$. Guvenen et al. (2014) provide the probability that 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, $\iota = 0.024$.

Table 2 summarizes the calibration of the remaining household parameters. We match 4 targets: 1) average illiquid assets (K/Y=2.86 annual), 2) average liquidity (B/Y=0.56 annual), 3) the fraction of borrowers, 16%, and 4) the average top 10% share of wealth, which is 67%. This yields a discount factor of 0.993, a portfolio adjustment probability of 5.5%, borrowing penalty of 0.949% monthly (given a borrowing limit of two times average income), and a transition probability from worker to entrepreneur of 0.02%.[9]

We model the Q-state as a rare disaster state with almost zero mass in the steady state ($p_{ss}^{in} = 0.02\%$). In that state, households receive government transfers that replace 40% of

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

Table 2: Calibrated parameters

Targets	Model	Data	Source	Parameter
Mean illiquid assets (K/Y)	2.85	2.86	NIPA	Discount factor
Mean liquidity (B/Y)	0.55	0.56	FRED	Port. adj. probability
Top10 wealth share	0.67	0.67	WID	Fraction of entrepreneurs
Fraction borrowers	0.14	0.16	SCF	Borrowing penalty

their after-tax labor income capped at 50% of median income. This mimics the generosity of the U.S. unemployment insurance before the CARES Act. The exit probability from the Q-state is 50% per month ($p^{out} = 0.5$), so that the expected lockdown duration is two months, in line with recent developments. In our experiments in the next section, we will increase p_t^{in}, the probability of entering Q. We allow the probability of entering the Q-state to depend on income. In particular, we match the incidence of job losses across the income distribution during March/April 2020 as documented in Mongey et al. (2020). Specifically, they find that below median income workers are three times more likely to become unemployed (see their Figure 5B).[10]

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 0.717% per month. An elasticity of substitution between differentiated goods within a sector 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. We set the elasticity of substitution across sectors to 3, somewhat below the intertemporal elasticity of substitution. This ensures that the Q-shock shares the features of a "Keynesian supply shock" (Guerrieri et al., 2020), in addition to raising the income risk of households.

The government taxes labor and profit income. The level of taxes in the steady state, τ^L, is set to clear the government budget constraint that corresponds to a government share of $G/Y = 15\%$. We set steady-state inflation to zero as we have assumed indexation to the steady-state inflation rate in the Phillips curves. We set the steady-state net interest rate to 0.0%, in order to capture the average federal funds rate in real terms minus output growth over 1954-2018.

[10] We fit a logistic function and target the Q-incidence of the 25pct to the 75pct of the income distribution to be 3.

Table 3: Aggregate frictions and policy rules (monthly frequency)

Real frictions				Nominal frictions			
δ_s	1.483	ϕ	0.698	κ	0.009	κ_w	0.011
Government spending				Taxes			
ρ_G	0.965	γ_B^G	-0.100	ρ_τ	0.965	γ_B^τ	-0.400
Monetary policy							
ρ_R	0.965	θ_π	1.500				

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. (2020b). Tax and government spending rules parameterized to ensure debt sustainability.

The Taylor rule coefficients on inflation, 1.5 and interest rate inertia, 0.965 at a monthly level, 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 lockdown 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 the steady state after a debt build-up.

The parameters that govern the real and nominal frictions are set to the values estimated via Bayesian methods in Bayer et al. (2020b); see Table 3. It is noteworthy that the estimated real frictions 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 in line with the representative-agent literature, with price and wage stickiness being less than 12 months on average.

4 Results

We now present the results of various model simulations. In a first step, we develop our baseline scenario for which we expose the model economy to the quarantine shock, or "Q-shock" for short. For this baseline we do not consider fiscal transfers yet. We do so in a second step, as we model the transfer payments of the CARES Act in addition to the Q-shock. In this way, we allow for an interaction of the transfer payments and the Q-shock. This is essential for our analysis because—while the model is linear at the aggregate level—

the Q-shock generates income risk at the household level and the transfers may offset this risk to the extent that they are known to be targeted to the quarantined. To make this point as transparent as possible, we zoom in on the design of the transfer payments in a third step. Here we also quantify the transfer multiplier. Lastly, we report results regarding the distributional effects of the Q-shock and the transfer component of the coronavirus stimulus.

4.1 The Q-shock

First, to set the stage, we develop a baseline scenario for the lockdown. Recall that we assume that the lockdown applies to workers, capital, and final-goods sectors alike. The essential aspect of the lockdown in our analysis is that workers and capital under quarantine do not receive income. Final goods of sectors under quarantine, in turn, are temporarily unavailable for consumption. To quantify the extent of the lockdown, we target the increase in unemployment as reflected in the initial claims to unemployment, shown in Figure 1 above. Specifically, for the actual lockdown period between March and May 2020, we compute the initial claims to unemployment in each month in excess of the monthly average during 2019: it amounts to 6.4% of total employees in March, 12.7% in April, and 7.5% in May 2020.[11]

We use these numbers to specify the shock process that determines the probability of being put under quarantine in the next month (p_t^{in}). In this way we assume an exogenous increase in this probability starting in February 2020. At this point it becomes known that 6.4% of the labor force will be put under quarantine in March 2020. In March the outlook deteriorates further and everybody understands that the probability of being put under quarantine will be 12.7% in April. The situation in April is similar: it becomes known that another 7.5% of the labor force will be quarantined as of May. Afterwards p_t^{in} gradually returns to its (almost negligible) steady-state value. For this purpose we assume an AR(1) process with persistence parameter 0.85.

We show the probability of entering the Q-state in Panel A of Figure 2. Here, and in what follows, the horizontal axis measures time in months. The vertical axis measures the deviation from the pre-shock level in percent. From an aggregate perspective the increase in the probability represents the expected inflow into quarantine. From the household perspective it is important that the increase in the probability of entering the Q-shock becomes known one month in advance. As a result, income risk already increases in February 2020, and particularly so for low-income households for whom the quarantine incidence is twice as high, as discussed in Section 3 above. Income risk remains elevated for as long as there is a

[11] An alternative strategy is to target the unemployment rate. This yields similar results, but we prefer initial claims as a calibration target since misclassification is arguably less of an issue in this case (New York Times, 2020).

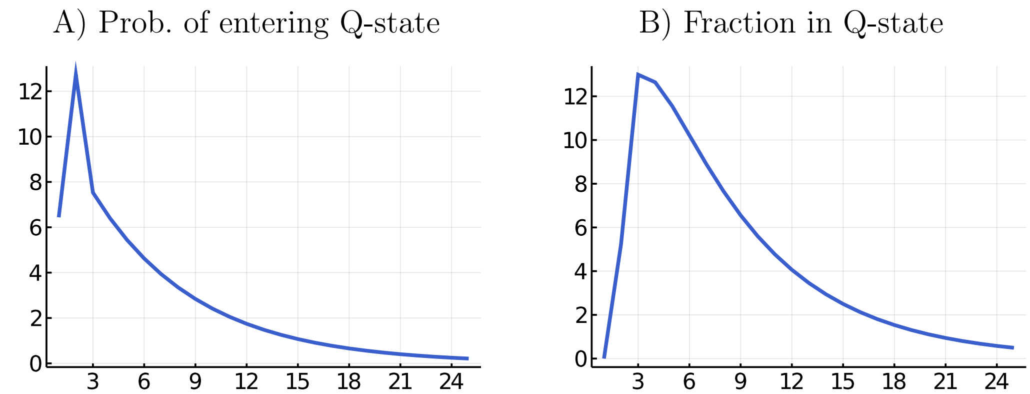

Figure 2: Quarantine shock. Notes: Panel A shows workers' probability of entering Q-state in the next month (p_t^{in}), measured in percent of the labor force (Y-axis). X-axis measures time in months. First period represents February 2020. Probability is set to capture initial claims to unemployment in excess of average monthly value for 2019. Panel B shows fraction of human capital, physical capital, and final goods in Q-state (in percent).

heightened inflow into the Q-state.

In Panel B of the same figure we display the stock of human capital put under quarantine (measured again in percent of the total). Because low-skill workers are more likely to be put under quarantine, the fraction of human capital under quarantine is somewhat smaller than the fraction of workers under quarantine.[12] The latter peaks in month 4 (April 2020) at about 16% (not shown). We assume that the fraction of capital and final goods under quarantine in each period equals the fraction of human capital under quarantine. Exit from the Q-state is governed by p^{out}, which we assume equals 0.5 throughout.

Figure 3 shows the adjustment of the economy to the Q-shock over time. We think of this baseline scenario as a counterfactual outcome that would have been observed in the absence of the fiscal stimulus provided under the CARES Act. Recall that time is measured against the horizonal axis in months, so that the 24 periods under consideration represent a two-year period. While quarantine starts only in period 2 (March) and reaches a maximum effect in period 3 (Figure 2), the economy responds instantaneously to the Q-shock as it becomes known in February 2020—the anticipation brings forward in time the adverse impact of the shock. Put differently, what is originally a supply shock leads to demand shortage (see also Guerrieri et al., 2020; Fornaro and Wolf, 2020).

Output (Panel A) drops by about 1%, consumption (Panel B) is fairly stable, but in-

[12]In line with this, equal incidence of quarantine would make the recession deeper because a larger fraction of human capital goes into quarantine. We find that the higher incidence of quarantine among income poor households as documented by Mongey et al. (2020) reduces the recession by 2 percentage points.

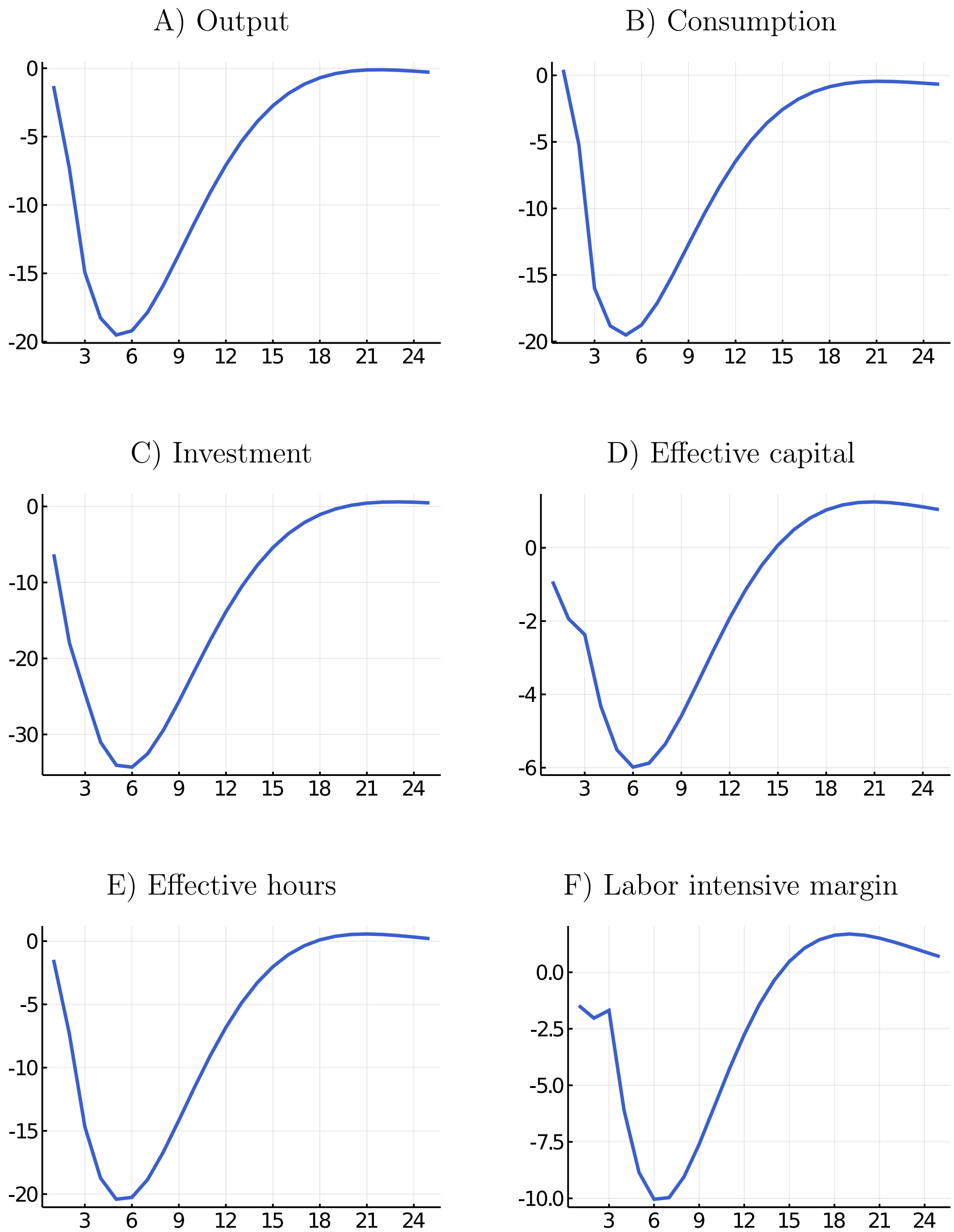

Figure 3: Dynamic adjustment to Q-shock. Notes: Impulse responses to quarantine shock w/o fiscal stimulus; see Figure 2 for details on the Q-shock. Output, consumption, and investment are deflated with the actual price index P_t^F rather than the ideal price index P_t. Effective capital, effective hours, and labor intensive margin refer to model variables $u_t H_t K_t$, $H_t N_t$, and N_t, respectively. Y-axis: Percent deviation from steady state. X-axis: Months.

vestment (Panel C) collapses by more than 5%. Importantly, these variables are deflated with the actual price index rather than the ideal price index. The utilization of capital, that is, the effective capital stock, declines likewise (Panel D). Initially, hours worked (Panel E) also decline, even though the labor force has not been decimated by quarantine yet. In fact, this is a response to the decline in aggregate demand and is achieved through a reduction of hours worked per person: the adjustment of the intensive margin of labor is shown in Panel F. On impact it declines sharply.

The effect of the shock becomes stronger over time and quickly so. The recessionary impact reaches its peak in month 5 (June 2020). At this point, output, consumption, and investment have declined strongly: the output loss amounts to almost 20% and investment has declined by more than 30%. Hence, the recession triggered by the Q-shock is very deep, in line with household expectations regarding the impact of the COVID-19 pandemic as surveyed by Dietrich et al. (2020) in mid-March 2020. But afterwards the economy recovers fast. After about 18 months output is almost back to its pre-shock level. This happens, against the backdrop of the massive drop in investment, by using the factors of production more intensively.

In sum, the quarantine shock reduces the effective labor force and the effective capital stock in the economy and lowers its production potential. However, it also adversely impacts aggregate demand to the extent that it increases idiosyncratic income risk. Households try to self-insure against this risk by increasing their liquid savings.[13] In order to isolate the distinct contribution of this channel to the transmission of the Q-shock, we simulate an alternative version of the model for which we assume that income is pooled across households with the same productivity. In this way we effectively provide insurance against idiosyncratic income risk due to the Q-shock. Figure A.1 in the appendix shows the results. By and large they are similar to the baseline in Figure 3, but we observe that the maximum output effect is reduced by about 2 percentage points. This is mostly the result of a weaker consumption response. Insuring the income risk due to quarantine reduces the drop in consumption by 3-4 percentage points.

In addition, there is considerable amplification because a number of final goods become temporarily unavailable due to the quarantine measure. To see this, we simulate a scenario where final goods are not put under quarantine and show the result in the appendix (Figure A.2). Observe that in this case, the Q-shock is much less contractionary than in the baseline (Figure 3) and, in fact, initially expansionary. Intuitively, as the Q-shock restricts the supply of labor and capital, it puts upward pressure on marginal costs and inflation, just

[13] 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).

like an adverse technology shock. Since monetary policy adjusts nominal interest rates only sluggishly, real interest rates may decline in the short run. This, in turn, leads households to increase consumption if a) the intertemporal elasticity of substitution is high and b) the shock is short lived. Both conditions are met in our model. However, for our baseline we do also assume that final goods are put under quarantine. This, as explained in detail by (Guerrieri et al., 2020), restricts the impact of the Q-shock on inflation if the intratemporal elasticity of substitution among final goods is low relative to the intertemporal elasticity of substitution. This condition is also met under our calibration and ensures that the economy contracts on impact.

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 a position to quantify their 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 in income risk due to the Q-shock. In our model simulations, we capture this conditional transfer by paying a lump-sum transfer equivalent of $600 per week to those households that lose income because they are put under quarantine. In total, this implies payments of about $780 billion. This is more than the $250 billion earmarked under the CARES Act because, in our simulation, the increase in unemployment is larger and the duration of the payment longer than what has been initially projected.[14] Importantly, by being made 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 is a minor form of conditionality and we refer to "unconditional transfers" for simplicity. In the simulations, we assume that the lump-sum payments arrive somewhat gradually to eligible households: disbursement begins in period 2 (March 2020) and is phased out over time (persistence parameter 0.5) so that the total transfer to an entitled person amounts to $1,200.

[14] The original cost estimates assume an increases in the unemployment rate to 12% and that payments end in July 2020. Instead, we assume that the top-up transfer is paid for as long as a worker is under quarantine.

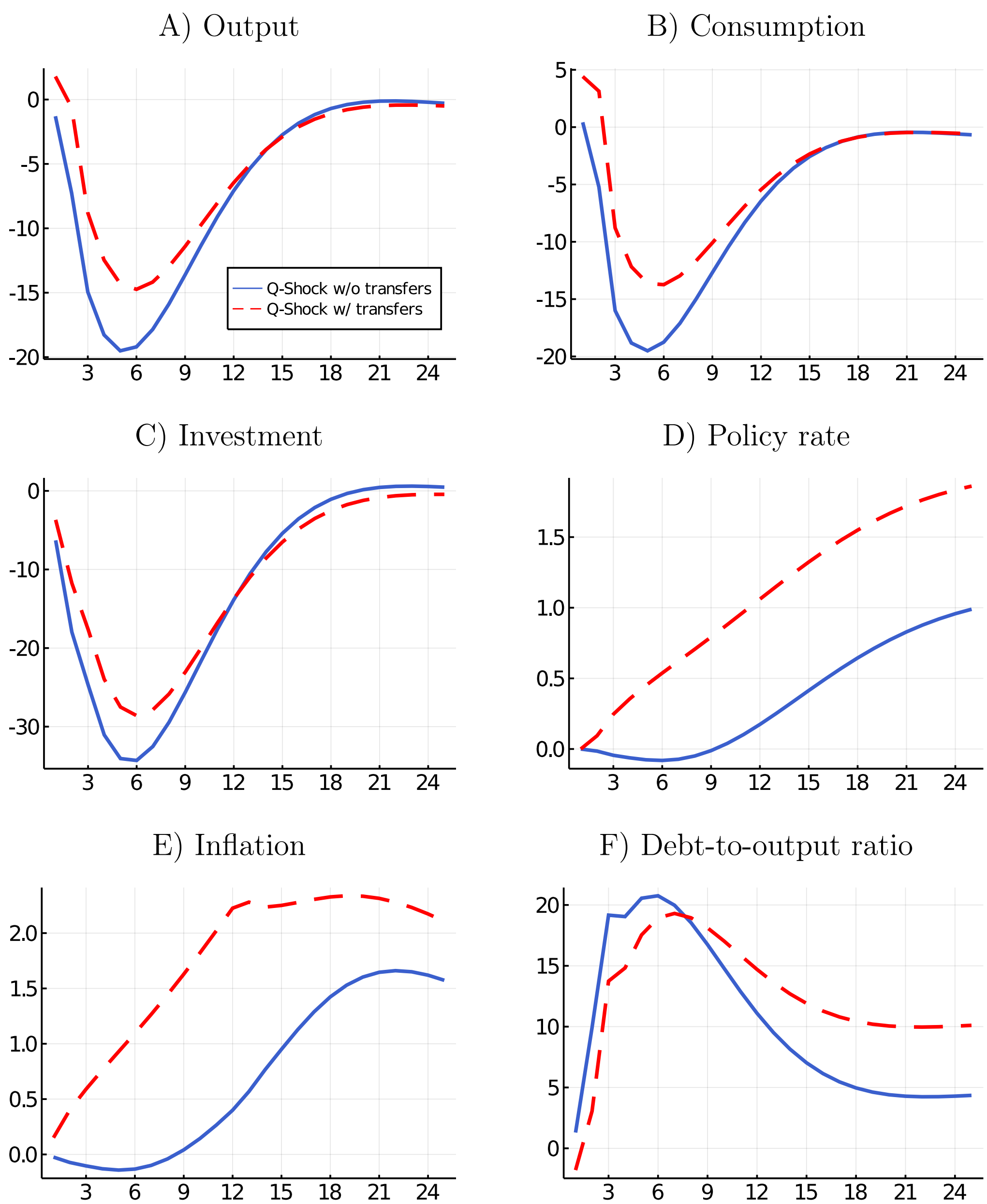

Figure 4: Dynamic adjustment to Q-shock with and without fiscal transfers. Notes: Red dashed line shows response w/ transfers, blue solid line w/o; see Figure 2 for details on the Q-shock. Y-axis: Percentage deviation from steady state, annualized percentage points in case of (y-o-y) inflation and interest rate. X-axis: Months.

Figure 4 shows the adjustment of the economy to the Q-shock with and without the transfer payments under the CARES Act. The blue solid lines serve as a natural 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 red 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 difference for the adjustment dynamics. With transfers to households, the recessionary impact of the Q-shock is substantially reduced. Output, shown in Panel A, declines by 15% rather than by 20% under the no-transfer benchmark. This is because the transfer is successful in stabilizing consumption (Panel B). It reduces its maximum decline to about 13% as opposed to almost 20% under the no-transfer benchmark. Note also that the effect of the transfer payment is strongest during the first six months. This is the period when most of the transfer payment comes online.

The transfer payments also mitigate the adverse impact of the Q-shock on investment (Panel C), although to a lesser extent than in the case of consumption. Panel D shows the response of the policy rate. It is declining somewhat in the absence of transfers because in this case the Q-shock is deflationary (Panel E). This is because a fraction of final goods is also put under quarantine (Guerrieri et al., 2020). In the presence of transfers, inflation increases gradually and plateaus at some 2% above its steady-state level after about 12 months. This, in turn, induces a gradual increase in the policy rate.

Lastly, we turn to the response of public debt. Panel F shows the adjustment of the debt-to-output ratio to the Q-shock, again with and without transfer payments. It increases in both instances, but in the short, run the increase is actually smaller in the case where there are transfer payments.[15] However, in the medium term, as the output effect of the transfer payments dissipates and interest rates pick up, the debt-to-output ratio exceeds the level under the no-transfer benchmark. At the end of the period under consideration, the debt ratio is about 5 percentage points higher. This difference is rather lasting because we assume that debt is only slowly reverting back to the steady-state level—as taxes and government spending adjust in equal proportions in order to stabilize debt (not shown).[16]

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 not. Panel A in Figure 5 displays the transfer multipliers for our baseline specification. As before, we measure time in months along the horizontal axis and measure the cumulative multiplier along the vertical axis: the cumulative output change in all periods up to horizon k that is due to the transfer, divided by the cumulative transfer

[15] Erceg and Lindé (2014) identify conditions under which fiscal stimulus may lower the debt-to-output ratio, notably in the context of the zero lower bound. Similarly, there is evidence that contractionary fiscal policy measures can at times raise the debt-to-output ratio (Born et al., 2020).

[16] We abstract from the possibility that the economic fallout from the COVID-19 pandemic impairs fiscal sustainability, since it is arguably less of an issue in the U.S. Huertgen (2020) analyzes fiscal sustainability during the COVID-19 pandemic for selected euro-area countries.

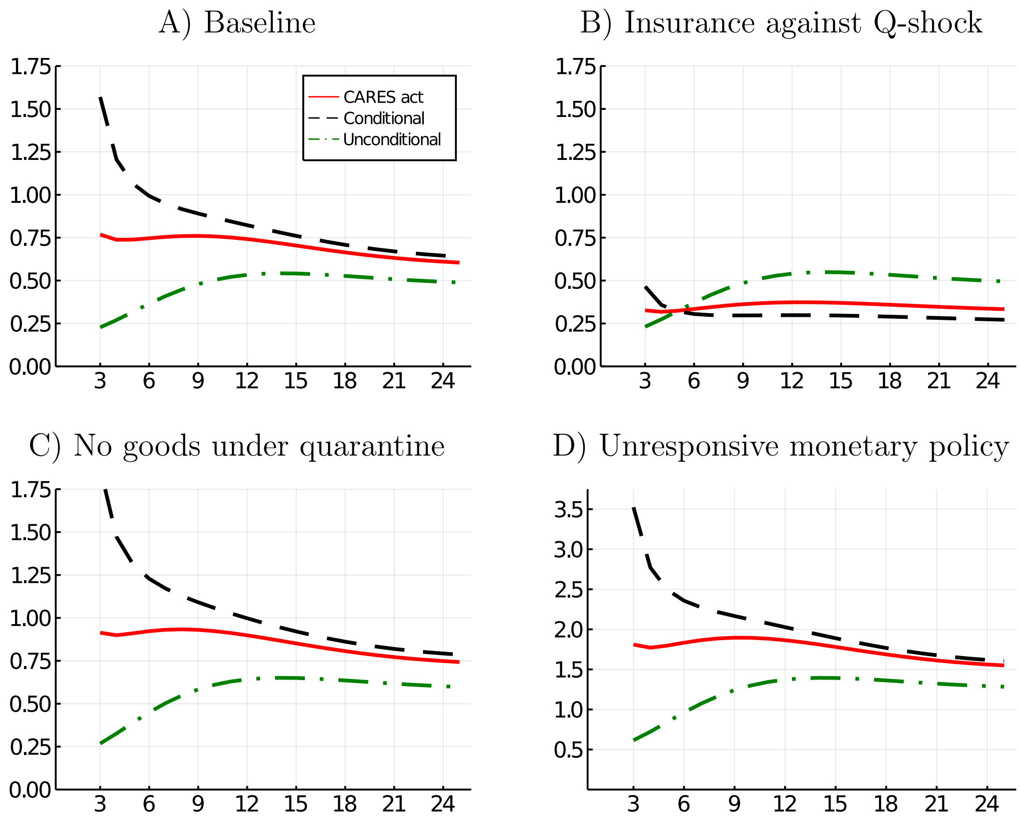

Figure 5: Cumulative transfer multipliers. Notes: Cumulative multiplier computed as $\sum_{j=1}^{k} y_i / \sum_{j=1}^{k} t_i$, where y_i is the deviation of output from baseline, t_i is the transfer payment (both measured in percentage points of steady-state output), and k is the time since announcement in period 1 (February 2020), measured along the horizontal axis. We report multipliers from period $k = 3$ onward, since transfers are zero or very small in the first two periods.

payments up to the same horizon (see, for instance, Ramey, 2019). In the figure, we show the cumulative transfer multiplier from period 3 onward because the largest part of transfer payments comes online only later.[17]

The red solid line represents the multiplier of the total transfers to households provided for by the CARES Act. Initially, that is, in period 3, the cumulative multiplier is about 0.75. This means that for every dollar disbursed to households up to April, total income increases by 75 cents on average. This is higher than the range of values obtained in model-based analyses (Coenen et al., 2012; McKay and Reis, 2016; Giambattista and Pennings, 2017). It squares with time-series evidence put forward by Gechert et al. (2020). To shed more light on this result, we decompose the multiplier: the black dashed line and the green dashed-dotted

[17] In fact, in the very first period there is no payout and the (anticipated) transfer boosts output. As result the multiplier is infinite.

line in the same panel represent the multiplier for the conditional and the unconditional transfer under the CARES Act. Here we obtain values of 1.5 and 0.25, respectively. The overall multiplier is a weighted average of the two.

The difference is rather stark: the conditional transfer multiplier is about 6 times as large as the unconditional transfer multiplier. Several aspects are driving this result. First, the conditional transfer is directed to the unemployed who have a high marginal propensity to consume. Importantly, 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": households that operate near their liquidity constraint may raise expenditures in response to an expected increase in income in the near future. This effect is not present in TANK models since there the borrowing constraint of non-optimizing households is always binding. Second, the conditional transfer boosts aggregate demand already in period 1 because it reduces income risk. This happens even though transfers have not yet materialized. Finally, note also that over time the cumulative multiplier of conditional transfers declines sharply with receding income risk. Instead, the unconditional transfer increases somewhat in the medium run. As a result, cumulative multipliers become more aligned for longer horizons. For a two-year horizon we obtain values between 0.5 and 0.7.

To see more in detail how both types of transfers work, we contrast in Figure 6 the adjustment dynamics under the no-transfer benchmark with the outcome that would obtain if either only conditional or unconditional transfers were put in place. The blue solid lines represent the benchmark, as already shown in Figure 3 above. The black dashed line represents the dynamics in the case where there is the conditional transfer, and the green dash-dotted line represents the case of unconditional transfers. The unconditional transfer, worth 5% of quarterly GDP, is paid out lump-sum to all households starting in March (period 2). The strongest effect takes places in the month when the transfer actually takes place, but the overall impact is moderate. The conditional transfer, instead, generates effects that are both stronger but also more front-loaded, for reasons given above. Recall that the two transfers differ in size, with conditional transfers roughly three times as large as unconditional transfers. Yet this difference in size does not matter for the cumulative multiplier since we normalize the output effect with the total amount of transfers in each instance.

We shed further light on the conditional transfer by considering once more an economy in which the income of workers with the same productivity level is pooled—thereby providing insurance against the idiosyncratic income risk caused by the Q-shock. By and large, this kind of insurance has a moderate effect on the adjustment dynamics to the Q-shock; see again Figure A.1 in the appendix. However, it is crucial for the conditional multiplier, as

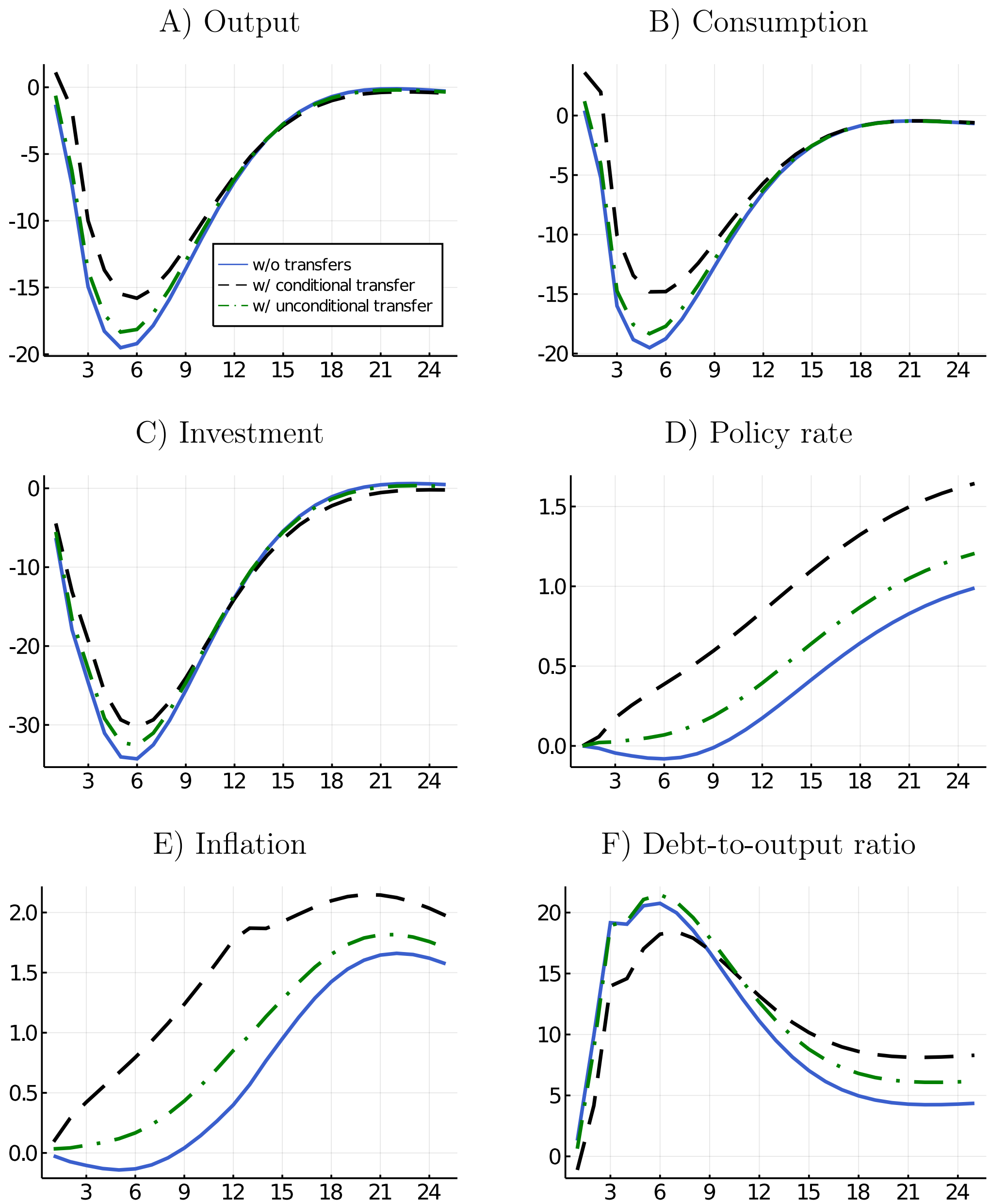

Figure 6: Dynamic adjustment to Q-shock w/o, w/ unconditional, and w/ conditional fiscal transfers. Notes: Black dashed line shows response w/ conditional transfers, green dash-dotted w/ unconditional transfers, and blue solid line w/o; see Figure 2 for details on the Q-shock. For variable descriptions, see Figure 3. Y-axis: Percentage deviation from steady state, annualized percentage points in case of (y-o-y) inflation and interest rate. X-axis: Months.

Panel B of Figure 5 shows: here we display cumulative multipliers for the economy with Q-shock insurance and observe a strong decline in the multiplier for conditional transfers relative to the baseline shown in Panel A of the same figure. In fact, with insurance, the conditional-transfer multiplier is now roughly of the same size as the unconditional-transfer multiplier.

In Panel C of Figure 5, we report the cumulative multiplier for a Q-shock scenario in which no final goods are put under quarantine. As discussed above, this plays a central role in the adjustment dynamics to the Q-shock. And yet, we find that whether or not final goods are put under quarantine is of little consequence for the transfer multiplier. The cumulative multipliers shown in Panel C resemble those shown in Panel A rather closely. This holds for conditional and unconditional transfers alike and hence for the overall multiplier effect of the transfers under the CARES Act.

Lastly, we turn to the role of monetary policy in the multipler. That monetary policy plays a key role for the transmission of fiscal policy has been a major theme in the analysis of the government spending multiplier (Christiano et al., 2011; Leeper et al., 2017; Woodford, 2011). Hence, we briefly look into how monetary policy alters 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 assuming substantial interest rate smoothing: we set $\rho_R = 0.997$ in the interest rate rule above and refer to this case as "unresponsive" monetary policy.[18] We report the cumulative multiplier under the unresponsive monetary policy in Panel D of Figure 5. We find that multipliers are strongly shifted upwards. The values for the cumulative multiplier in period 3 are now about unity (overall), 3.5 (conditional transfers) and 0.5 (unconditional transfers). This is because under the unresponsive monetary policy, the interest rate increases less in the short run as the inflationary pressure due to the fiscal stimulus mounts. As the real interest rate increases less, there is less crowding out of private expenditure.

4.4 Distributional Effects

The distributional effects of the economic fallout from the COVID-19 pandemic in general and the lockdown measures in particular are widely debated (e.g. Adams et al., 2020). The distributional impact of the transfer scheme is in some sense a necessary condition for it to have an effect at all. Since our framework puts household heterogeneity front and center, it lends itself naturally to assessing distributional aspects. However, in what follows we focus on the response of Gini coefficients to the Q-shock and to the transfer payments, since a full-fledged analysis of their distributional effects is beyond the scope of the present paper.

Figure 7 displays the impulse responses of various Gini coefficients to the Q-shock as such (blue solid line) and the Q-shock coupled with the transfer payments under the CARES Act

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

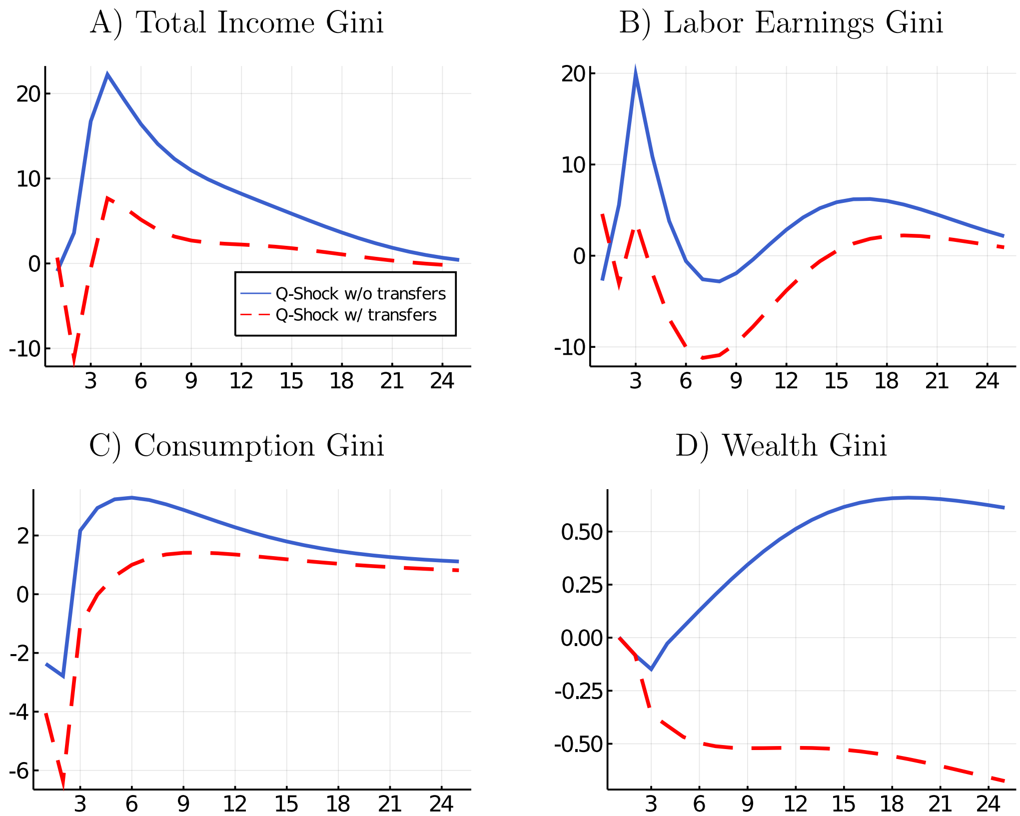

Figure 7: Dynamic adjustment to Q-shock with and without fiscal transfers. Notes: Red dashed line shows response w/ transfers, blue solid line w/o; see Figure 2 for details on the Q-shock. Y-axis: Percentage deviation from steady state, annualized percentage points in case of (y-o-y) inflation and interest rate. X-axis: Months.

(red dashed line). The Q-shock as such drives up the Gini coefficients of total income and labor earnings, shown in panels A and B. They peak with an increase of 20% in months 3 to 4 when the fraction of households in quarantine is largest. Likewise, albeit after initial falls, the Q-shock also pushes up the wealth (Panel D) and consumption Ginis, which eventually peak at 0.7% and almost 3% above their respective steady-state levels.

To understand these non-monotonicities note that the Q-shock initially affects investment the most. This has a strong impact on the wealthiest households because the price of capital falls drastically. This explains why wealth and also consumption inequality initially fall in response to the Q-shock. However, once a substantial fraction of households is in quarantine, all four measures of inequality increase.

The transfer payments are quite successful in containing the increase in inequality caused by the Q-shock. The stimulus is highly progressive in its distributional consequences such that the Gini coefficients of earnings and income actually fall by up to 10% during the first six months, when most payments are made, and are basically flat afterwards. This substantially lowers consumption inequality relative to the case w/o transfers. The wealth Gini shows the starkest contrast in responses without and with transfers. The long-term build-up in public debt under the CARES Act pushes up real interest rates on liquid assets and therefore lowers the liquidity premium. This most strongly adversely affects wealthier households, as they hold most of the illiquid assets (see also Bayer et al., 2020a).

5 Conclusion

How large is the transfer multiplier? As always the answer is: "it depends." Still in this case, this is particularly true. For the effects of the transfer payments implemented under the CARES Act differ fundamentally depending on whether transfers are conditional on the recipient being unemployed or not. To see this, we develop a benchmark scenario of a COVID-19-induced recession. It captures, in particular, that a substantial fraction of the economy has been shut down in response to the COVID-19 pandemic. Specifically, our model-based analysis features a quarantine state for households that reduces the effective amount of labor and capital in aggregate production. At the same time, a fraction of final goods become temporarily unavailable for consumption. This "Q-shock" generates a large recession: economic activity declines by almost 20% in the absence of transfers.

While the shock impacts the economy through various channels, a key aspect for our analysis is that it raises income risk at the household level. This is essential for understanding why conditional transfers are very effective in stabilizing the economy: by making payments conditional on the income loss in the Q-state, they limit income risk from an ex-ante point of view. In addition, they are targeted to households with a high marginal propensity to consume. For the short run, we find the multiplier of conditional transfers to be as high as 1.5. This is exceptionally high compared to the values typically reported in the literature. Instead, we obtain a short-run multiplier of 0.25 for unconditional transfers—in line with much of the earlier literature on the transfer multiplier.

Transfers to households are only a part of the fiscal stimulus under the CARES Act. Among other things it also provides for transfers to firms. It would be interesting to assess the impact of these policies as well as other fiscal-policy measures implemented in countries outside of the U.S. As our analysis makes clear, the effect of such measures is bound to interact in non-trivial ways with the specific conditions under which they are put in place. We leave a more comprehensive analysis for future research.

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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 Additional Figures

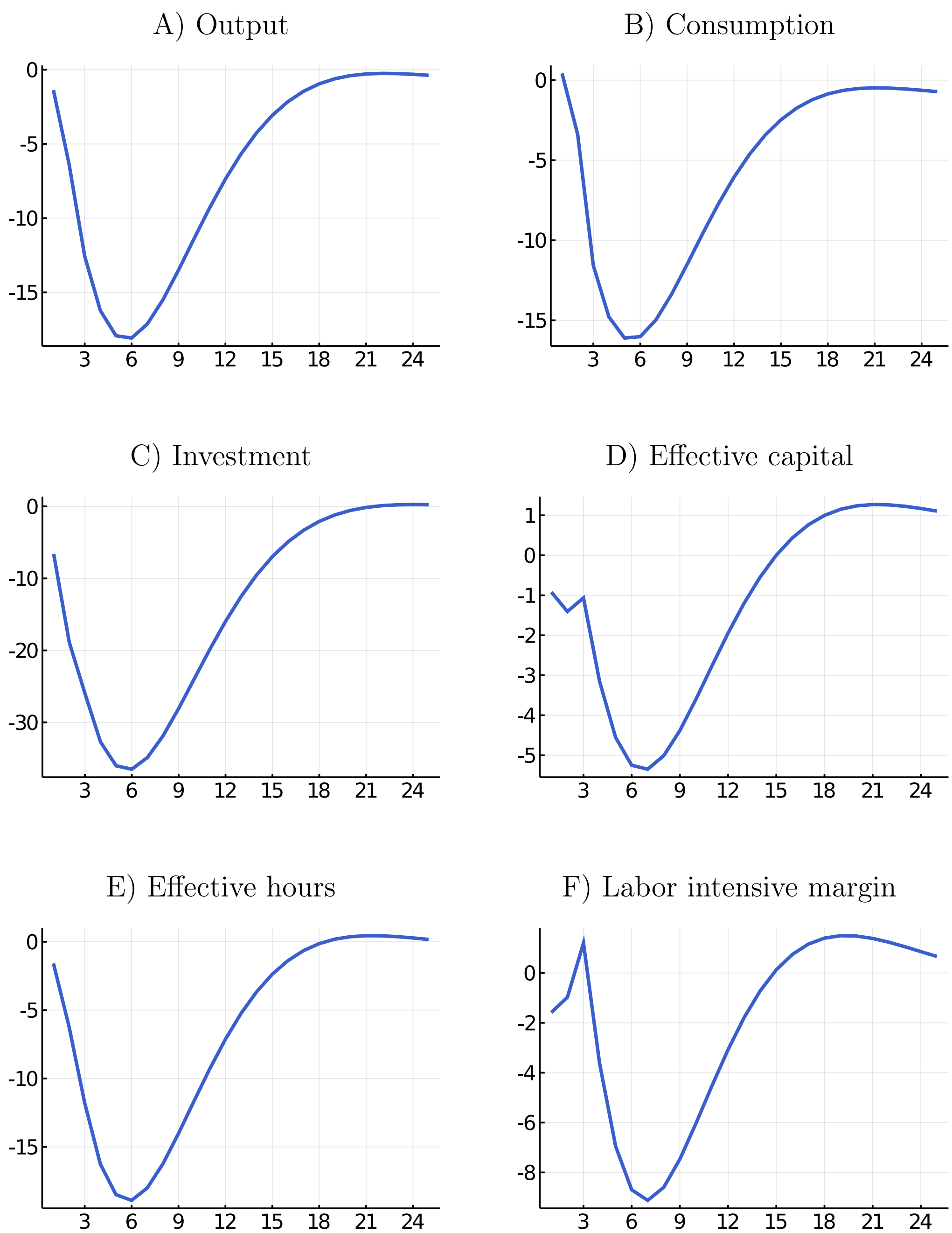

Figure A.1: Dynamic adjustment to Q-shock—perfect insurance against Q-shock. Notes: Impulse responses to quarantine shock without fiscal stimulus, see Figure 2 for details on the Q-shock. For variable descriptions; see Figure 3. Y-axis: Percent deviation from steady state. X-axis: Months.

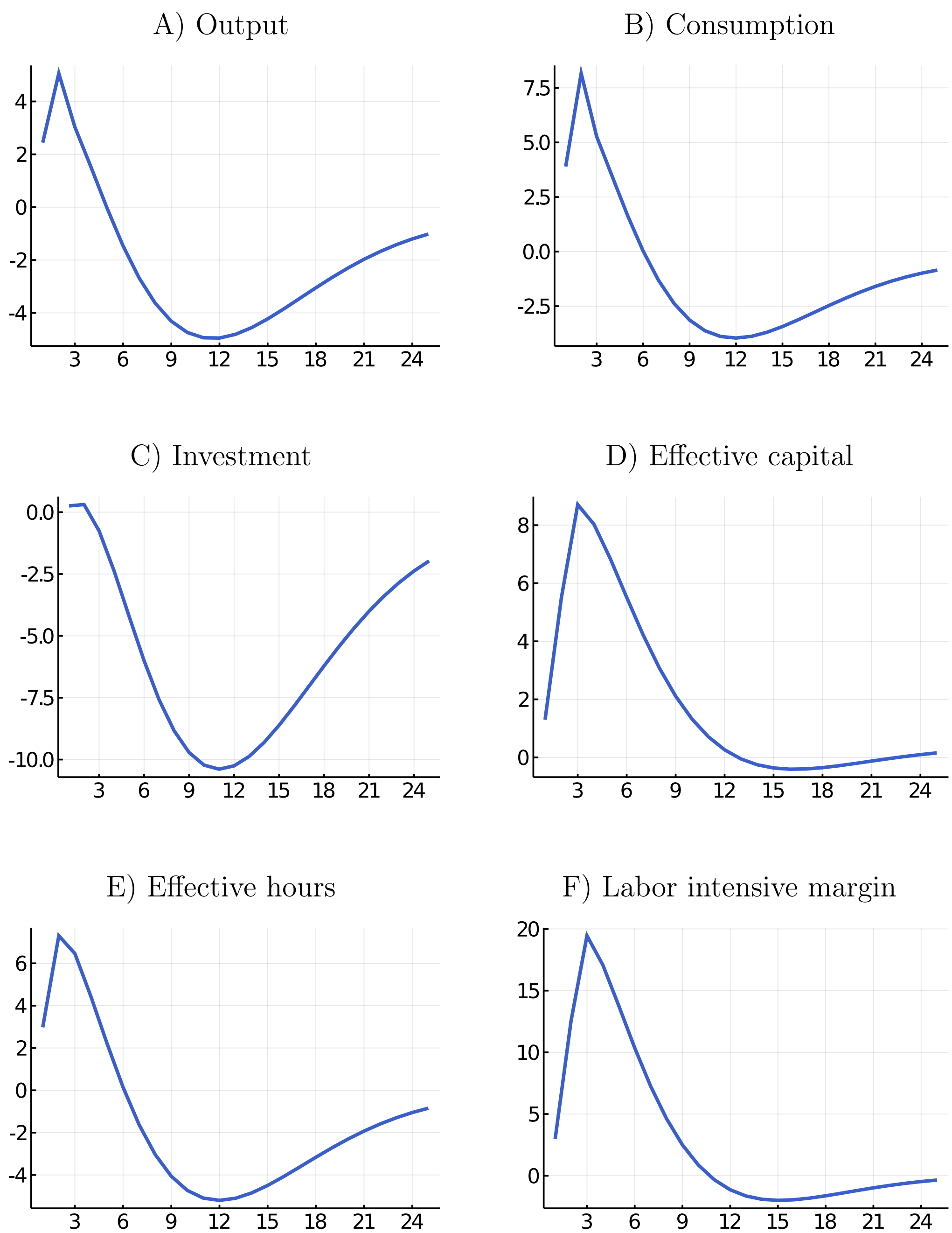

Figure A.2: Dynamic adjustment to Q-shock—no unavailability of varieties. Notes: Impulse responses to quarantine shock without fiscal stimulus, see Figure 2 for details on the Q-shock. For variable descriptions; see Figure 3. Y-axis: Percent deviation from steady state. X-axis: Months.