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ABSTRACT

We build a model that combines (i) heterogeneous households with incomplete markets, and (ii) state-dependent pricing with strategic complementarities by firms, to analyze the effects of large macroeconomic shocks and policy interventions. Both features significantly influence the transmission of fiscal stimulus and monetary policy—heterogeneous households because of failures of Ricardian equivalence, and state-dependent pricing because of its nonlinear effects on inflation. We use our model to quantify how monetary and fiscal policy shaped macroeconomic dynamics in response to the large shocks of 2020, and how alternative policy choices could have led to different aggregate and distributional outcomes. We find large departures from Ricardian equivalence and strong stepping-on-a-rake effects of interest rate changes. The large unfunded fiscal transfer program helped prevent deflation in 2020 and significantly raised output throughout 2021 and 2022, but led to permanently higher prices. The monetary easing through 2020 and 2021 also contributed to preventing deflation, but had a minimal impact on GDP. The monetary tightening from 2022 lowered the maximum inflation rate, but contributed to persistently above-trend inflation. These policies led to net welfare gains for low-wealth households and net welfare losses for high-wealth households, but those welfare effects are due to incomplete markets for idiosyncratic risk not aggregate stabilization. Alternative commitments to funding fiscal stimulus could have achieved similar short-term effects on inflation and output with a much smaller long-term increase in the price level.

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An online appendix is available at http://www.nber.org/data-appendix/w35400

1 Introduction

We develop a model for studying how monetary and fiscal policies affect the economy in response to large economic shocks. We use it to evaluate the effects of the COVID-era fiscal and monetary interventions in the United States. Our methodological innovation is to combine two features that the recent literature has shown to be crucial for understanding household and firm behavior: heterogeneous households with incomplete markets, and state-dependent pricing by firms. While these features have been studied extensively in isolation, we argue that their interaction becomes particularly relevant when analyzing large shocks and associated policy responses, such as those experienced by much of the developed world during the first half of the 2020's.

The COVID-19 pandemic and subsequent policy responses offer an unprecedented laboratory for studying how large economic shocks interact with monetary and fiscal policy. The episode featured a dramatic initial decline in economic activity, followed by extraordinary policy interventions: (i) direct fiscal transfers that were both larger and more targeted than in previous recessions, and for which the timing of *if*, *how* and *when* they would be financed was unclear; and (ii) sharp movements in monetary policy which lowered rates to the zero lower bound, followed by a rapid tightening. The scale of both the initial shock and policy responses raises important questions about whether frameworks that employ a representative household, fixed re-pricing frequencies, or local approximations remain valid for analyzing policy transmission in such extreme circumstances.

We use our model to answer a series of counterfactual questions about this episode, including how the economy would have evolved in the absence of these large fiscal and monetary interventions, and how alternative policy choices - such as different commitments about funding the stimulus packages, and alternative paths for the monetary policy rate - would have affected macroeconomic dynamics and household welfare.

Why Heterogeneous Agents? The motivation for incorporating household heterogeneity comes from empirical observations about household behavior. First, the marginal propensity to consume out of transitory income varies substantially across households and averages around 20-25% at quarterly frequencies. Second, much of the fiscal stimulus during COVID-19 took the form of direct transfers that were explicitly targeted toward lower-income households. Third, household cash balances increased dramatically during this period, particularly at the bottom of the income distribution, and remained elevated for several years. One consequence of these features of household spending behavior is that Ricardian equivalence fails, and hence the timing of if, when and how the government pays for a fiscal stimulus program matters for its effect on the economy. Since representative agent frameworks abstract from these features, they miss important aspects of how fiscal policy transmits through the economy. Additionally, heterogeneous agent models are a natural setting in which to study the effects of monetary and fiscal policy when governments run a persistent primary deficit. Finally, evaluating the desirability of these policy interventions requires assessing their distributional consequences because, as we will show, despite the large aggregate effects on the economy, the welfare consequences stem almost entirely from their redistributive effects, not their effects on macroeconomic aggregates.

Why State-Dependent Pricing? The motivation for incorporating state-dependent pricing comes from microeconomic evidence about firm price-setting behavior. The frequency of price changes in the US economy typically averages around 12% per month in normal times. However, during the recent inflation surge, the frequency of price adjustment increased to around 20%, driven by a doubling of the frequency of price increases. This state-dependence in price setting behavior, which is absent in standard time-dependent models, proves crucial for understanding how large shocks propagate through the economy. The degree of price flexibility, and hence the slope of the implicit "Phillips curve", depends on the size of the policy response and the extent to which policy smooths the impact of inflation over time - which we find to be an important way that interest rate policy affects the economy.

We adopt a model of state-dependent pricing that is consistent with standard steady-state price-setting statistics but can also match features of the most recent episode that existing models have found challenging to explain: the large increase in the frequency of price increases with almost no change in either the frequency of price decreases or the average absolute size of price changes. We describe our assumptions about pricing frictions in Section 2.2.

These Features Matter for Large Shocks We start by conducting a series of simple exercises to assess the importance of heterogeneous vs representative agents, and state-dependent vs time-dependent pricing, when studying large and small shocks, and to illustrate the economic forces through which fiscal policy and interest rate changes affect the economy in this environment. We find that although the distinction between heterogeneous and representative agents, or between state-dependent and time-dependent pricing, may not be quantitatively important for analyzing small shocks, it becomes crucial when studying episodes featuring large shocks and policy responses. Heterogeneous agents matter because the size and targeting of fiscal transfers affects their aggregate impact through the distribution of marginal propensities to consume. State-dependent pricing matters because the frequency of price adjustment endogenously responds to the size of shocks and policy changes, altering their transmission to inflation and output.

Unfunded and Funded Fiscal Stimulus In our model, an unfunded fiscal stimulus program generates an inflationary boom and a permanent increase in the price level, as in similar representative agent models. However, the presence of heterogeneous agents and incomplete markets introduces additional effects. First there is a larger short-run effect on inflation because real redistribution that arises from inflation leads to additional upward pressure on prices, as in Kaplan et al. (2023). When the transfers are targeted towards low wealth households as they were in the

United States, this is further exacerbated. Second, the short-run overshooting of inflation leads to a larger long-run effect on prices. Third, and most importantly, we find that the departure from Ricardian equivalence is large, so that even a fully funded stimulus program generates a temporary inflationary boom, whereas the equivalent policy in a representative agent economy has no effect on prices or inflation. This turns out to have important implications for counterfactual effects of alternative financing policies.

Interest Rate Policy with Long-Term Debt In our model, higher nominal rates that are not accompanied by a fiscal commitment to raise future surpluses, can temporarily lower inflation by lowering the nominal price of long-term government debt. We find these "stepping-on-a-rake" effects, as they have been described by Sims (2011), to be strong. Higher nominal rates can be effective at temporarily lowering inflation, but at the cost of persistently higher inflation in the medium term and a price level that ends up higher than it started.

Modeling the Covid Shock We then use our model to ask counterfactual questions about the policy response to the pandemic, with a focus on the US experience during and after COVID-19. We allow for two structural disturbances, one on the supply side of the economy and one on the demand side of the economy. The demand disturbance is a series of shocks to households' marginal utility of consumption and the supply disturbance is a series of shocks to labor productivity in the intermediate goods sector. We estimate the paths of innovations to these disturbances to exactly match the observed dynamics for GDP and inflation, conditional on paths for fiscal and monetary variables that match those in the data. We assume that the fiscal stimulus programs are unexpected in each quarter, and that expectations of future monetary policy rates are given by consensus forecasts from the FOMC Summary of Economic Projections. Our methodology is effectively a non-linear inversion exercise, given an assumed information structure for shocks and policy.

The Effects of Policy The model reproduces key features of the data including: (i) the magnitude of the initial contraction and subsequent recovery in output, (ii) the path of government deficits and debt, (iii) the delayed but sharp increase in inflation, and (iv) the eventual monetary policy tightening. Moreover, the model accounts for the observed increase in price adjustment frequency and the persistent elevation of household cash balances, particularly among low-income households.

We evaluate the effects of monetary and fiscal policy through a series of counterfactual exercises in which we simulate outcomes under the estimated sequence of shocks but with different assumptions about policy. Our baseline exercise asks how the economy would have evolved without the policy interventions. We find that monetary and fiscal policy were quantitatively very important in smoothing output and inflation over this period. Without any policy response, GDP would have fallen by around 15% in 2020 — significantly more than the roughly 10% decline observed — and would have recovered much more slowly. Inflation would have been far more volatile, with a sharp deflationary episode throughout 2020 followed by a much larger and more prolonged inflation surge peaking near 15% in mid-2022. However, without the policy responses both the deflation and subsequent inflation would have been temporary, and the long-run price level would have returned to trend, rather than settling at approximately 17% above trend.

The large unfunded fiscal transfer program was the dominant policy force. It was almost solely responsible for supporting GDP and preventing more than half the deflation that would otherwise have occurred. While the fiscal stimulus did not cause the inflation surge of 2021 and 2022 — which was primarily driven by the collapse in productivity — it did bring forward the run-up in inflation and is largely responsible for the permanently higher price level. A commitment to fund the stimulus through future taxes or transfers could have achieved similar short-term support for output and prices, but with substantially less permanent inflation, at the cost of either a future economic contraction or slightly weaker recovery depending on whether the required surpluses are raised through higher future labor taxes or lower future transfers.

Monetary easing through 2020 and 2021 contributed to preventing deflation but had minimal impact on GDP. The monetary tightening beginning in 2022 substantially reduced the peak of the inflation surge — from around 15% to below 10% — consistent with the stepping-on-a-rake mechanism. However, the cost was persistently above-trend inflation for several years thereafter, as the reduction in the long-term bond price temporarily suppressed inflation at the expense of higher inflation later. An earlier rate hike would not have improved outcomes: starting the tightening cycle a year sooner would have produced a much higher peak in inflation because the dis-inflationary phase of the stepping-on-a-rake effect would have dissipated before the supply-driven inflation surge arrived.

Welfare Implications The combined monetary and fiscal interventions produced aggregate welfare gains of around $9,000 per household. Fiscal policy generated welfare gains for households in the bottom 75 percent of the wealth distribution—equivalent to a transfer of around $20,000 per household for the bottom half —financed by welfare losses for those in the top 25 percent, who bore the cost of the policy through lower real returns on their wealth. Monetary policy provided more modest but broadly distributed gains across the wealth distribution.

Crucially, these welfare effects do not primarily reflect successful aggregate stabilization. The distribution of welfare effects is nearly identical when the same policies are implemented in the absence of the pandemic shocks. The welfare consequences stem almost entirely from the redistributive and market-completing properties of these policies in an economy with incomplete markets and heterogeneous households, not from their role in smoothing the aggregate effects of the pandemic. Through the lens of our model, a policy maker who favors these interventions in the wake of the pandemic should favor them in normal times too. This is a reminder of the relative welfare gains from completing markets versus aggregate stabilization.

Literature In the interest of both space and a trend towards unnecessarily broad and tangential literature reviews in economic papers, we defer our discussion of related papers to the points in our analysis where they are most relevant. Our paper builds on and draws from many vast literatures, including heterogeneous agent models, New Keynesian models, menu cost models, models of the Covid pandemic, models of funded and unfunded stimulus, the fiscal theory of the price level, welfare costs of stabilization, redistributive effects of inflation, non-linear dynamics. A meaningful review would be a paper on its own. Rather than arbitrarily choosing papers to cite, we mention Bianchi et al. (2023) and Alves and Violante (2026)—the two papers we are aware of that recover a time-series of structural shocks for the 2020's by inverting a fully-specified general equilibrium model and use it to perform counterfactual analyses to learn about the effects of policy.[1]

Both papers are motivated by similar objectives to us but use different models and reach different conclusions. Bianchi et al. (2023) share our emphasis on the financing of fiscal stimulus. However because they work in a representative-agent setting with Ricardian equivalence, their framework is not well suited to studying fiscal transfers (and targeted transfers, in particular), nor an economy with steady-state primary deficits. It also cannot speak to the key welfare consequences of the policy interventions, which arise from redistribution. Alves and Violante (2026) is the closest paper to ours. They work with a heterogeneous agent model that includes a richer theory of labor supply than ours does. However, they abstract from state-dependent pricing, restrict attention to fully funded fiscal policies and use first-order methods to recover structural shocks – all features that we show to be essential for drawing conclusions about the counterfactual effects of policies when faced with shocks and policies of the size of those experienced by the United States in the 2020s. Nonetheless, despite these differences, their model and ours agree on a key normative conclusion: even though policy was important for stabilizing aggregate output and inflation, the welfare effects of these interventions derive almost entirely from cross-sectional redistribution, not from the stabilization per se.[2]

2 Model

2.1 Households

The economy is populated by a continuum of infinitely-lived households indexed by $j \in [0, 1]$. Households are heterogeneous in their productivity and asset holdings, and face idiosyncratic productivity shocks. They choose consumption, labor supply, and asset holdings to maximize expected

[1] Other related papers include Faria-e Castro (2021); Bayer et al. (2023); Gagliardone and Gertler (2023); Comin et al. (2023); Bernanke and Blanchard (2025); Andolfatto and Martin (2026).

[2] Alves and Violante (2026) were motivated to explore this force in their model after reading an early draft of this paper.

lifetime utility:

$$\max \mathbb{E}_0 \int_{t=0}^{\infty} e^{-\rho t} \left(e^{\mathcal{E}_t^C} \log c_{jt} - \psi \frac{h_{jt}^{1+\frac{1}{\nu}}}{1+\frac{1}{\nu}} \right) dt \tag{1}$$

subject to the flow budget constraint:

$$dA_{jt} = \left[i_t A_{jt} + \omega_{jt} h_{jt} W_t + P_t d_{jt} - P_t \tau_{jt} - P_t c_{jt} \right] dt \tag{2}$$

and the borrowing constraint, $A_{jt} \geq 0$.

Households supply labor h_{jt} at nominal wage rate W_t and receive an idiosyncratic productivity shock ω_{jt}. They can save in nominal assets A_{jt} which earn nominal interest rate i_t. They receive nominal dividends $P_t d_{jt}$ from firms and pay nominal taxes (net of transfers) $P_t \tau_{jt}$ to the government. The common preference shock $\mathcal{E}_t^C$ affects the marginal utility of consumption and is equal to 0 in the steady-state. We discuss its dynamics outside steady-state in Section 5.

The idiosyncratic productivity shock ω_{jt} follows an N-state Poisson process with switching intensities $\lambda_{\omega,\omega'}$. We assume $\omega_{\min} > 0$ and normalize $\int_{j=0}^{1} \omega_{jt} dj = 1$ for all t. A dividend distribution rule $\mathcal{D}_t$ maps idiosyncratic productivity into real dividend income, $d_{jt} = \mathcal{D}_t(\omega_{jt})$. A tax and transfer function $\mathcal{T}_t$ maps real labor and dividend income, which we denote by $x_{jt} := \omega_{jt} h_{jt} \frac{W_t}{P_t} + d_{jt}$ into real net tax payments, $\tau_{jt} = \mathcal{T}_t(x_{jt})$. We describe these functions in Section 3.

We define $a_{jt} = A_{jt}/P_t$ as real assets held by household j and $\mu_0^h(a, \omega)$ as the initial distribution of households across assets and productivity. Given paths for aggregate prices and wages $\{W_t, i_t, P_t\}$ and functions $\{\mathcal{T}_t, \mathcal{D}_t\}$, the household problem can be solved recursively to obtain paths of policy functions for consumption $c_t(a, \omega)$ and hours $h_t(a, \omega)$, as well as paths for the distribution of households over assets and productivity $\mu_t^h(a, \omega)$. We take the terminal condition for the household value function to be the time-invariant solution, consistent with the experiments we will run in which the economy starts and returns to its steady-state equilibrium.

2.2 Production

The production side of the economy consists of three types of firms: final goods producers, retailers, and intermediate goods producers.

National Accounting We denote gross output of final goods as Y_t, final goods used as materials in production of intermediate goods as M_t, and GDP as $Y_t^{\text{GDP}} = Y_t - M_t$. GDP can be used for household consumption and government purchases, $Y_t^{\text{GDP}} = C_t + G_t$. Intermediate goods are denoted by I_t.

Final Goods Producers A representative firm aggregates varieties of goods y_j, $j \in [0,1]$ into the final good Y according to the production function:

$$Y_t = \left(\int_0^1 (\zeta_{jt} y_{jt})^{\frac{\epsilon-1}{\epsilon}} \, dj \right)^{\frac{\epsilon}{\epsilon-1}} \tag{3}$$

where ζ_{jt} is a demand shifter for variety j and ϵ is the elasticity of substitution between varieties. The demand shocks evolve according to independent Ornstein-Uhlenbeck processes

$$d \log \zeta_{j,t} = -\theta_\zeta \log \zeta_{j,t} dt + \sigma_\zeta dB_{\zeta,jt}. \tag{4}$$

The firm maximizes profits by choosing quantities of each variety, taking prices as given,

$$\max_{y_{jt}, Y_t} P_t Y_t - \int_0^1 p_{jt} y_{jt} dj. \tag{5}$$

This yields demand for variety j:

$$y_{jt} = \zeta_{jt}^{\epsilon-1} \left(\frac{p_{jt}}{P_t} \right)^{-\epsilon} Y_t \tag{6}$$

where the price of final goods, which is also the aggregate price level is defined by the aggregator

$$P_t = \left(\int_0^1 \left(\frac{p_{jt}}{\zeta_{jt}} \right)^{1-\epsilon} dj \right)^{\frac{1}{1-\epsilon}}. \tag{7}$$

Inflation is defined as the rate of change of the price index, $\pi_t := \frac{\dot{P}_t}{P_t}$.

Retailers There is a monopolistic retailer for each variety $j \in [0,1]$. Retailers purchase quantities $I_{j,t}$ of a homogeneous intermediate good in a competitive market at price $P_{I,t}$. They transform the intermediate good into their unique variety j according to the production function

$$y_{j,t} = \frac{I_{j,t}}{z_{j,t}}, \tag{8}$$

where $z_{j,t}$ are idiosyncratic productivity shocks that evolve according to independent Ornstein-Uhlenbeck processes

$$d \log z_{j,t} = -\theta_z \log z_{j,t} dt + \sigma_z dB_{z,jt}. \tag{9}$$

Retailers set a price $p_{j,t}$ and sell to final goods producers. Given the demand function (6) and production function (8), the flow real profits for a retailer charging price p are

$$\Pi_t(p, \zeta, z) = \zeta^{\epsilon-1} \frac{1}{P_t} \left(\frac{p}{P_t} \right)^{-\epsilon} Y_t \left(p - z P_{I,t} \right) \tag{10}$$

Pricing Frictions We assume that retailers face two types of pricing frictions. The first is that retailers must exert effort to generate opportunities to adjust their price, as in Alvarez et al. (2022). They choose the arrival rate λ of these opportunities and incur an effort cost given by the functional form proposed by Cavallo et al. (2024),

$$\kappa(\lambda) = (\gamma_0 \lambda)^{1+\gamma_1}, \quad \gamma_0, \gamma_1 > 0. \tag{11}$$

In Section 3 we explain that this cost function is sufficiently flexible to match the key steady-state micro moments of the price change distribution – the average frequency of adjustment, and the mean absolute size and kurtosis of price changes.

The second pricing friction is a perceived cost of large price changes during times of elevated inflation. We specify the cost function as

$$\chi_t(\Delta \log p) = \begin{cases} \gamma_\chi \tilde{\pi}_t^2 \left(|\Delta \log p| - \overline{\mathbb{E}\,|\Delta \log p|} \right)^2 & \text{if} \quad |\Delta \log p| > \overline{\mathbb{E}\,|\Delta \log p|} \text{ and } \tilde{\pi}_t > 0 \\ 0 & \text{else} \end{cases}$$

where $\tilde{\pi}_t$ is an index of recent deviations of inflation from steady state,

$$\tilde{\pi}_t = \frac{1}{\delta_\pi} \int_{s=0}^{t} e^{-\delta_\pi (t-s)} (\pi_s - \bar{\pi}) ds, \quad \tilde{\pi}_0 = 0,$$

and $\overline{\mathbb{E}\,|\Delta \log p|}$ is the mean absolute size of price changes in steady-state. When recent inflation is above its steady-state level, $\tilde{\pi}_t > 0$, firms incur a cost that is increasing in the size of their price change beyond the typical size in the steady-state, $\overline{\mathbb{E}\,|\Delta \log p|}$. The dependence on time in the cost function is due to its dependence on the aggregate inflation rate through the index of recent inflation $\tilde{\pi}_t$. We introduce this pricing friction because it is a simple way to capture the idea that when inflation is high, customers particularly dislike firms changing their prices by large amounts.[3] In Section 3 we describe how we choose γ_χ, which governs the strength of this force, to match the peak increase in the frequency of price increases in 2022.

The solution to the retailer pricing problem consists of paths for (i) the optimal policy function for the arrival rate of adjustment opportunities $\lambda_t(p, z, \zeta)$; (ii) the optimal reset price $p_t^*(z, \zeta)$; and (iii) the distribution of firms across prices, demand shocks and productivity shocks $\mu_t^f(p, z, \zeta)$. Full details of the pricing problem, including the recursive formulation can be found in Appendix A.1.

Intermediate Goods Producers A representative firm produces the intermediate good I using labor L and final goods as materials M according to the production function

$$I_t = e^{\mathcal{E}_t^Z} L_t^\alpha M_t^{1-\alpha}, \tag{12}$$

[3] A micro-founded theory would include fairness considerations and search behavior (Sara-Zaror, 2024; Eyster et al., 2021; Kahneman et al., 1986; Chavanne et al., 2022).

where $\mathcal{E}_t^Z$ is an aggregate productivity shock. The firm maximizes profits taking prices as given

$$\max_{L_t, M_t, I_t} P_{I,t} I_t - W_t L_t - P_t M_t, \tag{13}$$

yielding the intermediate goods price

$$P_{I,t} = e^{-\mathcal{E}_t^Z} \left(\frac{W_t}{\alpha}\right)^{\alpha} \left(\frac{P_t}{1-\alpha}\right)^{1-\alpha} \tag{14}$$

When $\alpha < 1$ the model has a roundabout production structure as in Basu (1995) and Klenow and Willis (2016), yielding a "macro real rigidity", in the language of Ball and Romer (1990). The parameter α governs the resulting degree of strategic complementarity in price setting.

2.3 Government

Taxes and Transfers The government implements fiscal policy through a tax and transfer function applied to real household labor and dividend income

$$\mathcal{T}_t(x) = \varsigma_{1,t} x - \varsigma_{0,t} \tag{15}$$

where $\varsigma_{1,t}$ and $\varsigma_{0,t}$ are time-varying proportional tax rates and lump-sum transfers. The government can also enact fiscal stimulus programs consisting of type-specific lump-sum transfers $\varepsilon_t^\tau(a, \omega)$. The net taxes paid by household j are therefore

$$\tau_{j,t} = \varsigma_{1,t} x_{j,t} - \varsigma_{0,t} - \varepsilon_t^\tau(a_{j,t}, \omega_{j,t}). \tag{16}$$

The real primary surplus (if positive) or deficit (if negative) is given by

$$\begin{aligned} s_t &= \int_j \tau_{j,t} dj - G_t - \mathcal{E}_t^\Pi \\ &= \varsigma_{1,t} Y_t^{\text{GDP}} - \varsigma_{0,t} - \mathcal{E}_t^\tau - (\bar{G} + \mathcal{E}_t^G) - \mathcal{E}_t^\Pi, \end{aligned} \tag{17}$$

where G_t are non-valued government purchases. These consist of steady-state purchases $\bar{G}$ and government spending shocks $\mathcal{E}_t^G$. Aggregate fiscal stimulus payments are given by $\mathcal{E}_t^\tau := \int_j \varepsilon_t^\tau(a_{j,t}, \omega_{j,t}) dj$. We also allow for lump-sum profit subsidies to intermediate goods firms, which are denoted by $\mathcal{E}_t^\Pi$, to capture features of the Covid-era stimulus packages. These are discussed in more detail in Section 5.1.

In steady state, there are no fiscal stimulus payments, spending shocks or profit subsidies, so $\mathcal{E}_t^G = \varepsilon_t^\tau(a, \omega) = \mathcal{E}_t^\tau = \mathcal{E}_t^\Pi = 0$, and the lump-sum transfer and proportional tax rates are constant at $\varsigma_{0,t} = \bar{\varsigma}_0$ and $\varsigma_{1,t} = \bar{\varsigma}_1$. The steady-state tax function is therefore $\bar{\mathcal{T}}(x) = \bar{\varsigma}_1 x - \bar{\varsigma}_0$, and steady-state surpluses are given by $\bar{s} = \bar{\varsigma}_1 \overline{Y^{\text{GDP}}} - \bar{\varsigma}_0 - \bar{G}$. We discuss tax and transfer policies outside of steady-state below.

Government Debt The government issues short-term and long-term bonds. Short-term bonds B_t^S pay an instantaneous nominal return i_t and have market price 1. Long-term bonds are nominal perpetuities with exponentially declining coupons at rate δ_b. We denote the number of outstanding bonds as B_t^δ and the market price of a bond with coupon equal to 1 as Q_t. The nominal market value of government debt is denoted by $B_t := B_t^S + Q_t B_t^\delta$. With prefect foresight, a no-arbitrage condition determines the long-term bond price as

$$dQ_t = [(i_t + \delta_b)Q_t - 1]\, dt, \tag{18}$$

The government budget constraint in terms of nominal market value is

$$dB_t = [i_t B_t - s_t P_t]\, dt. \tag{19}$$

The government budget constraint in terms of growth-adjusted real variables is

$$db_t = [(i_t - \pi_t)b_t - s_t]\, dt = [r_t b_t - s_t]\, dt, \tag{20}$$

where b_t is the real value of outstanding debt and $r_t := i_t - \pi_t - g$ is the growth-adjusted instantaneous real interest rate.

Monetary Policy The monetary authority sets the short-term nominal interest rate i_t, and we denote the nominal rate in steady-state as $\bar{i}$.[4]

Monetary and Fiscal Policy Outside Steady State Rather than assuming particular rules for monetary and fiscal adjustments, we specify monetary and fiscal policy outside steady state in terms of paths of current and planned future nominal rates $\{i_{t+s}\}_{s\geq 0}$, transfers and taxes $\{\varsigma_{0,t+s}, \varsigma_{1,t+s}\}_{s\geq 0}$, fiscal stimulus payments $\{\varepsilon^\tau_{t+s}(a,\omega)\}_{s\geq 0}$, government spending $\{\mathcal{E}^G_{t+s}\}_{s\geq 0}$, and profit subsidies $\{\mathcal{E}^\Pi_{t+s}\}_{s\geq 0}$ at each t. Monetary and fiscal *shocks* are the revisions to these paths.

In the language of Leeper (1991), we thus assume active fiscal policy and passive monetary policy. However, given our approach to recovering structural shocks that we describe in Section 5, nothing in our analysis relies on this assumption. Because of observational equivalence between different policy regimes (see Cochrane (2023)), the resulting allocations in both the actual and counterfactual environments could alternatively be implemented with passive fiscal and active monetary rules. However, we think that defining policies in terms of sequences of current and forecasted policy variables as we do is the simplest way to perform the relevant counterfactual

[4]We abstract from the details of how the central bank implements its nominal interest rate policy. One way is to assume that it pays interest on reserves, which are perfectly elastically supplied, and are perfect substitutes with short-term government debt.

policy exercises that we study in Section 5. This allows us to explicitly define counterfactual policy settings in terms of the realized paths of nominal interest rates and fiscal transfers. In Section 5 we present some counterfactual experiments that also involve rules for fiscal policy, which we describe there.

Equilibrium

Given initial distributions $\mu_0^h(a,\omega)$, $\mu_0^f(p,z,\zeta)$, initial government bonds B_0^δ, B_0^S, paths of tax and dividend functions $\mathcal{T}_t$, $\mathcal{D}_t$, paths of policy variables $i_t, \varepsilon_t^\tau, \mathcal{E}_t^G, \mathcal{E}_t^\Pi$, and paths of structural shocks $\mathcal{E}_t^C, \mathcal{E}_t^Z$, an equilibrium consists of paths for functions:

- Household policy functions and distribution: $c_t(a,\omega)$, $h_t(a,\omega)$; $\mu_t^h(a,\omega)$
- Retailer policy functions and distribution: $\lambda_t(p,z,\zeta)$, $p_t^*(z,\zeta)$, $\mu_t^f(p,z,\zeta)$

and paths for scalars:

- Aggregate inputs and outputs: M_t, I_t, L_t, Y_t, Y_t^{GDP}
- Nominal prices and wages: W_t, P_t, $P_{I,t}$
- Price and quantities of government bonds: B_t^S, B_t^δ, Q_t

such that:

1. Households optimize: $c_t(a,\omega)$, $h_t(a,\omega)$ solve the household problem
2. Retailers optimize: $\lambda_t(p,z,\zeta)$, $p_t^*(z,\zeta)$ solve the price-setting problem
3. Aggregation: $\mu_t^h(a,\omega)$, $\mu_t^f(p,z,\zeta)$ are generated by optimal policies of households and firms
4. Price level determined by retailer prices: $P_t^{1-\epsilon} = \int (p/\zeta)^{1-\epsilon}\mu_t^f(p,z,\zeta)d(p,z,\zeta)$
5. Intermediate goods firm optimizes: $P_{I,t} = e^{-\mathcal{E}_t^Z}\left(\frac{W_t}{\alpha}\right)^\alpha \left(\frac{P_t}{1-\alpha}\right)^{1-\alpha}$, $L_tW_t = \alpha P_{I,t}I_t$, $P_tM_t = (1-\alpha)P_{I,t}I_t$, $I_t = e^{\mathcal{E}_t^Z}L_t^\alpha M_t^{1-\alpha}$
6. Government budget constraint holds: $dB_t = [i_tB_t - s_tP_t]\,dt$ where $s_t = \varsigma_{1,t}(Y_t - M_t) - \varsigma_{0,t} - (\bar{G} + \mathcal{E}_t^G) - \mathcal{E}_t^\tau - \mathcal{E}_t^\Pi$
7. No arbitrage in bond market: $dQ_t = [(i_t + \delta_b)Q_t - 1]\,dt$,
8. Asset market clears: $\frac{B_t}{P_t} = \frac{B_t^S + Q_tB_t^\delta}{P_t} = \int a\mu_t^h(a,\omega)d(a,\omega)$
9. Labor market clears: $L_t = \int \omega h_t(a,\omega)\mu_t^h(a,\omega)d(a,\omega)$
10. Goods market clears: $Y_t^{\text{GDP}} = \int c_t(a,\omega)\mu_t^h(a,\omega)d(a,\omega) + G_t = Y_t - M_t$

It is useful to verify that the number of equations equals the number of unknowns. The policy functions and distributions are determined by conditions 1-3. The 11 scalars are determined by conditions 4-11, which contain 11 equations of which one is redundant due to Walras's Law. The missing equation is a government debt management policy between short and long term debt outside of steady-state. In our exercises we assume $B_t^S = 0 \ \forall \ t$. This definition of equilibrium determines paths for all nominal variables in the economy. When an equilibrium exists, real variables can be readily defined by dividing appropriate variables by P_t. A steady-state equilibrium is defined analogously with $(\mathcal{E}_t^C, \mathcal{E}_t^Z, \mathcal{E}_t^\tau, \mathcal{E}_t^G, \mathcal{E}_t^\Pi) = 0$ for all t.

3 Steady-State Calibration

3.1 Parameterization

We calibrate the model's steady state to match key features of U.S. household wealth and consumption behavior, and firm price-setting patterns in the decade from 2010 to 2019. Appendix B contains a description of data sources and methods. Here we describe the most important elements.

Households The income process parameters $\lambda_{\omega,\omega'}, \{\omega_n\}_{n=1}^N$ are taken from Kaplan and Violante (2022). We set the Frisch elasticity of labor supply $\nu = 1$, in line with standard macro estimates. We set the labor disutility parameter ψ so that average hours worked in steady-state equals one.

Production We set the elasticity of substitution across goods $\epsilon = 10$, implying an average markup of 11%. We set the weight on labor in production to $\alpha = 0.45$ to generate a share of intermediates in gross output of 50% (Klenow and Willis, 2016; Nakamura and Steinsson, 2013).

Pricing Parameters In steady-state, the only pricing friction that is active is the effort cost of influencing the arrival rate of adjustment opportunities, $\kappa(\lambda)$. We set the two parameters of effort cost function γ_0, γ_1 and the variance of idiosyncratic shocks σ_z^2 to match three moments from the micro price data, following Nakamura et al. (2018) and Alvarez et al. (2022): (i) quarterly rate of price adjustment of 37.5% per quarter, equivalent to a monthly rate of 12.5%; (ii) average absolute size of price changes of 7.5%; and (iii) kurtosis of price changes of 3. These moments uniquely identify the three parameters governing price adjustment $(\gamma_0, \gamma_1, \sigma_z^2)$.[5]

Tax and Transfer System In 2019, total US government revenues were 27% of GDP and expenditures were 29.2% of GDP, for a primary deficit of 2.2% of GDP.[6] Accordingly, we set the proportional tax rate $\bar{\varsigma}_1$ on labor and dividend income to 0.27. Government expenditures comprise

[5]See Cavallo et al. (2024) for a discussion of identification. Alvarez et al. (2016) show that in simple state-dependent pricing models, these moments are the main determinants of the cumulative output response to monetary shocks.

[6]Bureau of Economic Analysis, Table 3.1. Includes federal, state and local revenues and expenditure.

transfers to households (15% of GDP), government consumption (14% of GDP), and subsidies to firms (0.2%). In steady-state we treat subsidies to firms as part of government consumption, and so set the steady-state lump-sum transfer $\bar{\varsigma}_0$ to 0.15, and government consumption $\bar{G}$ to 0.142.

Government Debt We construct an empirical analogue to the value of nominal government debt B_t by first adding the market value of privately held federal debt to the monetary base.[7] We then subtract the component of the monetary base that is a claim by the government, which is given by the value of the Treasury Account held at the Fed. The resulting series reflects the net nominal liabilities of the consolidated federal government held by the private sector. At the start of 2020 this amounted to 88% of GDP. We therefore choose the household discount rate ρ to match a target of $\bar{b} = 0.88$. We assume that all debt is long-term ($B^S = 0$) and set the maturity rate on long-term debt δ_b to match an average duration of 5 years.

Interest Rates The steady-state government budget constraint implies a steady-state growth-adjusted real interest rate of

$$\bar{r} = \frac{\bar{s}}{\bar{b}} = \frac{-0.022}{0.88} = -2.5\%$$

Net interest payments on government debt to the private sector were around 1.6% of GDP in 2020, 1.8% in 2019, 1.6% in 2018 and 1.4% in 2017.[8] The average level of government debt in 2019 was 0.833 times GDP. If we take interest expenses to be 1.6% of GDP, this implies a nominal interest rate of $0.016/0.833 = 1.9\%$. Using the Fisher equation this means that $-2.5\% = 1.9\% - \bar{\pi} - g$. We set inflation $\bar{\pi} = 2\%$, implying a real interest rate of $\bar{r} = -0.1\%$ and a growth rate of $g = 2.4\%$. Indeed we estimate a linear trend in log real GDP from 2010-19 of 2.37%.

3.2 Steady-state Distributions

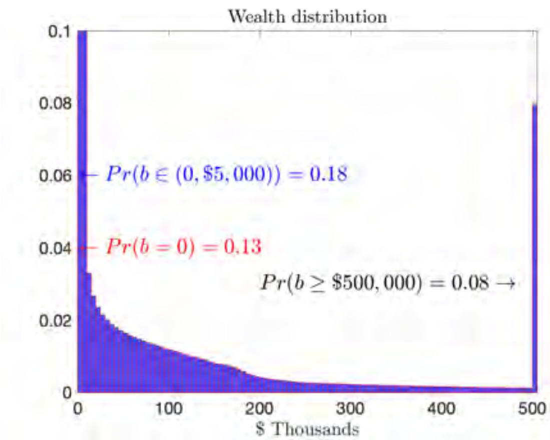
Household Distribution Figure 1a shows the steady-state cross-sectional distribution of household wealth. By construction, mean wealth is equal to 88% of annual GDP (around $150,000 per household). Approximately 13% of households have zero wealth and a further 18% have less than $5,000. Around 8% of households have more than $500,000 of wealth. These statistics are broadly consistent with the distribution of liquid wealth in the 2019 Survey of Consumer Finances: mean household liquid wealth was $178,000, 21% of households had zero or negative liquid wealth and 5% of households had more than $500,000.[9]

Figure 1b displays a histogram of the distribution of quarterly marginal propensities to consume (MPCs) out of a $500 windfall. The mean MPC is around 21%, broadly in line with empirical

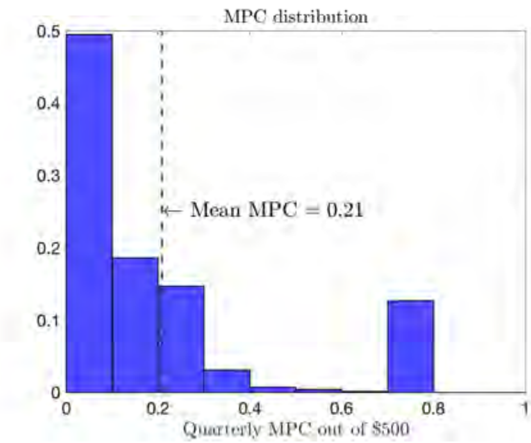
[7] Our measure of privately held federal debt comes from the Federal Reserve Bank of Dallas, and the monetary base as reported by Federal Reserve. See Appendix B for details.

[8] We use CBO data because it nets out intra-government interest payments. See Appendix B for details.

[9] We define liquid wealth as in Kaplan and Violante (2022), which includes financial assets less certificates of deposit, savings bonds, cash value of life insurance policies, other managed assets, quasi-liquid retirement accounts, credit card balances, lines of credit not secured by real estate and other debt.



(a) Household wealth distribution



(b) MPC distribution

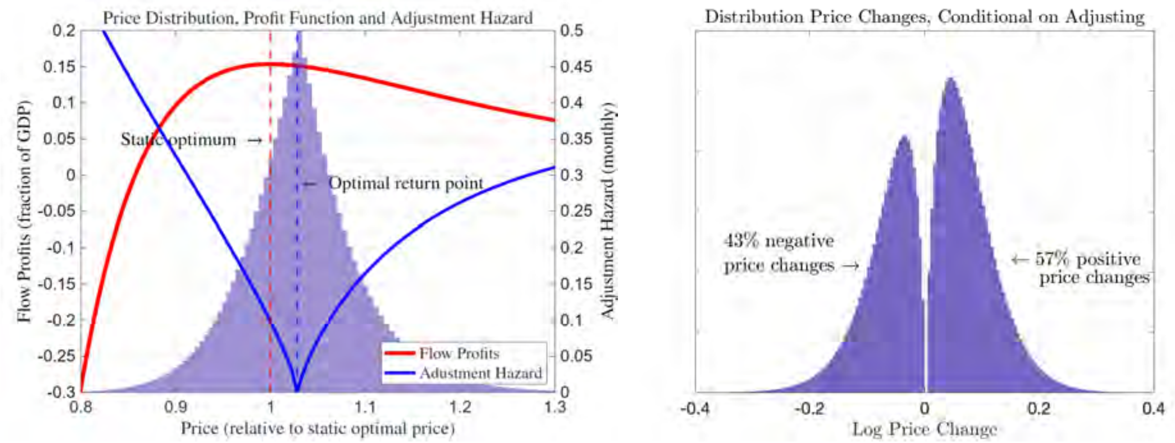
Figure 1: Steady-state wealth distribution (left panel), and MPC distribution (right panel).

estimates. The model also generates a large degree of dispersion in MPCs. A little under half of households have an MPC below 10% and around 14% of households have quarterly MPCs between 60% and 80%.

Price Distribution Figure 2a shows the steady-state distribution of retail prices, along with the flow profit function and the monthly hazard rate of adjusting prices. The flow profit function displays a large degree of asymmetry, and hence the optimal return point is above the static optimal price. The asymmetry arises both because of the non-quadratic CES profit function and also because steady-state inflation is positive, however the vast majority of the asymmetry in Figure 2a is due to the asymmetry in the profit function. This asymmetry results in an asymmetric adjustment hazard for large shocks. This is reflected in Figure 2b, which shows the steady-state distribution of log price changes, conditional on adjusting. The mean absolute price change is calibrated to 7.5%. Of the 12.5% monthly price changes, 5.4% are negative and 7.1% are positive. Together these features imply that the model exhibits more price adjustment for inflationary than deflationary shocks.

4 Heterogeneous Agents and State-Dependent Pricing: Some Simple Exercises

We start by conducting some simple exercises to illustrate the importance of the two key features of our model – heterogeneous agents and state-dependent pricing – for studying large fiscal and monetary interventions such as those observed in the early 2020's. These experiments also clarify some of the effects of fiscal and monetary stimulus in our environment that may not be familiar to all readers and that underlie some of the quantitative findings in Section 5.



(a) Price distribution

(b) Price change distribution

Figure 2: Steady-state price distribution, flow profit function and hazard of adjustment (left panel), and price change distribution (right panel).

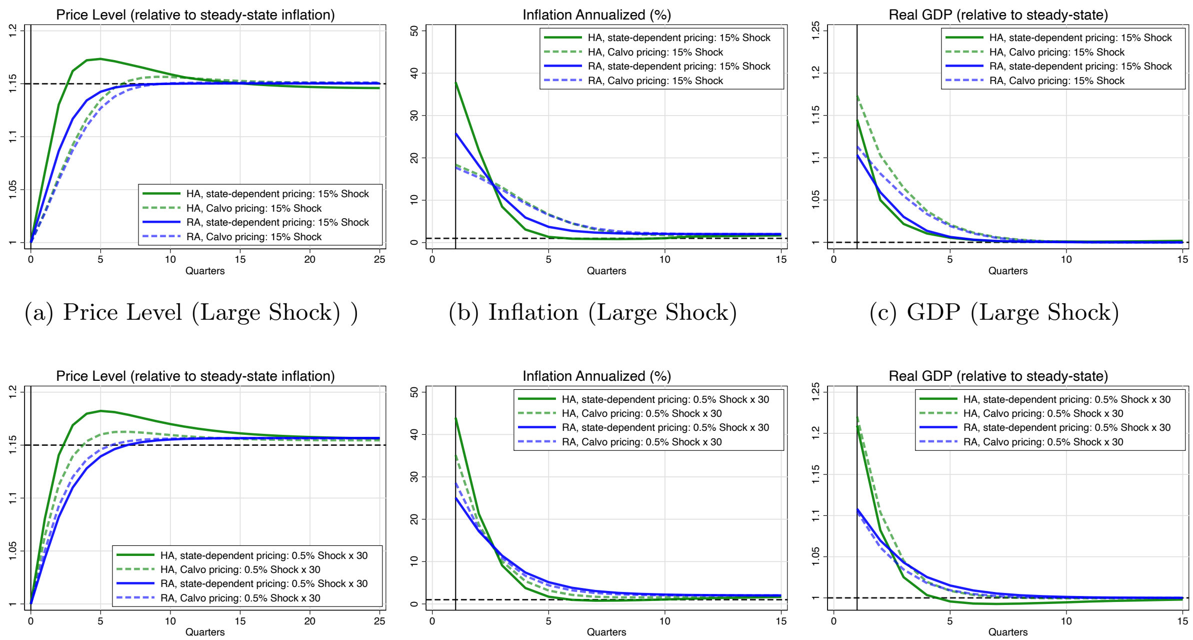
4.1 A Large Unfunded Fiscal Stimulus

Starting from steady-state, the government unexpectedly announces a large unfunded fiscal stimulus program that provides a one-time transfer to households in the bottom half of the wealth distribution. The aggregate size of the fiscal helicopter drop is equal to 15% of steady-state government debt, which is around 13% of GDP per-capita. This is the approximate magnitude of the Covid-era stimulus packages in the United States. The stimulus is unfunded in the sense that the government does not change its future taxes or transfers, and hence the costs are paid entirely through future inflation. To keep the experiments as clean as possible, we assume the central bank keeps the nominal rate constant and that the primary deficit is exogenous and does not respond to changes in output.[10]

The effects of the fiscal expansion are shown by the solid green lines in the top row of Figure 3. To assess the importance of state-dependent pricing for a shock this size, we also plot the corresponding dynamics in an analogous model with time-dependent, or Calvo, pricing, shown in the lighter green dashed lines. The Calvo model is a special case of the full model in which the curvature of the effort cost function for changing prices is large, $\gamma_1 \to \infty$, so that the optimal hazard of adjustment is constant. We set the monthly rate of price adjustment in the Calvo model to 25%, twice the average steady-state rate of price adjustment in the state-dependent economy.[11]

[10]For these experiments only, to keep the deficit constant, we treat the proportional taxes as a type-specific lump-sum tax so that net tax payments at the individual level are always the same as in steady-state. To illustrate cleanly the effects of state-dependent pricing, we also set $\gamma_\chi = 0$ for the exercises in this section.

[11]Alvarez et al. (2016) show that in simple models, the ratio of kurtosis of price changes to frequency of price changes is a sufficient statistic for the economy's response to a nominal cost shock. In our baseline model the kurtosis of price changes is 3. Since the kurtosis of the Calvo model is 6, we double the frequency of price adjustment. See also Auclert et al. (2024).



(a) Price Level (Large Shock))

(b) Inflation (Large Shock)

(c) GDP (Large Shock)

(d) Price Level (Small Shock)

(e) Inflation (Small Shock)

(f) GDP (Small Shock)

Figure 3: Impulse response to an unfunded fiscal helicopter drop. Top row shows a large shock with aggregate size of 15% of outstanding steady-state debt. Bottom row shows a small shock of 0.5% outstanding steady-state debt, multiplied by 30 for comparability.

This ensures that in simple economies, the two pricing models generate the same impulse responses for small shocks, which turns out to remain the case in the representative agent version of our more complicated economy. The analogous impulse responses for the corresponding representative agent economy are shown in the blue lines in Figure 3.[12] The panels in the bottom row, which show the effects of a fiscal stimulus program whose cumulative size is 0.5% of steady-state debt illustrate this equivalence for small shocks – note the similarity between the solid and dashed blue lines. For comparison with the large stimulus program, we multiply the impulse responses to the small shocks by 30, which is equivalent to the impulse responses we would have obtained had we solved for the effects of the large shock using perturbation.

Price Level Rises Faster with State-Dependent Pricing Panel (a) of Figure 3 shows that for a stimulus of the size implemented in the US, prices rise much more quickly in the state-dependent pricing model than in the Calvo model. The reason is the burst of price adjustment in the wake of a large shock that is not present in the Calvo model – in this experiment the rate of price changes increases by around 60% on impact (see Figure C.1 in Appendix C). As a result,

[12]Since the representative agent economy cannot accommodate a steady-state primary deficit, we reduce the lump-sum transfer $\bar{\varsigma}_0$ from 0.15 to 0.11, resulting in a steady-state primary surplus of 1.8% and a growth-adjusted real rate of 2.05%.

there is less short-run real non-neutrality in the state-dependent model which can be seen in the larger inflation response (panel (b)) and smaller GDP response (panel (c)). In both models, the long-run effect on the price-level is approximately the same, settling down at 15% above trend, which is the size of the fiscal helicopter drop.

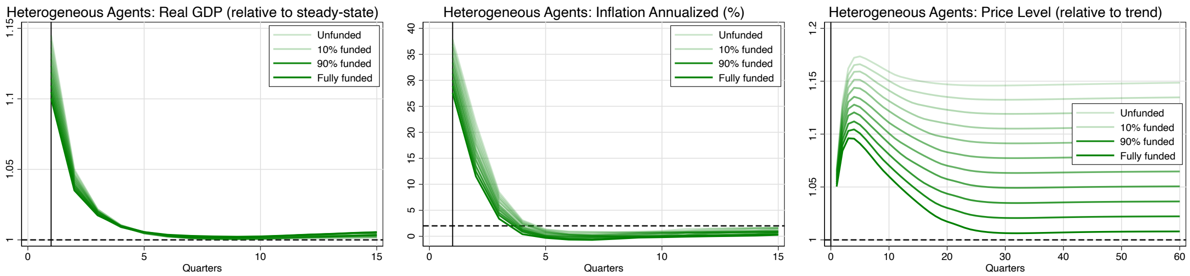
Large Shocks Amplify the Differences Between State- and Time-Dependent Pricing Comparing the top and bottom rows of Figure 3 illustrates how the pricing model matters more for aggregate dynamics in response to a large shock than for a small shocks. The impulse responses for the two pricing models (compare the solid and dashed lines) are much closer together in the bottom row than in the top row. This is particularly pronounced for the representative agent model (blue lines) where the impulse response are nearly identical for a small stimulus but differ for a large stimulus, consistent with theoretical results mentioned above.

Heterogeneous Agents Amplify the Effects of State-Dependent Pricing The top row of Figure 3 also shows that the short-run inflationary effects of state-dependent pricing are larger with heterogeneous households than with a representative household. This is most notable in the solid green lines in panels (a) and (d), which reveal a substantial overshooting of the price level in the heterogeneous agent economy that is not present in the representative agent economy. The reason is due to movements in the real interest rate that arise because of heterogeneity in marginal propensities to consume.[13] A uniform unfunded fiscal helicopter drop is effectively a transfer of real wealth from high wealth to low wealth households. All households receive the same dollar amount of transfers but the cost is borne disproportionately by high wealth households, who pay for it via a period of low real returns from high inflation. But since low wealth households have a higher marginal propensity to consume, this redistribution places additional upward pressure on spending which raises output and inflation by more than in the representative agent economy. In our experiment, this force is further exacerbated by the fact that the fiscal stimulus is directed towards households in the bottom half of the wealth distribution, who have high marginal propensities to consume.

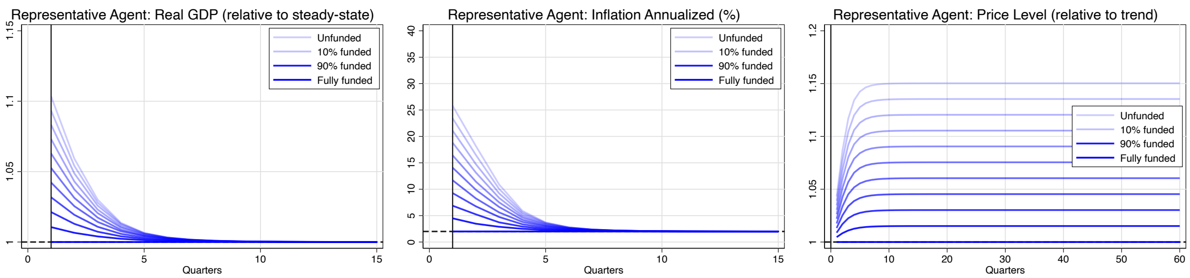
4.2 Partially Funded Stimulus and Ricardian Non-Equivalence

One of the starkest differences between a representative agent and heterogeneous agent economy is in the effects of partially funded fiscal stimulus. The palest green lines in the top row of Figure 4, labeled "Unfunded", show the effects of an unfunded stimulus whose size is 15% of steady-state government debt, as in the previous subsection. The darker lines show the effects when the government commits to fund a fraction of the cost of the stimulus by cutting future transfers. These cuts commence after 5 years and follow a fiscal rule that repays the funded component of the

[13] See Kaplan et al. (2023) for similar effects in a flexible price economy, and Kwicklis (2025) for similar points in a HANK model with Rotemberg pricing.



(a) Heterogeneous agents: GDP (b) Heterogeneous agents: inflation (c) Heterogeneous agents: price level



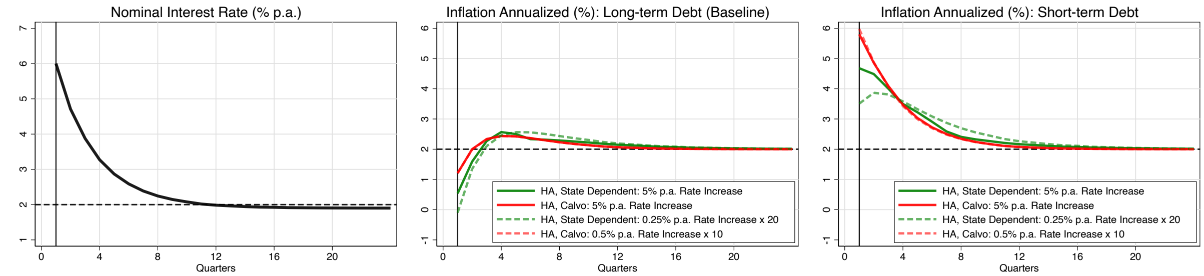
(d) Representative agent: GDP (e) Representative agent: inflation (f) Representative agent: price level

Figure 4: Impulse response to an increase in uniform lump-sum transfers, equivalent to 15% of outstanding government debt, for different degrees of funding in 10% increments from unfunded to fully funding. Funding is implemented by reductions in lump-sum transfers commencing after 5 years.

stimulus by lowering future lump sum transfers. The different shaded lines correspond to different proportions that are funded (see Appendix A.2 for full details of implementation). The blue lines in the bottom row of Figure 4 show the same impulse responses in the analogous representative agent economy.[14]

Effects of Partially Funded Stimulus on Short-Run Inflation Figure 4e illustrates how in the representative agent economy, the fraction of the stimulus program that is not financed by smaller future deficits maps directly into the increase in inflation in the immediate wake of the program. This is the logic that lies behind the empirical strategy of Barro and Bianchi (2024), who use the cumulative realized inflation in OECD countries from 2021 to 2023 to infer the fraction of Covid-era stimulus programs. However, in the heterogeneous agent economy, the degree of fiscal financing of the stimulus program is largely divorced from the short-run inflation and output response. The reason is due to the failure of Ricardian equivalence in the heterogeneous agent economy. Even for a fully funded stimulus program, there is a large short-run increase in inflation and output, as households do not immediately incorporate the full effects of lower future transfers

[14]Analogous figures with time-dependent pricing are in Figure C.2 in Appendix C and qualitatively tell the same story.



(a) Nominal interest rate (b) Long-term debt (c) Short-term debt

Figure 5: Impulse response to 500 basis point and 25 basis point increases in the nominal interest rate, with no change in taxes or transfers. Panel (a) is for baseline model with long-term debt. Panel (b) is for an economy with short-term debt.

into their current spending decisions.

Modeling correctly the extent of departures from Ricardian equivalence is therefore important to accurately assess how inflation would have evolved under counterfactual fiscal financing plans. For example, through the lens of the representative agent economy, it would appear that a stimulus program with a commitment to finance half of the costs with lower future transfers would have roughly halved the first year inflation response. In contrast, in the heterogeneous economy, such a commitment to finance part of the costs of stimulus would have had only a small effect on short-run inflation.

Effects of Partially Funded Stimulus on Long-Run Price Level Figures 4c and 4f plot the long run price-level responses in the heterogeneous agent and representative agent economies. These figures clarify that in both economies the long-run price level response is indeed governed by the degree of funding and is approximately equal to the cumulative amount of unfunded transfers as a fraction of steady-state debt.

4.3 A Large and Persistent Interest Rate Hike

To appreciate some of the results that follow in our main exercise, it is useful to comment briefly on the effects of a change in the nominal interest rate in our environment. Figure 5 shows the inflation response to an unexpected 500 basis point increase in the nominal rate decaying with a half-life of 2 quarters (Figure 5a), which is roughly the magnitude of the tightening in the US in 2022. Unlike in textbook New Keynesian experiments, we do not assume any simultaneous change in taxes or transfers.

The green solid line in Figure 5b shows that upon impact, inflation falls sharply, but recovers within a year after which it overshoots and remains elevated for several years. As the remaining lines in Figure 5b show, these dynamics are not due to either state-dependent pricing or the size of the shock. They are also not due to heterogeneous agents - analogous representative agent figures in Figure C.4 in Appendix C shows almost identical dynamics. Rather these dynamics are due to the "stepping-on-a-rake" forces identified by Sims (2011) and Cochrane (2024) that arise with long-term debt in the absence of a fiscal contraction. The initial fall in inflation is due to the fall in the long-term bond price, and the subsequent increase is due to the additional inflation required to finance the higher interest payments on debt in the absence of higher surpluses. Without long-term debt, inflation rises in response to this policy change, as illustrated in Figure 5c. We draw attention to these effects because they illustrate how, in the presence of long-term debt, an interest rate hike can shift the timing of inflation.[15] These forces are important for understanding the role of monetary policy in shaping post-Covid inflation and output dynamics.

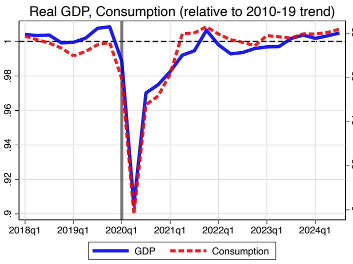
5 Policy Response to the Large Shock of 2020

In the previous section we explained why it is important to allow for heterogeneous agents and state depending pricing when analyzing the effects of large fiscal and monetary programs. But fiscal and monetary interventions don't happen in a vacuum; large policy changes come in response to large shocks, as they did in 2020. In this section we use our framework to first account for the main macroeconomic outcomes experienced by the United States in the wake of the 2020 shocks and policy responses. We then ask how different those outcomes would have been had the fiscal and monetary authorities acted differently. Finally, we assess the impact of these policy responses for households at different parts of the distribution.

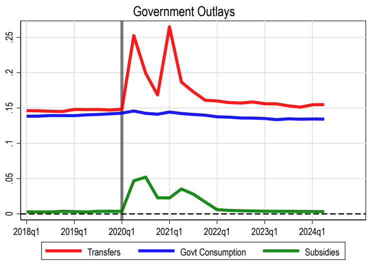
5.1 The Exercise

Aggregate Data To conduct this exercise, we must first decide how to model the economic effects of Covid in the context of our model. Figure 6 shows the dynamics from 2018 to the end of 2024 for six key macroeconomic variables that inform our analysis. Figure 6a shows a large drop and fast recovery in output (left axis) and consumption (right axis), concentrated in 2020Q2. Figure 6b shows the three main components of federal outlays over this period, as a fraction of the pre-Covid trend in GDP. The various rounds of stimulus programs are reflected in the extraordinarily large increases in transfers and subsidies from 2020Q2 to 2021Q3. Figure 6c displays the resulting increase in real government liabilities and Figure 6d shows the subsequent surge in inflation according to four commonly used measures of inflation. In Figure 6e we plot the dynamics of the federal funds rate alongside median forecasts of future rates at each date. At the onset of Covid, the Fed immediately lowered the federal funds rate to zero, after which it aggressively raised the nominal rate after inflation began to rise. Below, we will explain how we use these forecasts to discipline households' evolving expectations of the path of future rates. Finally, Figure 6f shows that at the end of 2024, the CPI was around 11% higher than its pre-pandemic

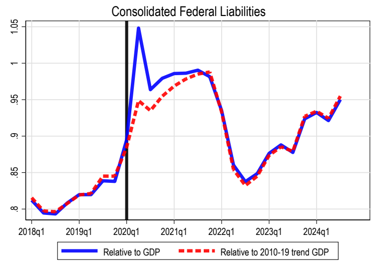
[15] For more details on these effects see Caramp and Silva (2023), Cochrane (2024) and Kaplan (2025).



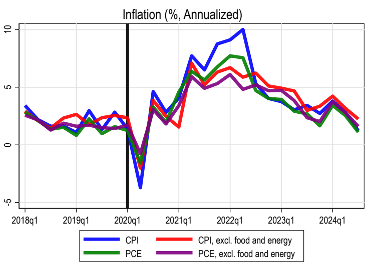
(a) GDP, Consumption



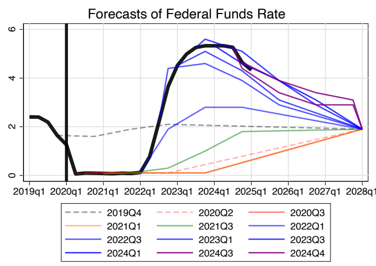
(b) Government outlays (relative to trend GDP)



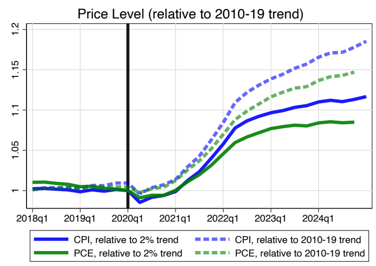
(c) Government debt



(d) Inflation



(e) Federal funds rate



(f) Price level relative to trend

Figure 6: Time series for key aggregate variables

level relative to a two percent trend, and around 18% higher relative to a trend based on average inflation over 2010-19.

Aggregate Shocks We capture the economic effects of the pandemic via two series of structural shocks to the economy, one affecting the supply side of the economy and one affecting the demand side of the economy. We model supply shocks as affecting productivity in the intermediate goods sector, $\mathcal{E}_t^Z$. We model the demand shock as affecting households' preference for consumption $\mathcal{E}_t^C$.

We assume that prior to 2020Q2, the economy is in steady state. Starting in 2020Q2, which we label $t = 0$, at the beginning of each quarter q an innovation to TFP of size ε_q^Z unexpectedly arrives. Each such innovation persists over time according to an exponentially declining path at rate δ_Z. Conditional on a shock arriving, households have perfect foresight over its subsequent dynamics, but each quarterly shock is unexpected. The level of TFP at time t, $\mathcal{E}_t^Z$, is the sum of the remaining effects of past quarterly innovations,

$$\mathcal{E}_t^Z = \sum_{q=0}^{\lfloor t \rfloor} \varepsilon_q^Z e^{-\delta_Z (t-q)}$$

where $q = 0$ corresponds to 2020Q2, q counts the number of full quarters elapsed since the start of 2020Q2, and $\lfloor t \rfloor$ indexes the most recent quarterly innovation that has arrived by time t. The process for shocks to the marginal utility of consumption is analogous.

These processes of exponentially decaying innovations are analogous to a quarterly AR(1) process in which each shock realization is an "MIT" shock. For our baseline analysis we set $\delta_Z = \delta_C = 0.051$ quarterly, equivalent to a quarterly AR coefficient of 0.95. None of our main conclusions are sensitive to assuming faster or slower mean reversion. In Appendix E we provide a full set of figures for $\delta_Z = \delta_C = 0.013$ (slower decay, equivalent to an annual AR coefficient of 0.95) and for $\delta_Z = \delta_C = 0.173$ (faster decay, equivalent to an annual AR coefficient of 0.5).

We choose the paths for the innovations, $\{\varepsilon_t^Z, \varepsilon_t^C\}$, so that given the fiscal and monetary policies described below, the equilibrium model dynamics for GDP and inflation match the corresponding dynamics for GDP (Figure 6a) and CPI inflation (Figure 6d). Given our assumption about the shock dynamics, this is effectively a non-linear inversion exercise and we are able to match the realized paths exactly.[16]

We choose these two series as our targets because they are well suited to distinguish the role of demand versus supply shocks. We do not want to take an ex-ante stand on the extent to which the multitude of economic effects of the pandemic are better captured by a supply or demand shock, and so we allow for both types of shocks and let the relative movements of inflation and output inform their magnitudes and dynamics.

Fiscal Policy Response We implement the fiscal stimulus response to match the dynamics of outlays in Figure 6b. The transfer components of the stimulus program are implemented as shocks to lump-sum transfers $\varepsilon_t^\tau(a, \omega)$, which we assume are distributed equally to households in the bottom half of the asset distribution so that the aggregate amounts disbursed $\mathcal{E}_t^\tau$ align with the path for transfers in Figure 6b. We set the government expenditure $\mathcal{E}_t^G$ and profit subsidy $\mathcal{E}_t^\Pi$ components of the stimulus programs to match the blue and green line in 6b. In reality the subsidy component comprised a complicated mix of policies that we think are best modeled as additional firm profits, which ultimately flow through to households through dividends, in line with our assumptions about firm ownership. In our baseline analysis we assume that the fiscal stimulus program is unfunded.[17]

We assume that at the beginning of each quarter, households learn about the total amount of stimulus to be disbursed in that quarter $\mathcal{E}_t^\tau, \mathcal{E}_t^G, \mathcal{E}_t^\Pi$, which is then disbursed uniformly throughout the quarter. The full stimulus program is therefore a sequence of unexpected quarterly shocks. We

[16] Given the size of the shocks, the non-linearities, and the fact that we must solve for a sequence of unexpected innovations starting from endogenous initial conditions, this is a non-trivial computational problem. We solve it with a homotopy approach in the deviation of GDP and inflation from steady-state, sequentially building up initial guesses from smaller shocks. We stack the calibration targets alongside equilibrium conditions and use an in-built trust region non-linear solver in Matlab. We use automatic differentiation to compute the Jacobian of the residual functions inside the solver. The baseline model with state-dependent pricing and a sequence of 20 unexpected quarterly shocks takes around 30 minutes to solve and estimate on an Apple M3 Macbook Air.

[17] See Leeper (2026) and Cochrane (2026) for detailed discussions of communication of funding intentions of the Trump and Biden administrations regarding the stimulus packages. These communications overwhelmingly support a baseline assumption that no additional future surpluses would be raised to pay for these policies.

make this assumption because in reality the stimulus programs were announced and legislated in several rounds, and we think this is a much closer approximation to reality than the alternative feasible assumption that the full path of transfers in Figure 6b was expected by households in 2020Q2.

Monetary Policy Response We implement the monetary policy response to the pandemic by feeding into the model the forecasts for the federal funds rate in Figure 6e. In each quarter the actual federal funds rate is given by the solid black line, and households expect the future path of interest rates to be the median consensus forecasts at that quarter as illustrated by the colored lines.[18]

For the purposes of interpreting realized aggregate dynamics, this approach of feeding in directly the realized path of nominal rates and past forecasts avoids us having to take a stand on the monetary rule, since for any rule we could ex-post back out the sequence of monetary shocks that rationalizes the observed sequence of nominal rates. However, for constructing counterfactual paths of nominal rates under alternative fiscal policies as we do below, we will have to make assumptions about how monetary policy would have responded, which we discuss below.

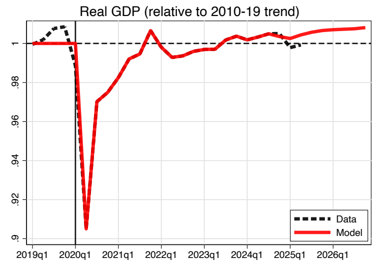
5.2 Interpreting Aggregate Dynamics

Model Fit Figure 7 shows the fit of the model along relevant dimensions. By construction, the model matches the paths of GDP (Figure 7a) and inflation (Figure 7b), as well as nominal rates and fiscal outlays (not shown). Figure 7c shows the evolution of the price level relative to a 2% trend, which matches the observed price level until the end of 2024 by construction. The model forecasts that inflation will remain persistently above trend until around 2028, after which the price level will settle at around 17% above a 2% trend measured from the start of the pandemic.

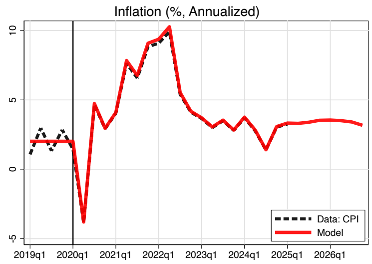
Figure 7d shows the fit of the primary deficit-to-gdp ratio. The model slightly overstates the deficit throughout 2022. This is because as GDP rose in this period, the model understates the increase in tax revenues. As a result, government debt is slightly higher in the model than in the data over this period (Figure 7e).

Implied Shock Series What paths of shocks are needed to account for these dynamics? The top row of Figure 8 shows the paths of productivity (left panel) and consumption utility shocks (right panel) implied by these dynamics, together with the implied forecasts at each date. The model rationalizes the initial drop in GDP as a large demand shock - there is a very large drop in consumption utility (around 35% at the peak of the pandemic in 2020), which then recovers gradually.

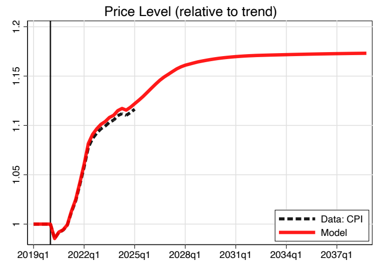
[18] The one change we make relative to the data is that we assume that the long-run forecast is always the model steady-state nominal rate, which is 1.9%. This avoids us having to contend with a transition to either a new steady-state real rate or new inflation target.



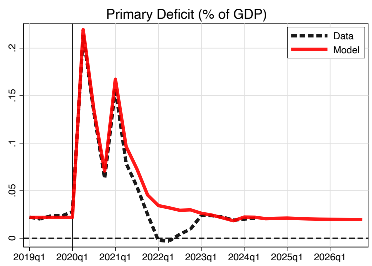
(a) GDP relative to trend



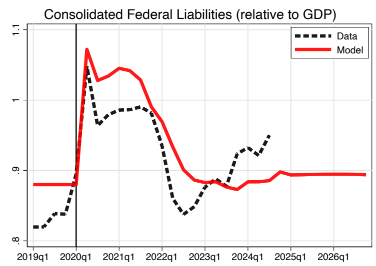
(b) Inflation



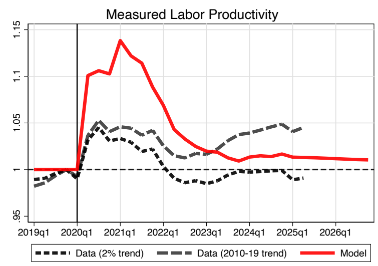
(c) Price level relative to trend



(d) Primary deficit relative to GDP



(e) Government debt relative to GDP



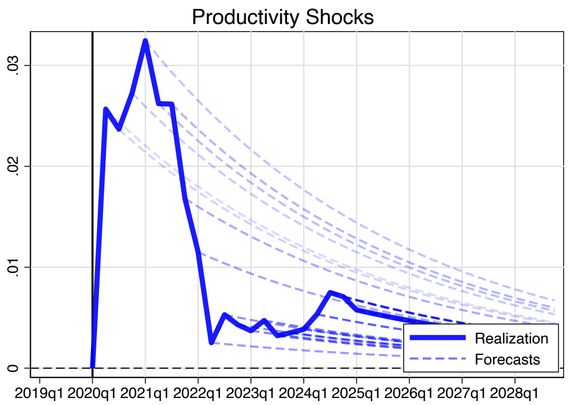
(f) Measured labor productivity

Figure 7: Time series model fit for aggregate variables

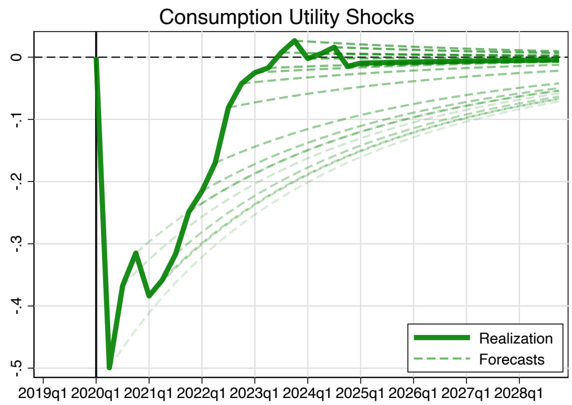
At the same time, there is a 3% increase in productivity, which is needed to rationalize the falling prices in the early phase of the pandemic. However, throughout 2021 and the first half of 2022, productivity collapses, consistent with the role of supply chain disruptions that manifested over this period, contributing to the surge in inflation. While at first glance it might appear counterintuitive to infer a positive productivity shock upon impact, this is in fact consistent with measured labor productivity over this period. Figure 7f shows GDP per hour in the model and the data.

Implied GDP and Inflation Forecasts The bottom row of Figure 8 shows the GDP and inflation forecasts implied by the model. In Figure B.1 in Appendix B.2 we construct an analogous figure using historical inflation expectations data constructed by the Center for Inflation Research at the Federal Reserve Bank of Cleveland. The dynamics match closely those in Figure 8d, providing comfort in our assumption for the decay rate of the two exogenous shocks – the alignment with the Cleveland Fed data is better for the baseline than for either the slower or faster assumed decay rates reported in Appendix E.

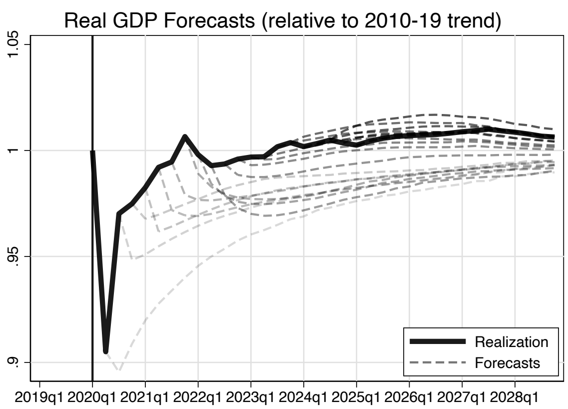
Historical Decomposition Figure 9 shows a historical decomposition of GDP and inflation into the effects of the two series of shocks, two types of policies and interaction terms between each of the shocks and policies. The interaction terms arise because of the model's non-linearity.



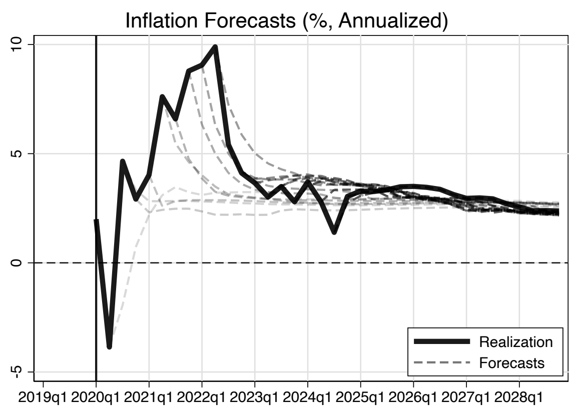
(a) Estimated TFP series



(b) Estimated consumption utility series



(c) Implied GDP forecasts



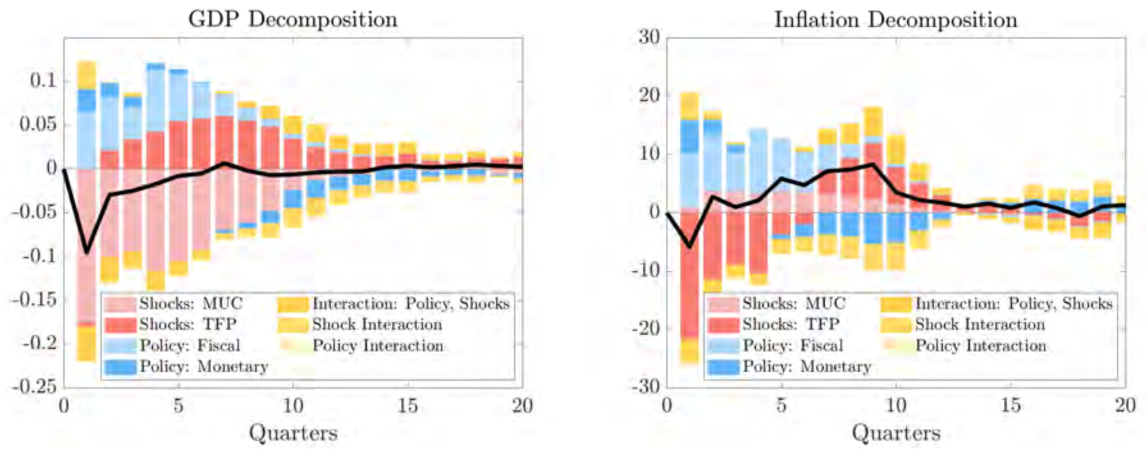
(d) Implied inflation forecast

Figure 8: Calibrated shocks and implied forecasts.

Two features of the historical decomposition deserve mention. First, the interaction effects are non-trivial, and account for several percentage points of both GDP and inflation, underscoring the importance of a non-linear model for shocks and policies of this size. Second, the decomposition hints at large offsetting effect between the shocks and policies, hinting that both fiscal and monetary policy played important roles in shaping the dynamics of inflation and GDP over this period. We return to these effects in Section 5.4 where we analyze counterfactual outcomes under alternative fiscal and monetary policies.

5.3 Relevant Micro Dynamics

Before turning to our counterfactual policy exercise, we illustrate two features of the microeconomic evidence that bear directly on the two main features of our model, heterogeneous agents and state-dependent pricing.



(a) Historical decomposition of GDP (b) Historical decomposition of inflation

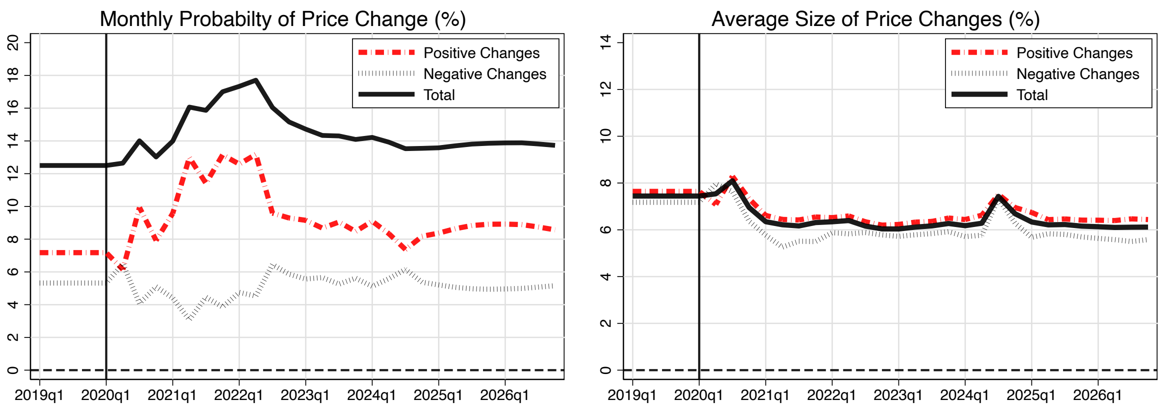
Figure 9: Non-linear historical decomposition of GDP and inflation into shock, policy and interaction terms.

Household Wealth In Appendix D.3 we report the dynamics of household wealth. Figure D.4a shows that median household wealth rises sharply as a result of the various rounds of stimulus, peaking at around 40% above its steady-state level. Wealth then remains elevated throughout 2021 and 2022, and is around 10% above steady-state at the end of 2024. These dynamics are broadly consistent with data on household cash balances. For example, Figure A5 in Wheat et al. (2024), reproduced in Figure D.4b shows a pattern for median real balances among JP Morgan account holders that matches almost perfectly that in the model.

Frequency and Size of Price Changes Figure 10a shows that the monthly frequency of price increases almost doubles from 7% in the steady-state to a peak above 13%. The fraction of price decreases is broadly constant throughout the period, declining by about 1 percentage point in 2021. Overall the monthly fraction of price changes increases from 12.5% in steady-state to a peak of 18%. Figure 10b shows that the average absolute size of price changes remains broadly constant.

These price dynamics are broadly consistent with the available evidence for this period. Montag and Villar (2025) report dynamics of price-adjustment probabilities (Figure 3) and the size of price changes (Figure 4) in the micro-data underlying the US Consumer Price Index. They show that the frequency of price changes rises steadily from 12.5% at the start of 2020, peaking at around 20% in early 2022. They show that this rise is driven entirely by a rise in the frequency of price increases with almost no change in the frequency of price decreases. They also show that the average absolute size of both price increases and decreases are roughly constant over this period.

The fact that our model matches these features of the data is by design. We choose the parameter γ_χ that governs the perceived costs of large price changes when recent inflation is large so as to generate an increase in the fraction of price increases (the red dashed line in Figure 10a)



(a) Frequency of price changes

(b) Size of price changes

Figure 10: Price change dynamics. Left panel shows monthly frequency of price changes. Right Panel shows average size of price changes.

of the same magnitude as in the data. To illustrate the effect of this feature of our pricing model, Figure D.5 in Appendix D.4 shows the frequency of price changes and average size of price changes after re-estimating the model under different values for γ_χ, including the generalized hazard model in Cavallo et al. (2024) with $\gamma_\chi = 0$.

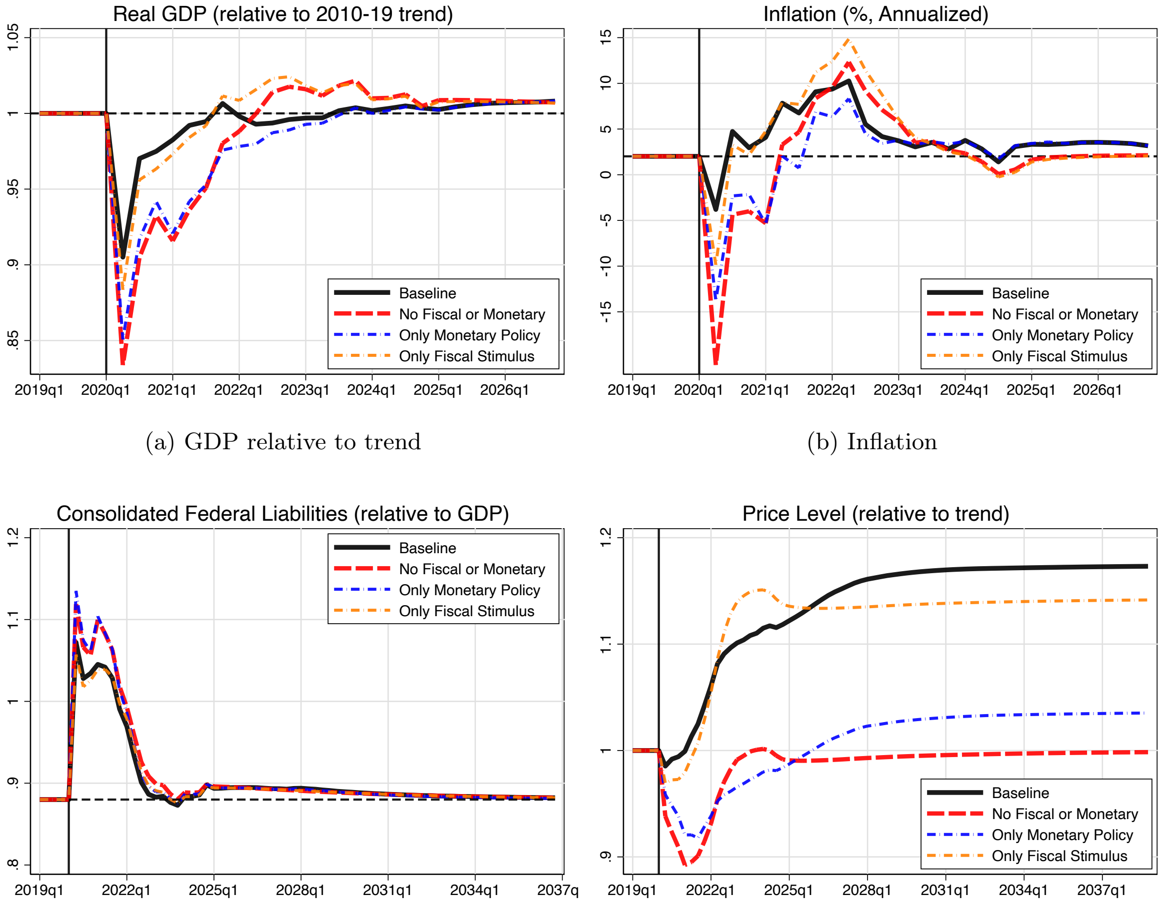
5.4 Counterfactual Fiscal and Monetary Policies

We use our model to ask how macroeconomic variables would have evolved had fiscal and monetary policy acted differently over this period.

Counterfactual Dynamics Without Policy Responses The red dashed lines in Figure 11 show the counterfactual dynamics for GDP, inflation, government debt and the price level, if there had been no monetary or fiscal response to the pandemic. By this we mean that the Fed would have kept the nominal rate constant throughout the period, and there would have been no fiscal stimulus program.

The combined monetary and fiscal response had a large effect on both GDP and inflation. Without the policy response, GDP would have fallen by around 15% relative to trend in 2020Q2, rather than 10%, and would have recovered much more slowly. Inflation would have been much more volatile, with a large deflation in 2020 followed by a much larger and prolonged spike in inflation, peaking in mid-2022. The net effect would have seen the price level returning to trend, rather than settling down about 17% above trend as in the baseline.

To understand how and why the policy responses had such a large effect on the economy, it is easiest to consider their effects in isolation. To do so, we simulate the economy with each of the fiscal and monetary responses, holding the other fixed at their steady-state policy stance. These



(a) GDP relative to trend

(b) Inflation

(c) Government debt relative to GDP

(d) Price level relative to trend

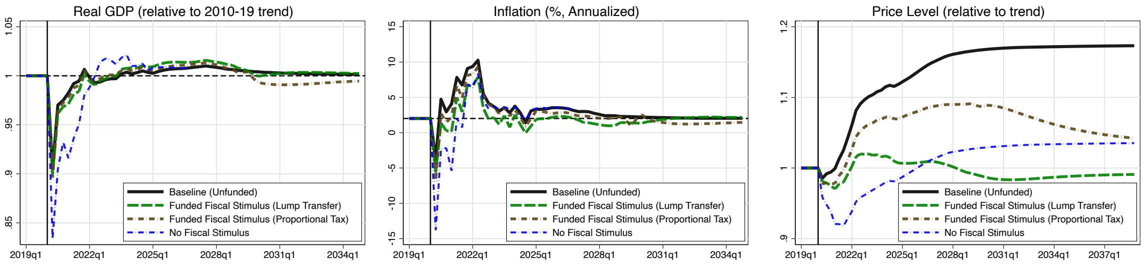
Figure 11: Counterfactual dynamics without monetary or fiscal responses

dynamics are shown in the blue dash-dot line (monetary policy) and orange dashed line (fiscal policy).[19]

Effects of Fiscal Stimulus The fiscal stimulus had a large effect on both GDP and inflation throughout 2020 and 2021 by supporting household spending in the face of the large shock to the marginal utility of consumption during this period. It was almost solely responsible for supporting GDP and accounts for preventing more than half the deflation that would otherwise have occurred.

However, although the fiscal stimulus was important in limiting deflation during 2020, it is not

[19] Despite the size of both the shocks and the policy response, as well as the various non-linearities in the model, the effects of the fiscal response and monetary response are close to additive, conditional on the structural shocks, and there is little interaction between the two policies. There is, however, an interaction between the shocks and each of the policies, particularly in the first few years. Specifically, the effect of either policy on GDP is smaller in the presence of the shocks. See Figures D.2 and D.1 in Appendix D.1. This is also suggested by the historical decomposition in Figure 9.



(a) GDP relative to trend (b) Inflation (c) Price level relative to trend

Figure 12: Counterfactual dynamics if Treasury had announced a plan to repay the Covid stimulus by lowering lump sum transfers starting 10 years after the first round of payments.

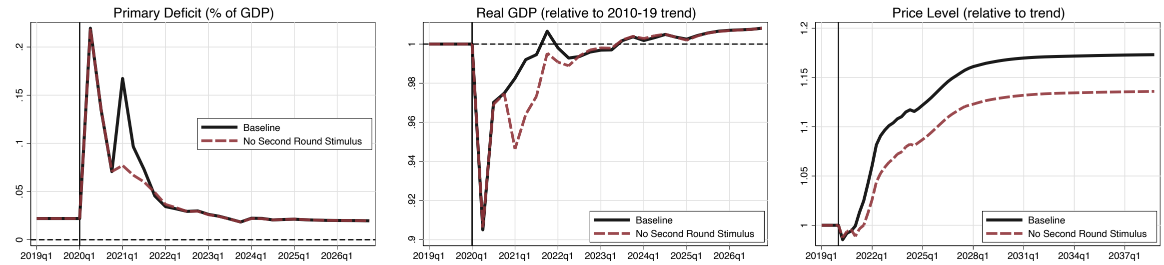
responsible for the inflation surge during 2021 and 2022. As the red lines in Figure 11b show, even in the absence of the stimulus inflation would have reached similar levels and tapered off at the same rate. The reason is the sharp decline in productivity throughout that period which also contributed to inflation. However, supply-side inflation had only a temporary effect on prices and as Figure 11d shows, the stimulus was largely responsible for the permanently higher price level.

Thus there is a sense in which those who blame the inflationary surge on supply chain disruptions and those who point to the unfunded stimulus are both correct. The stimulus brought forward the run up in inflation and helped to prevent a larger deflationary slump early on, at the cost of a permanently higher price level.[20]

A Funded Stimulus Program The permanent increase in prices arises because the fiscal stimulus programs were unfunded. How would the dynamics have differed if the government had instead committed to repay the costs of the stimulus? Figure 12 shows counterfactual dynamics for GDP and inflation if the government had committed to repaying the Covid stimulus by increasing primary surpluses starting 10 years after the first round of payments in 2030Q1. We consider two ways to raise primary surpluses, by lowering lump-sum transfers (green dashed lines) and by raising proportional taxes (olive dash-dot lines). In both cases, the debt is repaid gradually according to a rule that raises surpluses in proportion to the deviation of real debt from its steady-state level. See Appendix A.2 for full details of how we keep track of funded and unfunded components of the government budget outside of steady-state.

Figure 12a reveals that either of the fully funded stimulus programs are almost as effective at supporting GDP in 2020 as the unfunded stimulus program. When the stimulus is funded by lowering lump-sum transfers, the recovery in 2021 is a little weaker than in the baseline, but the benefit is lower inflation throughout and no permanent increase in the price level. In fact, because

[20] A feature of this class of models is that the inflationary effects of unfunded stimulus manifest very soon after the stimulus is enacted. However, in the data, inflation started increasing only in 2021. The model rationalizes this by inferring a large deflation in 2020 in the counterfactual, which in turn is rationalized by a large negative demand shock in this period.



(a) Primary deficit relative to GDP (b) GDP relative to trend (c) Price level, relative to steady-state trend

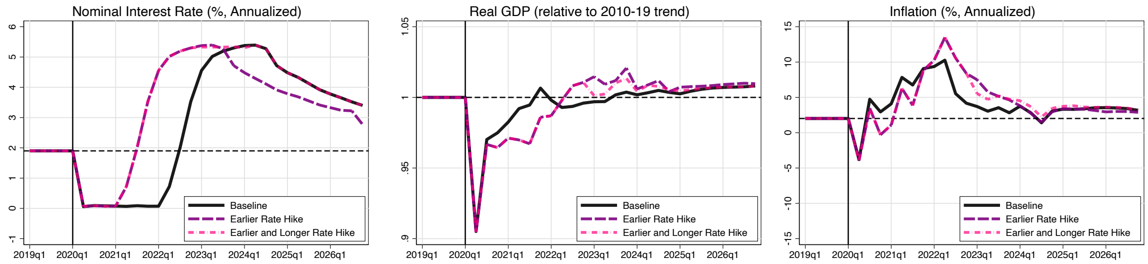
Figure 13: Counterfactual dynamics without the additional rounds of stimulus in 2021.

of wealth effects on labor supply from lower future transfers, output is actually higher than in the unfunded case for several years after the recovery.

When the stimulus is funded with higher proportional taxes, the effect on GDP during and following the pandemic is almost identical to the baseline. The trade-off relative to the unfunded case is a protracted downturn when the tax rate is raised in 2030 versus a smaller permanent increase in the price level. We defer discussion of the desirability of a funded versus unfunded stimulus to the following Section 5.5 where we compute welfare effects across the household distribution.

Only One Round of Stimulus? How differently would the economy have evolved without the later rounds of stimulus in early 2021? Figure 13 shows the effects of this alternative fiscal policy. Figure 13a displays our assumed hypothetical counterfactual path of deficits, which we generated by removing the additional transfers, government spending and firm subsidies in 2021. The remaining panels show that removing this component of the stimulus would have slowed the recovery in 2021 and temporarily lowered inflation. In the long-run, the price level would have been around 3% lower without the 2021 stimulus.

Effects of Monetary Policy Comparing the red dashed line and blue dash-dot lines in Figure 11 reveals the effects of the monetary policy response in isolation. The loose monetary policy throughout 2020 and 2021 had very little effect on GDP, which would have been almost identical if the policy rate had been held constant through this period, but did help in preventing a small amount of deflation at the start of the pandemic. The monetary tightening starting in 2022 lowered GDP moderately in 2022 and 2023. But the most important effects of monetary policy were in smoothing out the surge in inflation. Consistent with the "stepping on a rake" effects discussed in section 4.3, the higher nominal rates substantially reduced the spike in inflation. In the baseline, which also includes fiscal stimulus, inflation peaked below 10% (black line). Without the monetary response, inflation would have peaked at 15% (yellow dashed line). The cost of this smoothing was persistently higher inflation, which remained above trend for much longer than otherwise, as



(a) Nominal interest rate (b) GDP relative to trend (c) Inflation

Figure 14: Counterfactual dynamics if Fed had begun raising rates in 2021Q2 instead of 2022Q2

well as the aforementioned lower output in 2022 and 2023. There is a sense in which the monetary tightening did achieve the so-called "soft landing", but at the cost of persistent above-trend inflation.

An Earlier Rate Hike? Some commentators have criticized the Federal Reserve for being slow to respond to inflation, which had already risen above target by the start of 2021. What would have happened if the Fed had started raising rates sooner? The dashed purple lines in Figure 14 show a counterfactual scenario in which the path of nominal rates and associated forecasts were shifted forward by one year. It shows that shifting the rate hike earlier by a year would have held back the recovery in GDP and slowed the rise in inflation in 2021, but inflation would have spiked much higher than otherwise, peaking at 14% rather than 10%, and remaining around 4 p.p higher throughout 2022 and 2023. These dynamics lead one to conjecture that an alternative policy path would have been to begin raising rates in 2021, but to keep them high for as long as in the baseline. This scenario is displayed in the pink dash-dot lines in Figure 14. It shows that conditional on lifting off sooner, holding rates high for longer would not have reduced the inflation spike. The reason is that in this model, where the government is not assumed to raise primary surpluses in response to higher interest payments, the best that monetary policy can do in terms of influencing inflation is to smooth out its path, by lowering the price of long-term debt at the time of the rate hike. Thus if the goal is to smooth out a productivity-driven inflation surge, there is little value to raising rates too soon, and a better strategy is to wait until inflation is near its peak before raising rates, as in the baseline.

Alternative Pricing Frictions In Appendix E we provide a full set of analogous figures under alternative models of price-setting, including a version with exogenous opportunities to adjust prices, as in Calvo (1983) and a version with only the effort cost of influencing opportunities to adjust ($\gamma_\chi = 0$). None of these conclusions about the effects of policy are affected by these assumptions.

5.5 Welfare Implications of the Policy Response

What were the welfare implications of these effects of monetary and fiscal policy on output, inflation and the price level?

Equivalent Variation Asset Transfers To answer this question we compute the household-level equivalent variation associated with the combined policy responses, and with each in isolation. Let $V_0^{base}(a,\omega)$ be the expected present value of utility for a household with real assets a and idiosyncratic productivity ω at the start of 2020Q2, in the baseline economy,

$$V_0^{base}(a,\omega) = \mathbb{E}_0^{base}\left[\int_{t=0}^{\infty} e^{-\rho t}\left(e^{\mathcal{E}_t^C}\log c_t^{base}(a_t,\omega_t) - \psi\frac{h_t^{base}(a_t,\omega_t)^{1+\frac{1}{\nu}}}{1+\frac{1}{\nu}}\right)dt\,\middle|\, a,\omega\right]. \tag{21}$$

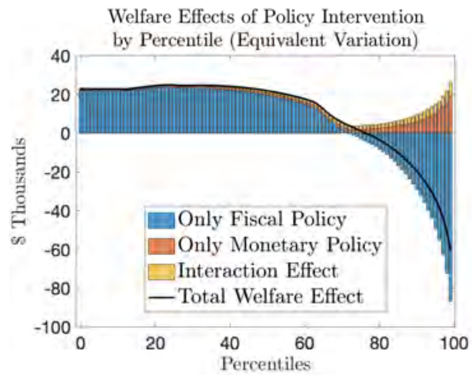
The expectation in (21) is taken with respect to the process for idiosyncratic shocks ω and implies a distribution of paths for (a_t,ω_t) in the baseline economy. The functions c_t^{base} and h_t^{base} are the corresponding paths of policy functions for consumption and hours, and the path of $\mathcal{E}_t^C$ (and all other aggregate variables) is the realized path in the baseline economy. The analogous value function in the economy without a policy response is denote by $V_0^{nopol}(a,\omega)$. We compute the equivalent variation $\Delta(a,\omega)$ as

$$V_0^{base}(a,\omega) = V_0^{nopol}(a+\Delta(a,\omega),\omega). \tag{22}$$

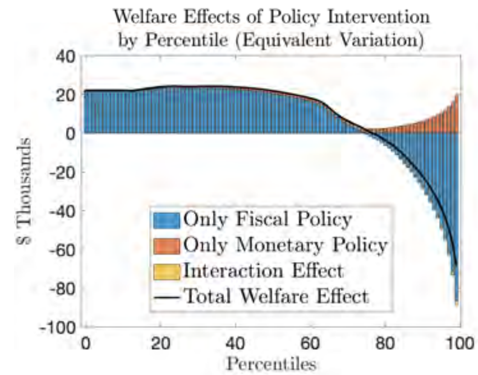
The definition in (22) describes the dollar value to an individual with assets and productivity (a,ω) of the monetary and fiscal policy interventions.[21]

Distribution of Welfare Effects Figure 15 shows the distribution of welfare effects. It shows the average value of $\Delta(a,\omega)$ at each percentile of the wealth distribution. The solid black line is the combined effects of the fiscal and monetary interventions, and the solid bars decompose this into the effects of each policy in isolation. For households in the bottom half of the wealth distribution, the fiscal stimulus policies had a welfare value equivalent to around a \$20,000 transfer to each household, largely because the transfers were explicitly targeted to these households. For households in the top 25 percent of the distribution the welfare effects of the fiscal stimulus were negative, largely because the direct costs of the inflation generated by the stimulus policies is borne by high wealth households via the lower real interest rate. The welfare effect of the monetary policy intervention is positive across the entire wealth distribution. For low wealth households, the higher real wages from the rate cut early in the pandemic slightly offset the effects of lower real wages later on when the interest rate rises. For higher wealth households there is an additional positive

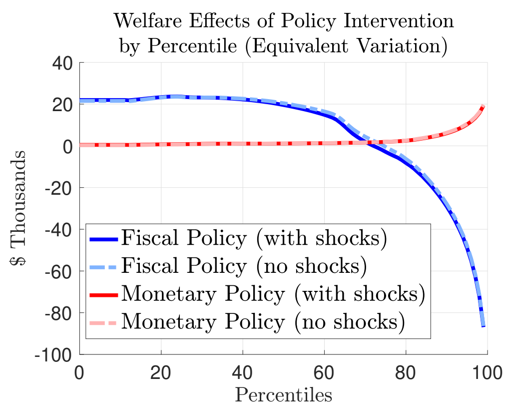
[21] We also evaluated the welfare effects using preferences that set $\mathcal{E}_t^C = 0$ and find very similar results. See Figure D.3 in Appendix D.2. This confirms that the welfare effects of the policies we measure are not due to shifting consumption over time in a way that aligns with households' exogenously changing marginal rates of substitution.



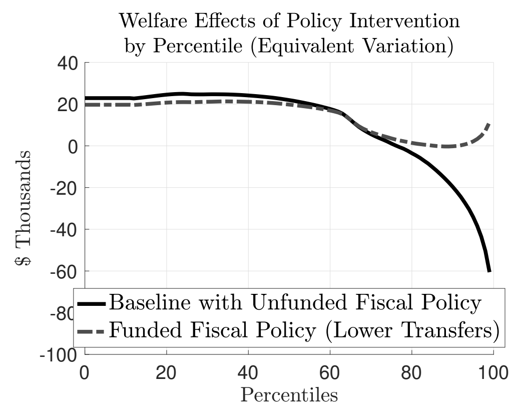
(a) Welfare effects by wealth percentile



(b) Welfare effects by wealth percentile, without pandemic shocks



(c) Comparison of welfare effects by wealth percentile, with and without pandemic shocks



(d) Comparison of welfare effects by wealth percentile, funded vs unfunded stimulus

Figure 15: Average welfare effects of the policy interventions across the wealth distribution. Welfare measured as equivalent variation in terms of assets at the onset of the pandemic. See text for details. Panel (a) is baseline model. Panel (b) shows the effects of the policy interventions in the absence of the pandemic shocks. Panel (c) compares the effects of policy with and without shocks. Panel (d) compares the effects of funded and unfunded fiscal stimulus.

welfare effect from the persistent higher real rates, which allow them to more efficiently smooth consumption.

Aggregate Welfare Effects To assess the aggregate desirability of the policy interventions we need to aggregate the distribution of welfare effects in Figure 15. One reasonable way to do this is to simply ask whether the aggregate value to households was positive or negative. We compute this by integrating $\Delta(a, \omega)$ with respect to the steady-state measure $\mu_0^h(a, \omega)$. We find this value to be positive, around $9,200 per household, of which about $4,900 come from the fiscal stimulus, $2,600 from the monetary response and the remainder due to interaction between the policies.[22]

[22]Note that conditional on the large shocks, although there is only a small amount of interaction between fiscal and monetary policy in their effects on aggregate dynamics, there is a very large interaction in their effects on

Aggregate Stabilization or Completing Markets? It is tempting to conclude from both the positive aggregate welfare effects, and the large welfare gains for low-wealth households that the monetary and fiscal interventions were successful in mitigating the effects of the pandemic and were therefore an appropriate and warranted response to the large aggregate shocks. However, caution is needed with such an interpretation because these welfare effects have little to do with responding to the aggregate shocks and much more to do with correcting the underlying inefficiencies in an economy with heterogeneous households and incomplete markets. To see this, Figure 15b shows the distribution of welfare effects of the monetary and fiscal policy interventions in an economy without the large pandemic shocks ($\mathcal{E}_t^C = \mathcal{E}_t^Z = 0$). Comparing this figure with Figure 15a reveals that the policy interventions have similar, although not identical, welfare effects regardless of whether they are implemented in response to the pandemic shocks or in steady-state (the key difference is the lack of interaction between the two policies in the absence of shocks). Figure 15c illustrates this by plotting the welfare effects of each policy with and without shocks alongside each other. The underlying reason is that the unfunded fiscal stimulus package is largely a redistributive policy that transfers resources to low wealth households, financed with lower real rates borne by high wealth households.

Welfare Effects of Funded Stimulus Figure 15d compares the welfare effects of the combined policy response at each percentile of the wealth distribution with the unfunded fiscal stimulus package versus a package funded by lower lump sum transfers starting in 2030. The average welfare gain under the funded package is \$13,700, about 50% larger than with the unfunded stimulus. The difference arises because the funded stimulus generates significantly less cumulative inflation, which neutralizes the welfare losses for high wealth households from the lower real returns under the baseline policy. For households in the bottom half of the distribution, the welfare gains are slightly lower than in the baseline, but as is evident in Figure 15d the combination of the monetary response and the funded stimulus is close to a Pareto improvement relative to the counterfactual of no policy intervention. (As above, this is due to completing markets rather than aggregate stabilization.)

6 Conclusion

Assessing the effects of large policy responses to unprecedented shocks, such as those experienced by the US and other developed countries in the first half of the 2020s, requires an appropriate model to construct counterfactuals. Current macroeconomic models are well suited to this purpose, but two features are essential when studying large shocks and policies: heterogeneous households with incomplete markets, and state-dependent price-setting by firms. We develop such a model and use it to shed new light on the effects of fiscal and monetary policy in the United States from 2020-25.

welfare.

Our model of pricing frictions offers a simple way to account for the dynamics of the frequency and size of price adjustment over this period that have proven to be a challenge for existing models.

What Caused the Inflation Surge and Increase in Price Level? The surge in inflation in 2021 and 2022 was caused predominantly by the collapse in productivity over this period, while the earlier deflation in 2020 was due to the collapse in household demand. In the absence of a fiscal or monetary response both the deflation and inflation would have been more extreme, with deflation dropping below -15% in 2020 and inflation rising to 15% in 2022. However, without the policy responses both the fall and rise in prices would have been temporary. Instead of ending up 17% above a 2% trend, the price level would have returned to trend. Inflation would have also returned to target much faster. There is thus a sense in which both of two prominent views were correct - the inflation surge was indeed due to a supply shock, but the persistent increase in the price level and persistent inflation were due to the unfunded stimulus package and monetary policy response

What Did Monetary Policy Achieve? Monetary policy's main role was in smoothing out the inflation dynamics. The well-timed hike in interest rates was largely responsible for inflation peaking at under 10%, rather than above 15%. But the stepping-on-a-rake effects were large. The cost of this lower peak was persistent above-trend inflation for several years, as well as lower output during the recovery.

What Did Fiscal Stimulus Achieve? The fiscal stimulus program was important in supporting GDP and preventing deflation at the height of the pandemic and contributed to a much faster recovery of prices and output than otherwise. But the cost of not paying for the stimulus with higher surpluses was a permanently higher price level, around 18 percentage points higher than without the stimulus. Because of the strong failure of Ricardian equivalence, a funded stimulus package could also have supported inflation and GDP during the pandemic, without the permanent effect on the price level.

Taking Distributional Considerations into Account, Was It All a Good Idea? On average, households were better off with the large policy interventions than without. We estimate the average value of the policies as $9,000 per household. However, two important caveats are in order. First, these policy interventions had a very large redistributive effect across the wealth distribution, particularly the fiscal stimulus policy, which benefited the bottom 75 percent of households at the expense of the top 25 percent of households. Second, these welfare effects should not be interpreted as the benefits of aggregate stabilization in the face of large exogenous shocks. The welfare effects of the fiscal and monetary intervention would have been broadly the same even if these policies had been implemented in steady-state. Rather, these welfare effects are due to completing markets and correcting inefficiencies that are present even in normal times. Finally, we note that a commitment to funding the stimulus package by cutting future transfers could have achieved similar stabilizing effects on output and inflation without the long-run increase in prices, thereby generating larger overall welfare gains that are spread more broadly across the wealth distribution.

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