How Does Monetary and Fiscal Policy Affect the Economy in the Face of Large Shocks?

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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 non-linear 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 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 permanently higher prices. These polices 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, but at the cost of lower future output.

JEL Codes: E3, E5, D3, D4

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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 have presented 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, time-dependent pricing, or local approximations remain valid for analyzing policy transmission in such extreme circumstances.

We use our model to answer a series of hitherto unanswered 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 three empirical observations about household behavior. First, the marginal propensity to consume out of transitory income varies substantially across households and averages around 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. Fourth, heterogenous 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 10% per month in normal times, with a high degree of kurtosis in the distribution of price changes. However, during the recent inflation surge, the frequency of price adjustment approximately doubled. 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.

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. 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 the departure from Ricardian equivalence is large, so that even a fully funded stimulus program generates a similar temporary inflationary booms, whereas the equivalent policy in a representative agent economy has no affect 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 Survey 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 successfully 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.[1]

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 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

[1]The version in this draft understates the size of the increase in price adjustment frequency in 2021-22, relative to US data. In on-going work we are including strategic complementarity in price-setting in an attempt to match this increase.

and subsequent inflation would have been temporary, and the long-run price level would have settled only around 7% above trend, rather than the approximately 18% above trend observed by end-2024.

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 a future economic contraction when the higher surpluses are raised.

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 step-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 $12,000 per household, roughly equally attributable to each policy. Fiscal policy generated large welfare gains for households in the bottom 80 percent of the wealth distribution — equivalent to a transfer of around $20,000 per household — financed by welfare losses for those in the top 20 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

- heterogenous 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 - to name a few. 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, like us, 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 conditional on those shocks to learn about the effects of policy.

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 of theory of labor supply than ours does. However, they abstract from state-dependent pricing, restrict attention to fully funded fiscal polices 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 the main 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 lifetime utility:

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

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

subject to the flow budget constraint:

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

and the borrowing constraint:

$$A_{jt} \geq 0. \tag{3}$$

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 1 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 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, $Y^{\text{GDP}_t} = Y_t - M_t = C_t + G_t$. 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:

$$Y_t = \left(\int_0^1 (\zeta_{jt} y_{jt})^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}} \tag{4}$$

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

$$d \log \zeta_{j,t} = -\theta_\zeta \zeta_{j,t} dt + \sigma_\zeta dB_{\zeta,jt}. \tag{5}$$

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

$$\max_{y_{jt}, Y_t} P_t Y_t - \int_0^1 p_{jt} y_{jt} dj. \tag{6}$$

This yields demand for variety j:

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

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

$$P_t = \left(\int_0^1 \left(\frac{p_{jt}}{\zeta_{jt}} \right)^{1-\epsilon} dj \right)^{\frac{1}{1-\epsilon}}. \tag{8}$$

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

$$y_{j,t} = \frac{I_{j,t}}{z_{j,t}}, \tag{9}$$

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

$$d \log z_{j,t} = -\theta_z z_{j,t} dt + \sigma_z dB_{z,jt}. \tag{10}$$

For most of our analysis, we will assume that the demand and productivity shocks for variety j are equal, $\zeta_{j,t} = z_{j,t}$, which simplifies the solution of the firm pricing problem.

Retailers set a price $p_{j,t}$ and sell to final goods producers. Given the demand function (7) and production function (9), the flow real profits for a retailer charging price p are

$$\Pi_t(p, \zeta, z) = \zeta^{\epsilon-1} \frac{1}{P_t} \left(\frac{p}{P_t} \right)^{-\epsilon} Y_t \left(p - z P_{I,t} \right) \tag{11}$$

We assume that retailers face frictions in adjusting their price. As in Alvarez et al. (2022), retailers choose how much effort to exert to increase the arrival rate λ of opportunities to adjust their price. We adopt the functional form for the effort cost function proposed by Cavallo et al. (2024),

$$\kappa_t(\lambda) = (\gamma_0 \lambda)^{1+\gamma_1}, \quad \gamma_0, \gamma_1 > 0. \tag{12}$$

In Section 3 we explain that this cost function is sufficiently flexible to match the key micro moments of the price change distribution that govern the aggregate response of prices to shocks.

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

$$I_t = e^{\mathcal{E}_t^Z} L_t^\alpha M_t^{1-\alpha}, \tag{13}$$

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

$$\max_{L_t, M_t, I_t} P_{I,t} I_t - W_t L_t - P_t M_t, \tag{14}$$

yielding the intermediate goods price

$$P_{I,t} = e^{-\mathcal{E}_t^Z} \left(\frac{W_t}{\alpha}\right)^\alpha \left(\frac{P_t}{1-\alpha}\right)^{1-\alpha} \tag{15}$$

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

$$\mathcal{T}_t(x) = \varsigma_1 x - \varsigma_{0,t} \tag{16}$$

where ς_1 is a proportional tax rate and $\varsigma_{0,t}$ is a time-varying lump-sum transfer. The government can also enact fiscal stimulus programs consisting of type-specific lump-sum transfers $\varepsilon_t^\tau(\omega, a)$. The

net taxes paid by household j are therefore

$$\tau_{j,t} = \varsigma_1 x_{j,t} - \varsigma_{0,t} - \varepsilon_t^\tau(a_{j,t}, \omega_{j,t}). \tag{17}$$

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

$$\begin{aligned} s_t &= \int_j \tau_{j,t} dj - G_t \\ &= \varsigma_1 Y_t^{\text{GDP}} - \varsigma_{0,t} - \mathcal{E}_t^\tau - (\bar{G} + \mathcal{E}_t^G) - \mathcal{E}_t^\Pi, \end{aligned} \tag{18}$$

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 is constant at $\varsigma_{0,t} = \bar{\varsigma_0}$. The steady-state tax function is therefore $\bar{\mathcal{T}}(x) = \varsigma_1 x - \bar{\varsigma_0}$, and steady-state surpluses are given by $\bar{s} = \varsigma_1 \overline{Y^{\text{GDP}}} - \bar{\varsigma_0} - \bar{G}$. 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 $B_t := B_t^S + Q_t B_t^\delta$. A no-arbitrage condition determines the long-term bond price as

$$dQ_t = \Big[(i_t + \delta^b) Q_t - 1\Big] dt, \tag{19}$$

The government budget constraint in terms of nominal market value is

$$dB_t = [i_t B_t - s_t P_t] \, dt. \tag{20}$$

The government budget constraint in terms of real variables is

$$db_t = [(i_t - \pi_t) b_t] \, dt - s_t = [r_t b_t - s_t] \, dt, \tag{21}$$

where b_t is the real value of outstanding debt, $r_t := i_t - \pi_t$ is the instantaneous real interest rate, and $\pi_t := \frac{\dot{P}_t}{P_t}$ denotes inflation.

Monetary Policy The monetary authority sets the short-term nominal interest rate i_t, and we denote the nominal rate in steady-state as $\bar{i}$.[3]

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 $\{i_{t+s}\}_{s\geq 0}$, lump-sum transfers $\{\varsigma_{t+s}\}_{s\geq 0}$, 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 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.

2.4 Equilibrium

Given initial distributions $\mu^{h}_{0}(a,\omega)$, $\mu^{f}_{0}(p,z,\zeta)$, initial government bonds $B^{\delta}_{0}, B^{S}_{0}$, paths of tax and dividend functions $\mathcal{T}_t$, $\mathcal{D}_t$, paths of policy variables $i_t, \varepsilon^{\tau}_{t}, \mathcal{E}^{G}_{t}, \mathcal{E}^{\Pi}_{t}$, and paths of structural shocks $\mathcal{E}^{c}_{t}, \mathcal{E}^{Z}_{t}$, an equilibrium consists of paths for functions:

- Household policy functions and distribution: $c_t(a,\omega)$, $h_t(a,\omega)$; $\mu^{h}_{t}(a,\omega)$
- Retailer policy functions and distribution: $\lambda_t(p,z,\zeta)$, $p^{*}_{t}(z,\zeta)$, $\mu^{f}_{t}(p,z,\zeta)$

and paths for scalars:

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

[3] 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.

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: $P_{I,t} = \frac{1}{\mathcal{E}_t^Z} \left(\frac{W_t}{\alpha}\right)^{\alpha} \left(\frac{P_t}{1-\alpha}\right)^{1-\alpha}$, $L_t W_t = \alpha P_{I,t} I_t$, $P_t M_t = (1-\alpha) P_{I,t} I_t$, $I_t = \mathcal{E}_t^Z L_t^{\alpha} M_t^{1-\alpha}$
6. Government budget constraint holds: $dB_t = [i_t B_t - s_t P_t]\, dt$ where $s_t = \varsigma_1 (Y_t - M_t) - \varsigma_{0,t} - (\bar{G} + \mathcal{E}_t^G) - \mathcal{E}_t^{\tau} - \mathcal{E}_t^{\Pi}$
7. No arbitrage in bond market: $dQ_t = \left[(i_t + \delta^b) Q_t - 1\right] dt$,
8. Asset market clears: $\frac{B_t}{P_t} = \frac{B_t^S + Q_t B_t^{\delta}}{P_t} = \int a \mu_t^h(a,\omega) d(a,\omega)$
9. Labor market clears: $L_t = \int \omega h_t(a,\omega) \mu_t^h(a,\omega) d(a,\omega)$
10. Goods market clears: $Y_t^{\text{GDP}} = \int c_t(a,\omega) \mu_t^h(a,\omega) d(a,\omega) + G_t = Y_t - M_t$

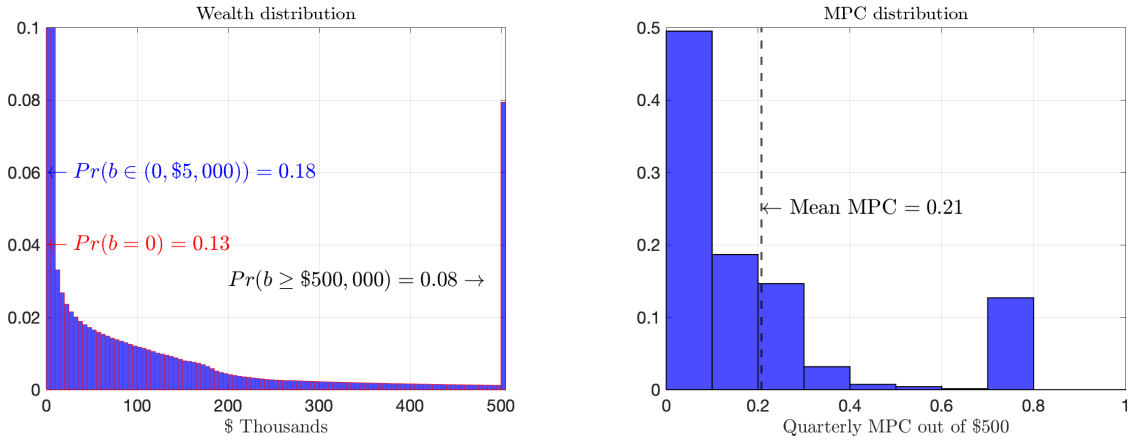
It is useful to verify that the number of equations equals the number of unknowns. The policy functions and distributions are determined by conditions 1-3. The 11 scalars are determined by conditions 4-11, which contain 11 equations of which one is redundant due to Walras's Law. This definition of equilibrium 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 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.



(a) Household wealth distribution

(b) MPC distribution

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

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 The price-setting side of the model is calibrated to match three key moments from the micro price data, following Nakamura et al. (2018) and Alvarez et al. (2022): (i) frequency of price changes of 32% per quarter (equivalent to a monthly hazard rate of 10%) (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: (i) γ_0, which controls the level of the effort cost of changing prices; (ii) γ_1, which controls the curvature of the effort cost function; and (iii) σ_z, the variance of idiosyncratic shocks. See Cavallo et al. (2024) for a discussion of identification. Alvarez et al. (2016) show that in simple state-dependent pricing models, these three moments are the main determinants of the cumulative output response to monetary shocks.

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.[4] Accordingly, we set the proportional tax rate $\bar{\varsigma}_1$ on labor and dividend income to 27%. Government expenditures comprise 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 transfers to households, and so set the steady-state lump-sum transfer $\bar{\varsigma}_0$ to 0.15, and government consumption $\bar{G}$ to 0.142.

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

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.[5] 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 $\delta_b = 1/20$ 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

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

In 2019 net interest payments on government debt to the private sector were around 1.6% of GDP (CBO).[6] The average level of government debt in 2019 was 0.833 times GDP, implying a nominal interest rate of $0.016/0.833 = 1.9\%$. Using the Fisher equation this means that $-2.5\% + g = 1.9\% - \pi$. We set inflation $\pi = 2\%$, 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

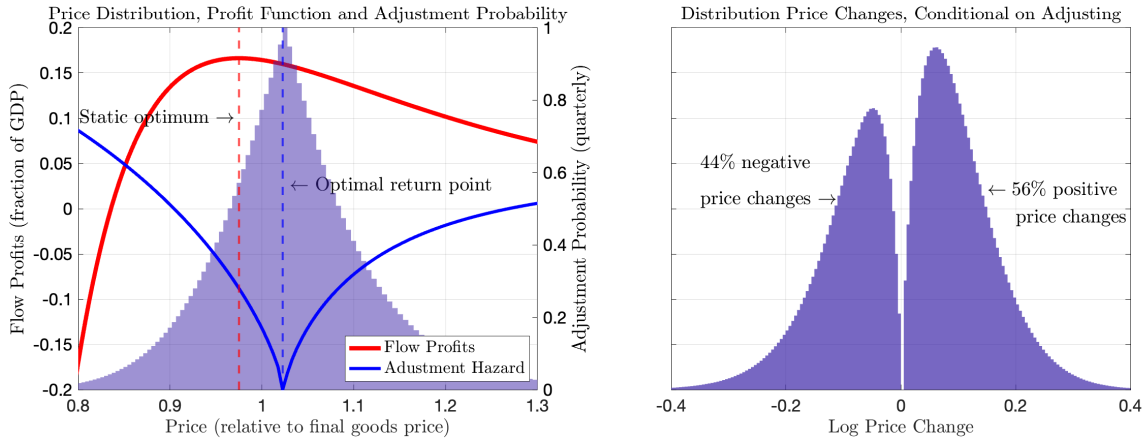
Household Distribution Figure 1a shows the steady-state cross-sectional distribution of household wealth. By construction, mean wealth is equal to 88% of annual GDP (around $150,000 per household). Approximately 13% of households have zero wealth and a further 18% have less than $5,000. Around 8% of households have more 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.[7]

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 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%.

[5] 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.

[6] We use CBO data because it nets out intra-government interest payments

[7] 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) Price distribution

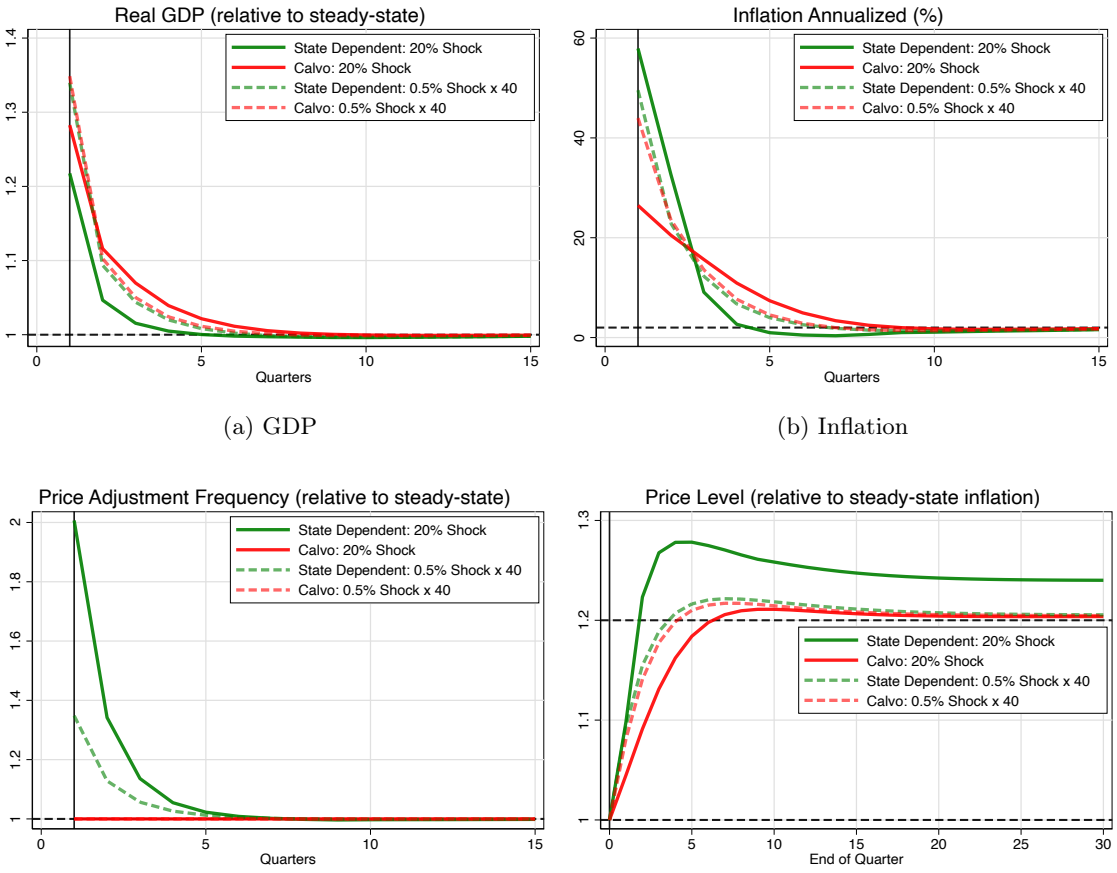
(b) Price change distribution

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

Price Distribution Figure 2a shows the steady-state distribution of retail prices, along with the flow profit function and the quarterly 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 11% monthly price changes, 6% are negative and 5% 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 exogenous shocks and large-scale 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) GDP

(b) Inflation

(c) Frequency of price adjustment

(d) Price Level (Relative to Steady-State)

Figure 3: Impulse response to a large and small unfunded increase in uniform lump-sum transfers. Large shock is 20% of outstanding steady-state debt, small shock is 0.5%. Figures for small shocks are multiplied by 40 for comparability.

4.1 Importance of State-Dependent Pricing

A large fiscal stimulus Starting from steady-state, the government unexpectedly announces a large unfunded fiscal stimulus program that provides additional lump-sum transfers to households in the bottom half of the distribution for one quarter. The cumulative amount paid out is equal to 20% of steady-state government debt.[8] The stimulus is unfunded in the sense that the government does not changes 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

[8]We implement this experiment as an increase in transfers that decay exponentially with a quarterly decay rate of 4.6, implying that 99% of the transfers are paid out within in the first quarter, thereby approximating a fiscal helicopter drop.

in output.[9]

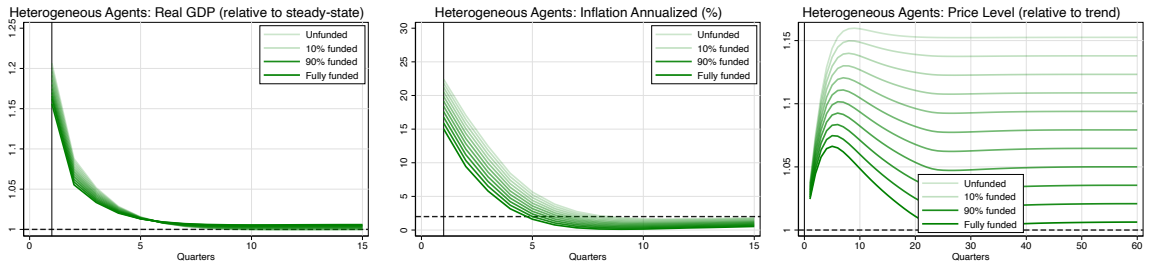
The effects of the fiscal expansion are shown by the green lines in Figure 3. To assess the importance of state-dependent pricing for a shock this size, we also plot the corresponding dynamics in an analogous model with time-dependent, or Calvo, pricing. The Calvo model is a special case of the full 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 price adjustment frequency in the Calvo model to 63% per quarter, twice the steady-state frequency of price adjustment in the state-dependent economy. 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 our more complicated economy.[10] The dashed lines in Figure 3 illustrate this equivalence. They show impulse responses to an analogous fiscal stimulus program whose cumulative size is 0.5% of steady-state debt, for the two pricing models. For comparison with the large stimulus program, we multiply the impulse responses to the small shocks by 40, which is equivalent to the impulse responses we would have obtained had we solved for the effects of the large shock using perturbation.

Panels (a) and (b) of Figure 3 show that for a small stimulus, GDP and inflation responses are the same under the two pricing models. But for a large stimulus of the size implemented in the US, the state-dependent pricing model exhibits much faster inflation in the first few quarters and a substantially smaller GDP response. Panel (c) shows that the reason for the faster inflation is the large increase in price adjustment in the wake of a large shock, which is absent in the Calvo model. This difference between the two models is that the endogeneity of price adjustment frequency is not consequential for small shocks, but is for a large shock.

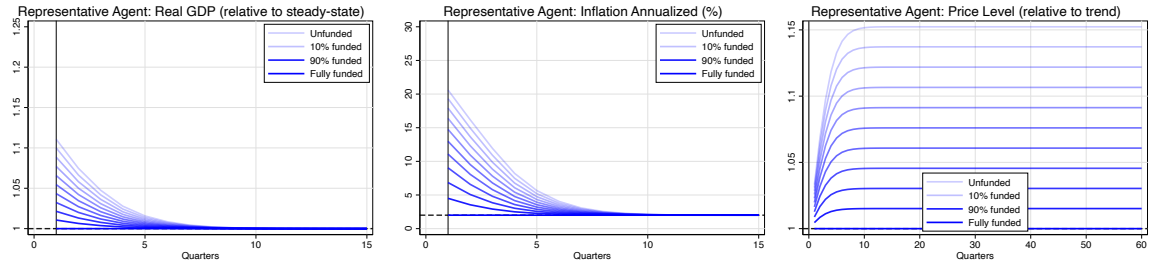
Panel (d) shows that for the small shock, and for the Calvo model with a large shock, the long-run response of the price level is a little higher than 20%, the cumulative size of the transfer. In a flexible price, representative agent economy the price level would jump by exactly 20% on impact and remain constant. The slightly larger cumulative price increase arises because of sticky prices. In representative agent versions of the same experiments (shown in Figure 17 in Appendix C), the long-run price level response is also slightly larger than 20% in both pricing models. The reason is that it is a weighted average of cumulative inflation at different horizons, as opposed to the cumulative price increase, that equals 20%. In Appendix A.3 we include an analysis of the cumulative price increase in response to a fiscal helicopter drop and discuss this issue further (see also Cochrane (2024)). This also explains why for a large shock with state-dependent pricing, the long-run price response in the heterogeneous agent model is larger than 20% (solid green line in Panel (d)). The very high inflation early on contributes more to the long-run effect on prices. We discuss the differences between the representative and heterogenous agent economies further

[9] 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.

[10] 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) 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, with time-dependent pricing. Funding is implemented by reductions in lump-sum transfers commencing after 5 years.

in Section 4.2.

4.2 Importance of Heterogeneous Agents

We illustrate the importance of heterogeneous agents and incomplete markets by comparing the effects of a large stimulus program under different assumptions about how the program is financed. The palest line labeled "Unfunded" in Figure 4c show the effects of an unfunded stimulus whose size is 15% of steady-state government debt. The darker lines show the response of GDP assuming that 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 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). In Figure 4d we plot the same impulse responses for GDP in the analogous representative agent economy. The corresponding inflation dynamics are shown in Figures 4b and 4e. To emphasize the distinction between heterogeneous and representative agents these figures are with time-dependent pricing. Analogous figures with state-dependent pricing are in Appendix A.2.

Short run effects of partially funded stimulus 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 after the first quarter. The reason is due to the failure of Ricardian equivalence in the heterogeneous agent economy. Even in response to 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 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 inflation in the short-run (although a large effect in the long-run, see below).

Short run effects of unfunded stimulus With an unfunded stimulus programs, there are no changes in future taxes or transfers so the failure of Ricardian equivalence is not a consequential difference from the representative agent economy. Yet, even in this case the effects on GDP and inflation are larger in the heterogeneous agent economy. The reason is due to movements in the real interest rate that arise because of heterogeneity in marginal propensities to consume (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). An unfunded stimulus lump-sum transfer program 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.

Long-run price level Figures 18c and 18f 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 governed by the degree of funding. In the representative agent economy, the long-run increase in prices is approximately equal to the cumulative amount of unfunded transfers as a fraction of steady-state debt. For example in the 50% financed case, the long

run increase in prices is 7.6% compared with a 7.5% increase in debt, with the small difference due to the higher inflation early on that is absent in a flexible price economy (see Appendix A.3).

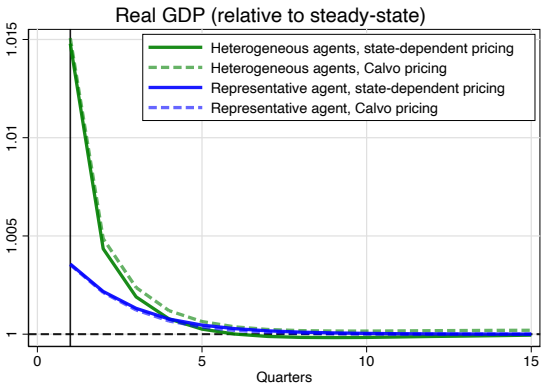
However, in the heterogeneous agent economy, the cumulative effect on the price level is larger than in the representative agent economy at all levels of funding, and even a fully funded transfer has a permanent effect on prices. For the 50% financed example above, the long-run effect on the price level increase is 7.9%. The additional inflation early on because of the failure of Ricardian equivalence leads to an overshooting in the price level. As explained in Appendix A.3, the intertemporal restriction imposed by the government budget constraint relates the average cumulative price increase to the long-run price increase, and the overshooting early on leads to a permanent effect on the price level. For this reason, the long-run effect is even larger with state-dependent pricing and heterogeneous agents (8.9% in this example).

Interaction Between Heterogeneous Agents and State-Dependent Pricing We have illustrated the difference between heterogeneous and representative agent economies in the context of a large stimulus program with time dependent pricing. With state-dependent pricing, these qualitative differences are exacerbated . This is reflected in Figure 5 which shows GDP and inflation responses to a small fiscal stimulus of which 50% is funded by a decrease in future transfers (top row), and a similarly financed large stimulus (bottom row). Each panel plots the response in the heterogeneous agent economy (green lines) and representative agent economy (blue lines), under state-depending pricing (solid lines) and Calvo pricing (dashed lines). Figure 20 in Appendix C contains analogous figures for an unfunded stimulus.

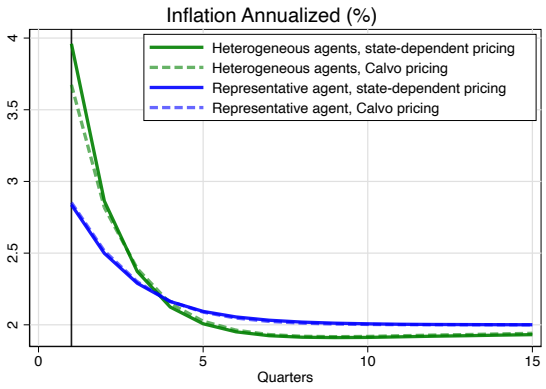
Figure 5 shows that for small shocks there are important differences in the effect of half-funded fiscal transfer between the representative and heterogeneous agent economy, because of the failure of Ricardian equivalence. However, the extent of these differences is the same in both pricing models (top row). But for a large stimulus program, the pricing model matters for how the failure of Ricardian equivalence in the heterogeneous agent economy manifests in inflation vs output (bottom row). With state-dependent pricing, there is a bigger surge in inflation and correspondingly smaller increase in output than in the Calvo model because the frequency of price adjustment increases in response to a large shock (green lines). In the representative agent model, even for a large half-financed stimulus program the model of pricing does not matter much for the dynamics of output and inflation (blue lines).

4.3 A Large and Persistent Interest Rate Hike

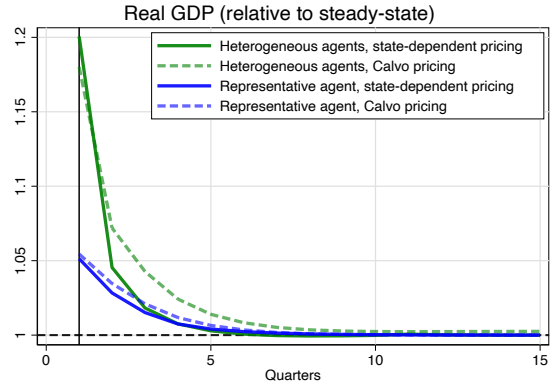
Before moving to the main experiment, it is useful to comment briefly on the effects of a change in the nominal interest rate in our environment. Figure 6a shows the inflation response to an unexpected 500 basis point increase in the nominal rate decaying with a half-life of 2 quarters, which is roughly the magnitude of the tightening in the US in 2022. Unlike in textbook New



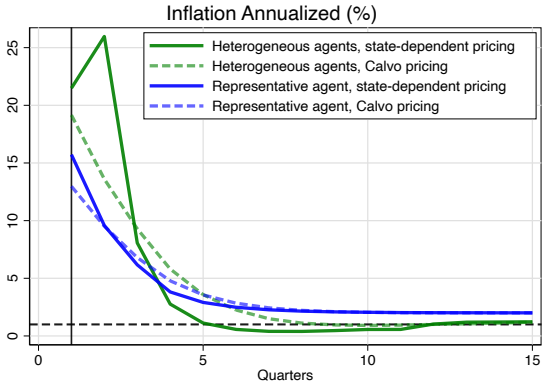
(a) Small fiscal stimulus: GDP



(b) Small fiscal stimulus: inflation



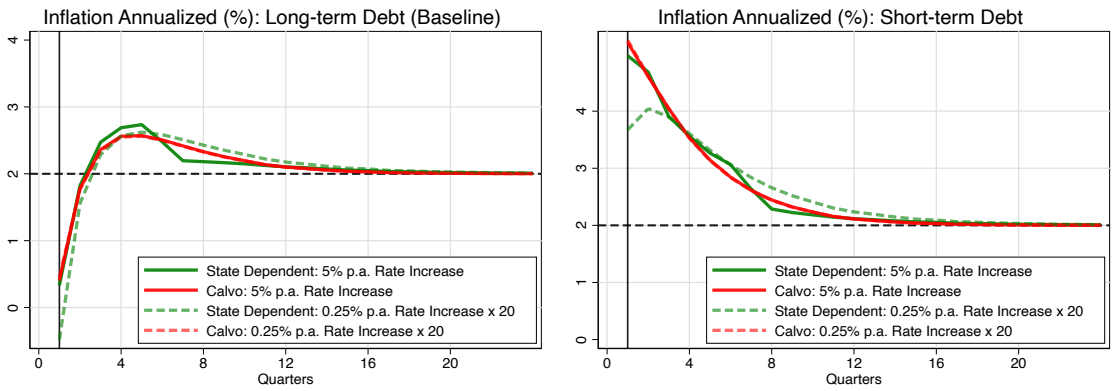
(c) Large fiscal stimulus: GDP



(d) Large fiscal stimulus: inflation

Figure 5: Impulse response to a 50% funded increase in uniform lump-sum transfers under different pricing models and heterogenous vs representative agent. Funding is implemented by reductions in lump-sum transfers commencing after 5 years. Panels (a) and (b) show a small stimulus equivalent to 1% of outstanding government debt. Panels (c) and (d) show a large stimulus equivalent to 15% of outstanding government debt.

Keynesian experiments, we do not assume any simultaneous change in taxes or transfers. 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 6a show, these dynamics are not due to either heterogeneous agents, state-dependent pricing or the size of the shock. Rather these dynamics are due to the "stepping-on-a-rake" forces identified by Sims (2011) and Cochrane (2024) that arise in the absence of a fiscal contraction with long-term debt. The initial fall in inflation is due to the fall in the long-term bond price, and the subsequent increase is due to the addition 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 6b. We draw attention to these effects because they illustrate how, in the presence of long-term



(a) Long-term debt

(b) Short-term debt

Figure 6: 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.

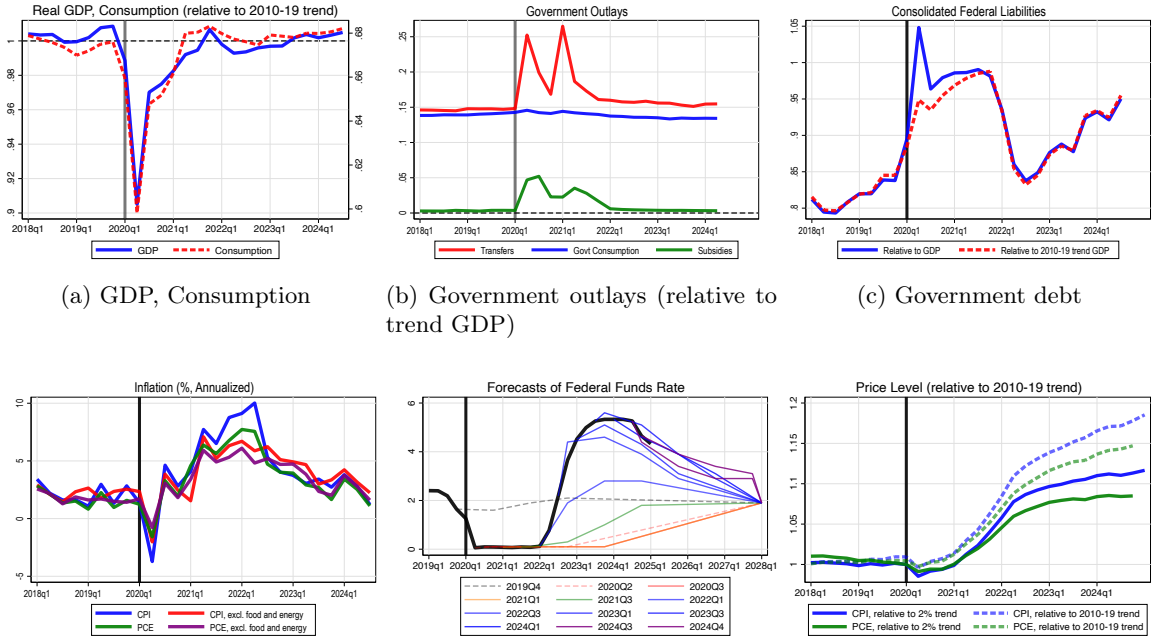
debt, an interest rate hike can shift the timing of inflation. For more details on these effects see Cochrane (2024) and Kaplan (2025). These forces will be important for understanding the role of monetary policy in shaping post-Covid inflation and output dynamics.

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 7 shows the dynamics from 2018 to the end of 2024 for six key macroeconomic variables that inform our analysis. Figure 7a shows a large drop and fast recovery in output (left axis) and consumption (right axis), concentrated in 2020Q2. Figure 7b shows the three main components of federal outlays over this period, as a fraction of the pre-Covid trend in GDP. Prior to 2020, government consumption and transfers were each around 15% of



(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 7: Time series for key aggregate variables

GDP. The various rounds of stimulus programs are reflected in the extraordinarily large increases in transfers and subsidies from 2020Q2 to 2021Q3. Figure 7c displays the resulting increase in real government liabilities and Figure 7d shows the subsequent surge in inflation according to four commonly used measures of inflation. In Figure 7e 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 7f shows that relative to a two percent trend, at the end of 2024 the price level was around 11% higher than its pre-pandemic level.

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,

$$\mathcal{E}_t^Z = \sum_{q=1}^{\lfloor t \rfloor} \varepsilon_q^Z e^{-\delta_Z (t-q)}$$

where q counts the number of full quarters elapsed since the start of 2022Q1, and $\lfloor t \rfloor$ is the most recent quarter. 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 $\delta_Z = \delta_C = 0.35$, so that the half-life of a shock is two quarters. None of our findings are sensitive to assuming faster or slower mean reversion, or to assuming hump shape dynamics, which we implement using an approximation to an AR(2) process.

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 7a) and CPI inflation (Figure 7d). Given our assumption on the shock dynamics, this is effectively a non-linear inversion exercise and we are able to match the realized paths exactly.[11]

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 7b. 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 7b. 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 7b. 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.[12]

We assume that at the beginning of each quarter, households learn about the total amount of

[11] Given the large shocks and non-linearities, this is a non-trivial computational problem, which we attack using a homotopy approach starting with small shocks.

[12] See Leeper (2026) and Cohrane (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.

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 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 7b 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 7e. 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. 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.

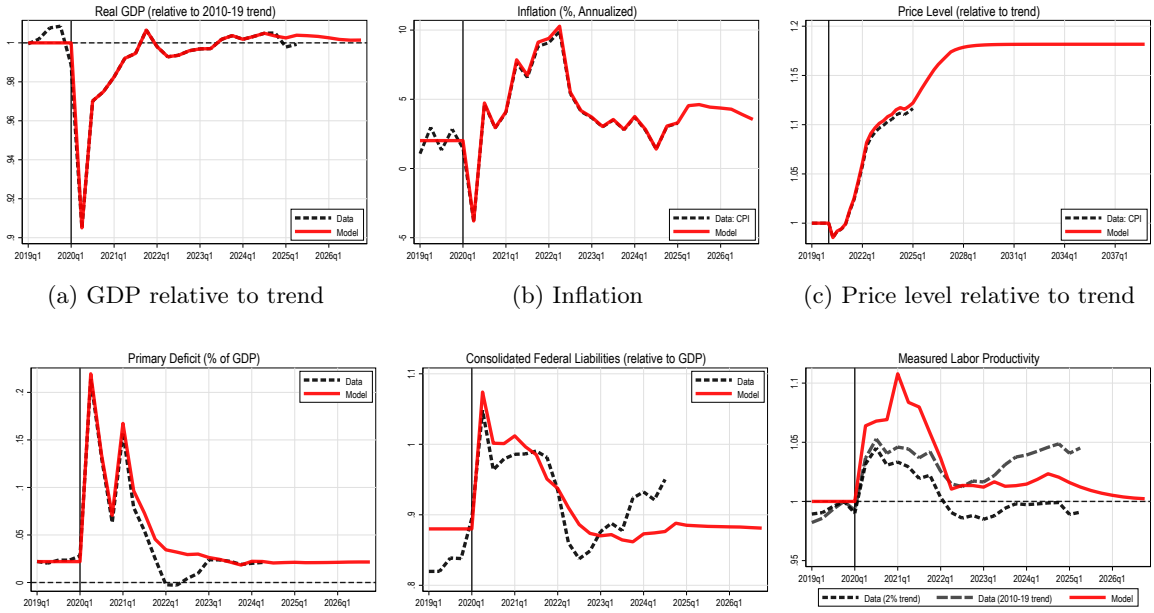
For the purposes of interpreting realized aggregate dynamics, this approach of feeding in directly the realized path of nominal rates and past forecasts avoids us having to take a stand on the monetary rule, since for any rule we could ex-post back out the sequence of monetary shocks that rationalizes the observed sequence of nominal rates. However, for constructing counterfactual paths 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 8 shows the fit of the model along relevant dimensions. By construction, the model matches the paths of GDP (Figure 8a) and inflation (Figure 8b), as well as nominal rates and fiscal outlays (not shown). Figure 8c shows the evolution of the price level relative to its pre-pandemic trend, which matches the observed price level until the end of 2024 by construction. The model forecasts that the price level will continue to rise above trend inflation.

Figure 8d 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 8e).

Implied Shock Series What paths of shocks are needed to account for these dynamics? The top row of Figure 9 shows the paths of productivity (left panel) and consumption utility shocks (right panel) implied by these dynamics, together with the implied forecasts at each data. The model rationalizes the initial drop in GDP as a largely demand shock - there is is a very large drop in consumption utility (around 25%) in 2020Q2, which then recovers gradually.



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

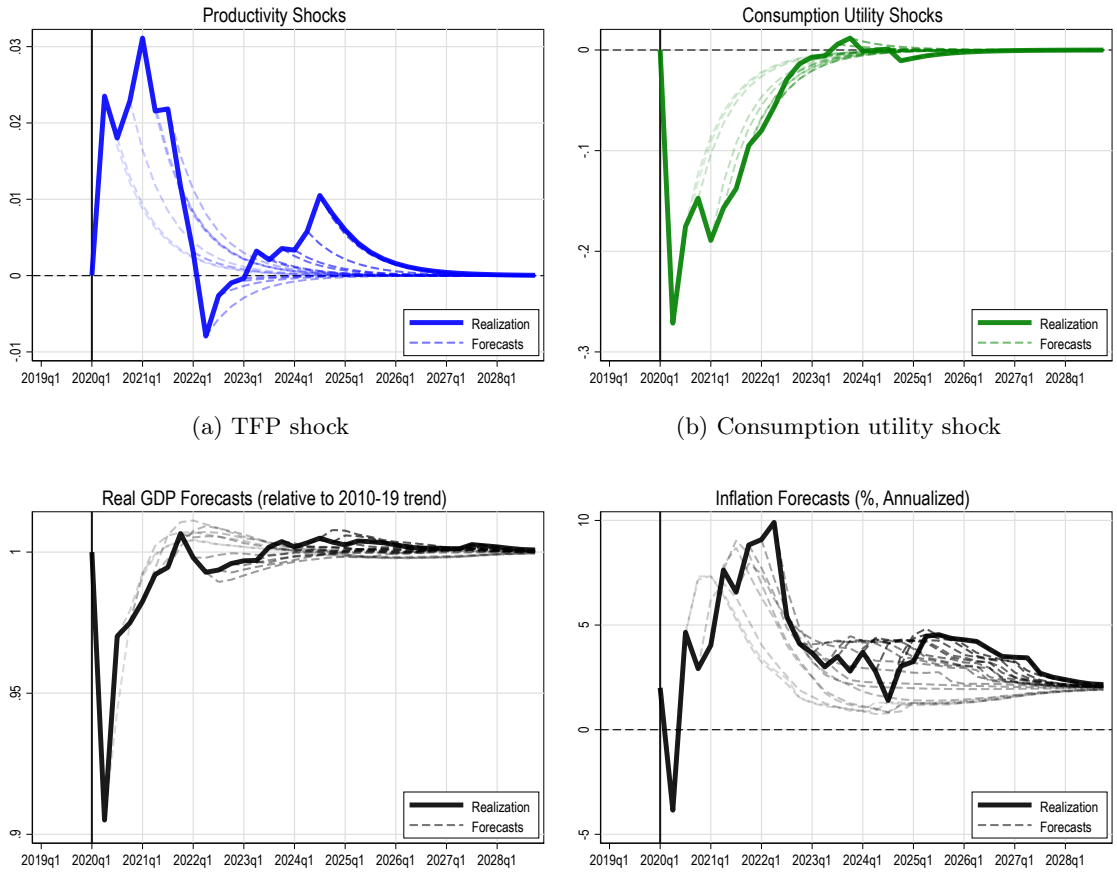
(d) Primary deficit relative to GDP (e) Government debt relative to GDP (f) Measured labor productivity

Figure 8: 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, there is a rapid decline in productivity, consistent with the role of supply chain disruptions that manifested over this period, contributing to the surge in inflation. While it might at first glance appear counterintuitive to infer a positive productivity shock upon impact, this is in fact consistent with measured labor productivity over this period. Figure 8f shows GDP per hour in the model and the data.

Implied GDP and Inflation Forecasts The bottom row of Figure 9 shows the GDP and inflation forecasts implied by the model.

Historical Decomposition Figure 10 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. 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



(a) TFP shock

(b) Consumption utility shock

(c) Implied GDP forecasts

(d) Implied inflation forecast

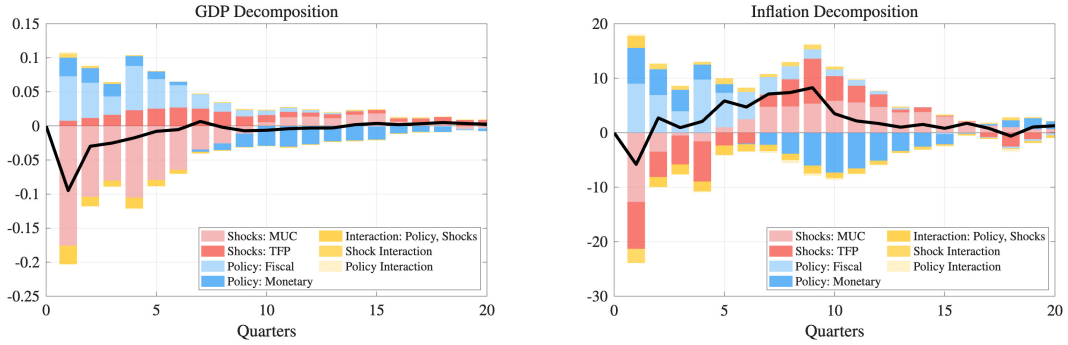
Figure 9: Calibrated shocks and implied forecasts, assuming exponential decay with half-life of two quarters.

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 feature of our model, heterogeneous agents and state-dependent pricing.

Household Wealth Figure 11a shows that median household wealth rises sharply as a result of the various rounds of stimulus, peaking at around 30% above its steady-state level. Wealth then remains elevated throughout 2021 and 2022, returning to steady-state only in 2025. These dynamics are broadly consistent with data on household cash balances. For example, Figure A5 in



(a) Historical decomposition of GDP

(b) Historical decomposition of inflation

Figure 10: Non-linear historical decomposition of GDP and inflation into shock, policy and interaction terms.

Wheat et al. (2024) shows a pattern for median real balances among JP Morgan account holders that matches almost perfectly the pattern Figure 11a.

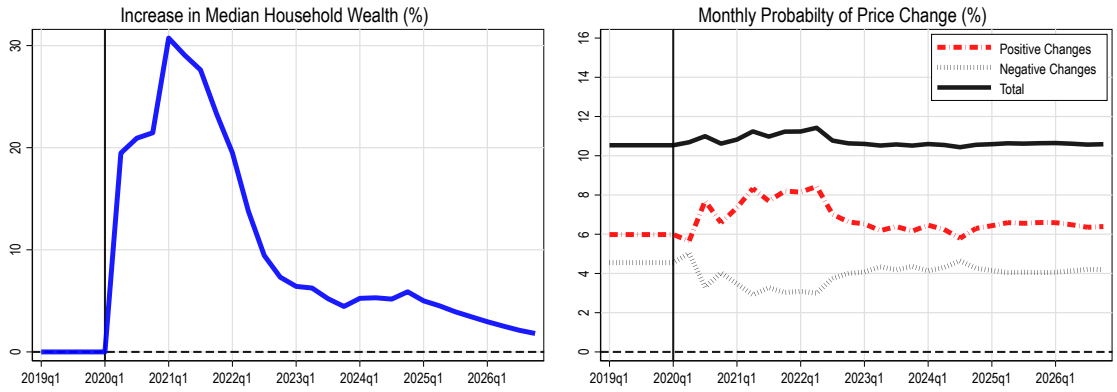
Frequency of Price Adjustment Figure 11b shows that the monthly frequency of price increase rises from 6% in the steady-state to a peak of 8%. Montag and Villar Vallenas (2025) (Figure 1) report changes in price-adjustment probabilities in the US using micro-data underlying the Consumer Price Index, and show that the frequency of price increases rises steadily from 6% at the start of 2020, peaking at around 15% in early 2022. Surprisingly, they also find that the frequency of price decreases rises slightly over this period, from 4% to over 5%, whereas in the model, the frequency of price decreases decline. In on-going work we are experimenting with models that allow for strategic complementarity in price-setting to try better match these dynamics of price adjustment.

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 12 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 around 15% relative to trend in 2020Q2, rather than 10%, and would have recovered much more slowly. Inflation would have



(a) Median household wealth

(b) Frequency of price adjustment

Figure 11: Model dynamics for relevant microeconomic features of household and firm behavior. Left panel shows median household wealth. Right panel shows monthly frequency of price adjustment.

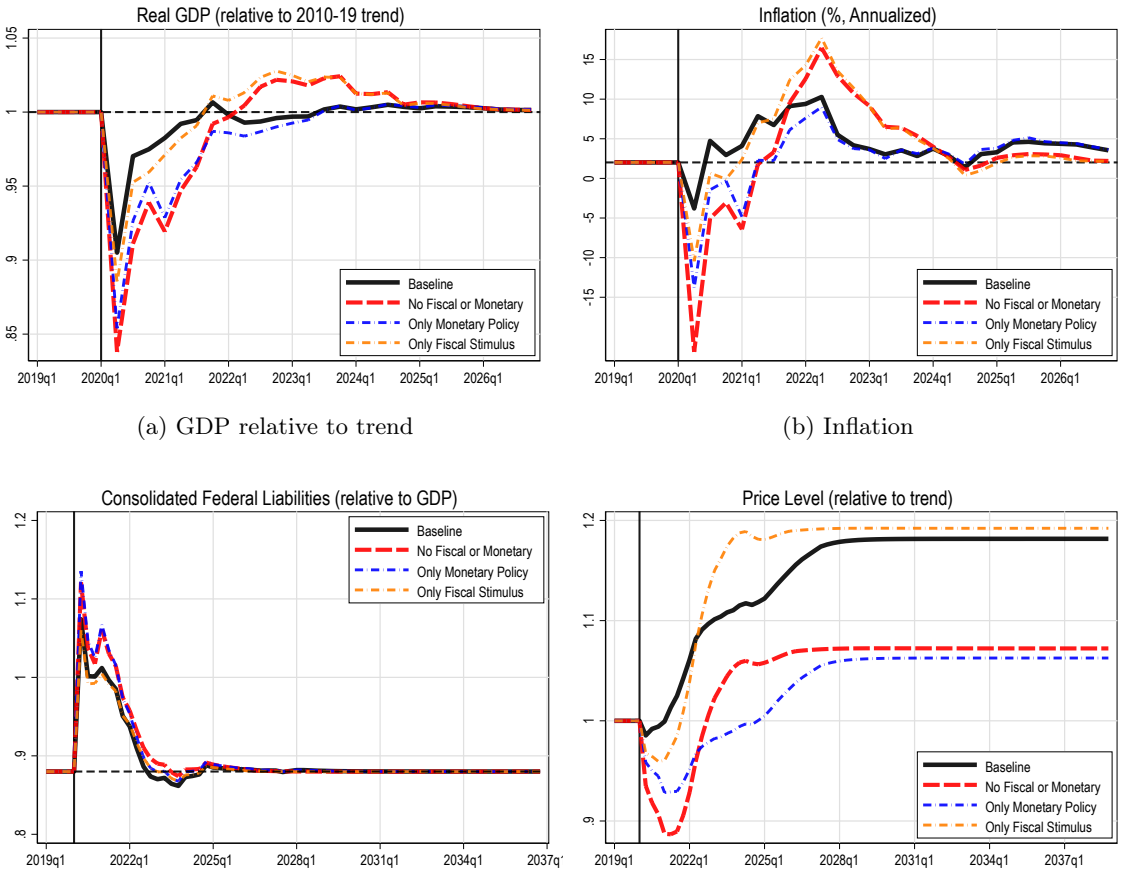
been much more volatile, with a large deflation throughout 2020 followed by a much larger and prolonged spike in inflation, peaking in mid-2022. The combined effect would have been a much smaller cumulative increase in the price level, with prices settling down about 7% above trend, compared with 18% above trend 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 dynamics are shown in the blue dash-dot line (monetary policy) and orange dashed line (fiscal policy).[13]

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 than would otherwise have occurred.

However, although the fiscal stimulus was important in limiting deflation during 2020, it is not responsible for the inflation surge during 2021 and 2022. As the red lines in Figure 8b show, even in the absence of the stimulus inflation would have reached similar levels and tapered off at the same rate. The reasons is the sharp decline in productivity throughout that period which also contributed to inflation. However, that supply-side inflation had only a temporary effect on prices

[13]Despite the size of both the shocks and the policy response, as well the various non-linearities in the model, the effects of the fiscal response and monetary response are close to additive, given the structural shocks, and there is little interaction between the two policies. There is, however, a strong interaction between the shocks and each of the policies, particularly in the first few year following the shock. See Figures 23 and 21 in Appendix C. This is also suggested by the historical decomposition in Figure 10.



(a) GDP relative to trend

(b) Inflation

(c) Government debt relative to GDP

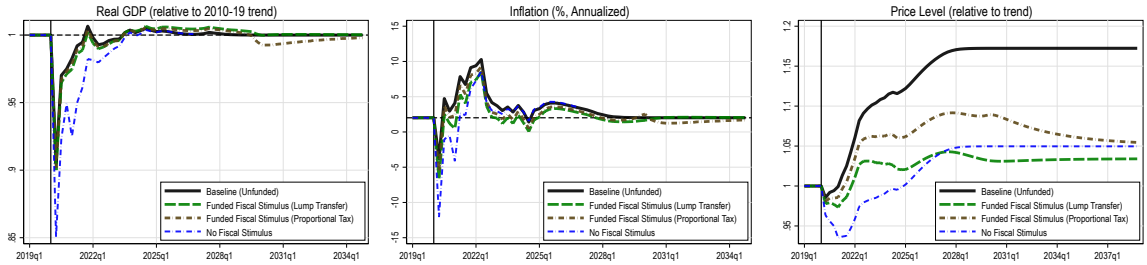
(d) Price level relative to trend

Figure 12: Counterfactual dynamics without monetary or fiscal responses

and as Figure 8c shows, the stimulus was largely responsible for the permanently higher price level.

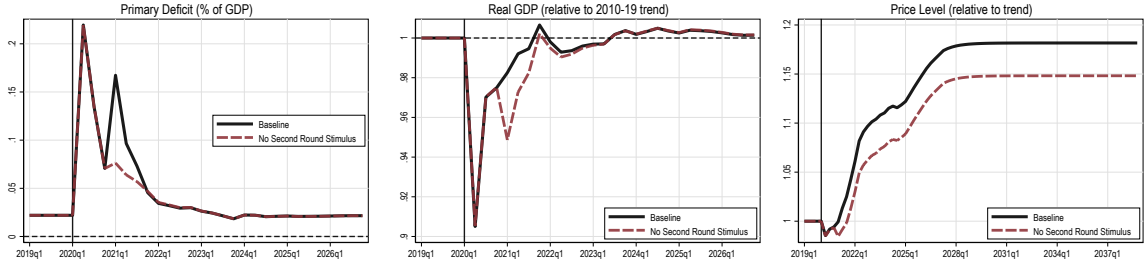
Thus there is a sense in which those who blame the inflationary sure on supply chain disruptions and those who point to the unfunded stimulus are both correct. The stimulus brought forward the run up in inflation and helped to prevent a larger deflationary slump early on, at the cost of a permanently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

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 by raising future taxes? Figure 13 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 case, the debt is repaid gradually according to a rule that raises surpluses in proportion to the deviation of real debt



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

Figure 13: 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. (NB: in this draft only these figures are for Calvo model, will be updated in subsequent draft).



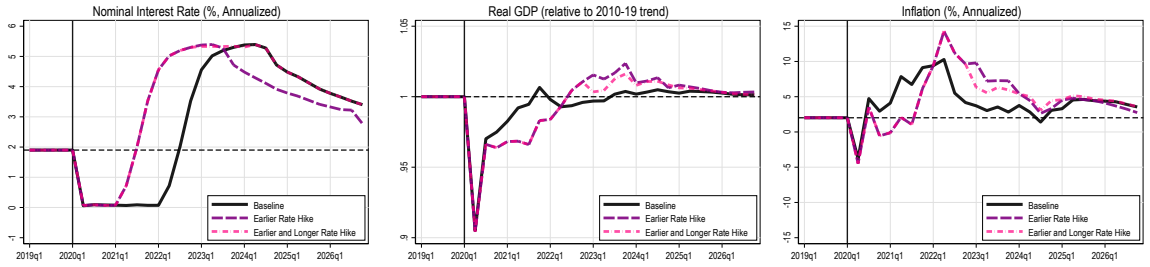
(a) Primary deficit relative to GDP (b) GDP relative to trend (c) Price level, relative to steady-state trend

Figure 14: Counterfactual dynamics without the additional rounds of stimulus in 2021.

from its steady-state level. See Appendix A.2 for full details of the government budget outside of steady-state

Figure 13a 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 a much smaller permanent increase in the price level. When the stimulus is funded with higher proportional taxes, the effect on both GDP during and following the pandemic is almost identical to the baseline. The trade-off relative to the unfunded case is a deep and 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 10 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 14 shows the effects of this alternative fiscal



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

Figure 15: Counterfactual dynamics if Fed had begun raising rates in 2021Q2 instead of 2022Q2

policy. Figure 14a 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 2% lower without the 2021 stimulus.

Effects of Monetary Policy Comparing the red dashed line and blue dash-dot lines in Figure 12 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 some 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, which peaked below 10%, compared with the counterfactual of 15%. The cost of this smoothing was persistently higher inflation, which remained above trend for much longer than otherwise, as 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 15 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 the associated earlier lowering of rates by one year meant that 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 suggest that an alternative policy path would may 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 15. 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, 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 on 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.

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,

$$V_0^{base}(a,\omega) = \mathbb{E}_0^{base}\left[\int_{t=0}^{\infty} e^{-\rho t}\left(e^{\mathcal{E}_t^C}\log c_t^{base}(a_t,\omega_t) - \psi\frac{h_t^{base}(a_t,\omega_t)^{1+\frac{1}{\nu}}}{1+\frac{1}{\nu}}\right)dt\middle| a,\omega\right]. \tag{22}$$

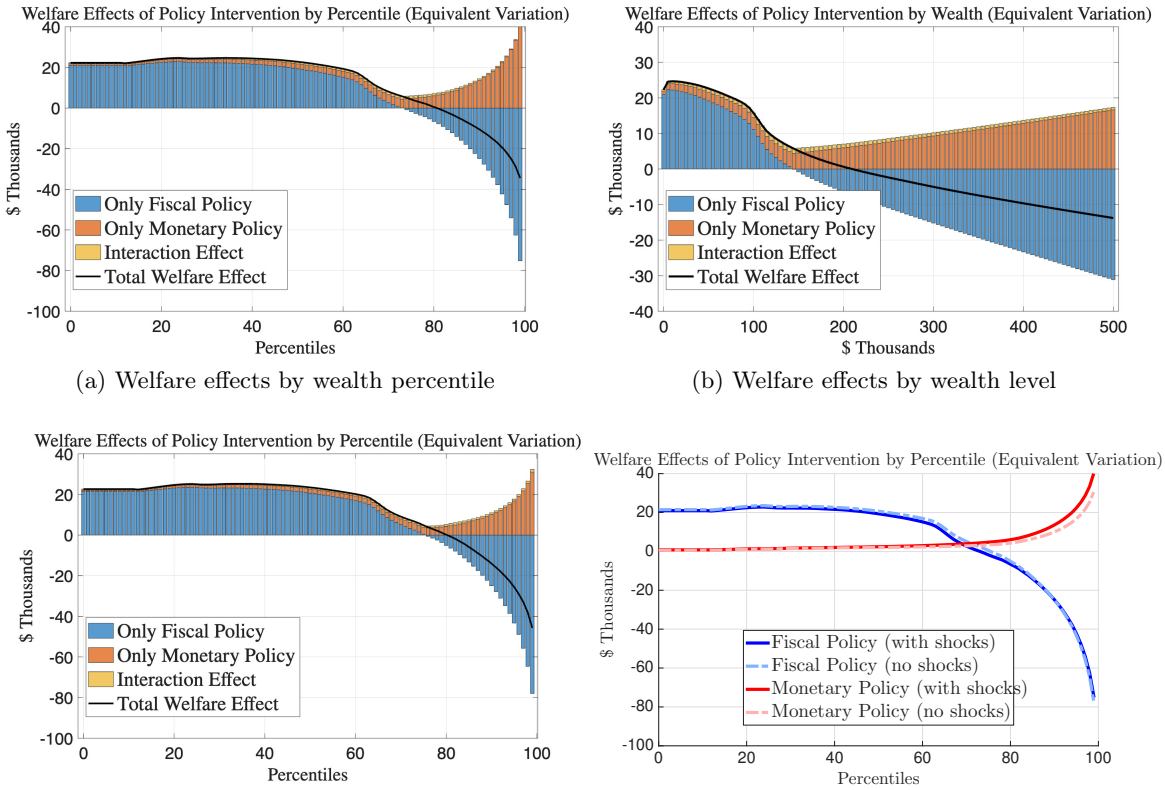
The expectation in (22) is taken with respect to the process for idiosyncratic shocks ω and implies a distribution of paths for (a_t,ω_t) in the baseline economy. The functions c_t^{base} and h_t^{base} are the corresponding paths of policy functions for consumption and hours, and the path of $\mathcal{E}_t^C$ (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

$$V_0^{base}(a,\omega) = V_0^{nopol}(a+\Delta(a,\omega),\omega). \tag{23}$$

The definition in (23) describes the dollar value to an individual with assets and productivity (a,ω) of the monetary and fiscal policy interventions.[14]

Distribution of welfare effects The top row of Figure 16 shows the distribution of welfare effects. The left panel shows the average value of $\Delta(a,\omega)$ at each percentile of the wealth distribution. The right panel shows the average value of $\Delta(a,\omega)$ for households with different amounts

[14] We also evaluated the welfare effects using preferences that set $\mathcal{E}_t^C = 0$ and find very similar results. See Figure 22 in Appendix C. This suggests that the welfare effects of the policies are not due to shifting consumption over time in a way that aligns with households' exogenously changing marginal rates of substitution because of the way we model the the pandemic demand shock.



(a) Welfare effects by wealth percentile

(b) Welfare effects by wealth level

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

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

Figure 16: 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. Left panel by percentiles, right panel by dollars. Bottom row shows the effects of the policy interventions in the absence of the pandemic shocks.

of wealth up to $500,000. The solid black line in each figure 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 20 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 early on from the rate cut slightly offset the effects of lower real wages later on when the interest rate rises. For higher wealth households there is an additional positive welfare effect from the persistent higher real rates

Aggregate welfare effects To assess the aggregate desirability of the policy interventions we need to aggregate the distribution of welfare effects in Figure 16. 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 \$12,000 per household, roughly equally split between the monetary and fiscal responses.

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, panel (c) in Figure 16 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 panel (a) 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. Panel (d) illustrates this by plotting the welfare effects of the each policy with and without shocks alongside each other. The reason is that the fiscal stimulus is largely a redistributive policy that transfers resources to low wealth households, financed with lower real rates borne by high wealth households. The monetary intervention generates on net a persistently higher real rate which allows households to better smooth consumption.

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.

What caused the inflation surge and increase in prices? 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 to 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 and the net effect on the long-run price level would have left it around 7% above trend, rather than 18%. Inflation would have also returned to trend 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 interest rate 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 persistently 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 taxes was a permanently higher price level, around 10 percentage points higher than without the stimulus. Because of the strong failure of Ricardian equivalence, a funded stimulus package, particularly one paid for with higher future taxes, could also have supported inflation and GDP during the pandemic, without the permanent effect on the price level. However, it would come at the cost of a future recession when taxes are ultimately raised.

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 $12,000 per household. However, two important caveats are in order. First, these policy interventions had a very large redistributive effect, particularly the fiscal stimulus policy, which benefited the bottom 80 percent of households at the expense of the top 20 percent of households. Second, these welfare effects should not be interpreted as arising from a response to the large exogenous shocks and should not be interpreted as the benefits of aggregate stabilization. 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.

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A Appendix Model Details

A.1 Details of Firm Pricing Problem

CES demand system. To obtain the demand for variety j in the main text note that the demand problem for the final good producer can be recast into solving for quantities $\tilde{y}_{jt} = \zeta_{jt} y_{jt}$ with prices $\tilde{p}_{jt} = p_{jt}/\zeta_{jt}$ per unit. The standard monopolistic competition demand formula then implies the one in the main text.

Preliminaries of Price Setting Problem. The main text shows that flow real profits at time t for a retailer with current price p, demand state ζ and productivity state z is

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

Here we impose the assumption that $z = \zeta$. This amounts to assuming that initial conditions on z and ζ coincide, the Brownian components are perfectly correlated and parameter values in both models coincide. With this assumption, real profits are

$$\begin{aligned}\left(\frac{p}{\zeta P_t}\right)^{-\epsilon}\left(\frac{p}{\zeta P_t}-\frac{P_{I,t}}{P_t}\right)Y_t &= \left(\frac{p}{\zeta P_t}\right)^{-\epsilon}\left(\frac{p}{\zeta P_t}-\frac{P_{I,t}}{P_t}\right)Y_t \\ &= \left(\frac{p}{\zeta P_t\frac{\epsilon}{\epsilon-1}\frac{P_{I,t}}{P_t}}\right)^{-\epsilon}\left(\frac{p}{\zeta P_t\frac{\epsilon}{\epsilon-1}\frac{P_{I,t}}{P_t}}-\frac{\epsilon-1}{\epsilon}\right)\left(\frac{\epsilon}{\epsilon-1}\frac{P_{I,t}}{P_t}\right)^{1-\epsilon}Y_t.\end{aligned}$$

Therefore we can define real profits in a single state variable which we refer to as **price gap**

$$x_t = \log p - \log\left[\frac{\epsilon}{\epsilon-1}\zeta_t P_{I,t}\right]$$

where we notice that $\frac{\epsilon}{\epsilon-1}\zeta_t P_{I,t}$ is the optimal price chosen by a flexible-price monopolist. Finally, real profits can be written as

$$\Pi_t(x) = \exp(-\epsilon x)\left[\exp(x)-\frac{\epsilon-1}{\epsilon}\right]\left(\frac{\epsilon}{\epsilon-1}\frac{P_{I,t}}{P_t}\right)^{1-\epsilon}Y_t.$$

Further assume that the mean reversion parameter $\theta_\zeta = 0$ so the demand shifter process is a random walk. Then, the law of motion of price gap x_t when the firm is not adjusting its price is

$$dx_t = -\sigma_\zeta dB_{\zeta,t} - \frac{\dot{P}_{I,t}}{P_{I,t}}dt.$$

where dot denotes derivatives with respect to time. At price change dates, x_t is controlled via an impulse of size equal to the price change which we will characterize next.

Firm's Price Setting Problem. At each instant, the firm receives flow profits $\Pi_t(x)$ and chooses repricing efforts λ which creates a flow utility cost. In real terms this cost is $\kappa(\lambda) = (\gamma_0\lambda)^{1+\gamma_1}$ with $\gamma_0, \gamma_1 > 0$. The benefit of exerting effort lies in affecting the arrival rate of price adjustment opportunities λ. Upon the arrival of a repricing opportunity, the firm chooses a reset price gap $\hat{x}_t$. The size of the log price change upon a change in price gaps from x to $\hat{x}$ is equal to $\Delta \log p = \hat{x} - x$ because the demand shifter and intermediate price processes have continuous sample paths.

The firm solves the following HJB equation

$$\rho v_t(x) = \Pi_t(x) - \frac{\dot{P}_{I,t}}{P_{I,t}} v_t'(x) + \frac{\sigma_\zeta^2}{2} v_t''(x) + \max_{\hat{x}\in\mathbb{R},\lambda\geq 0} \{\lambda(v_t(\hat{x}) - v_t(x)) - \kappa_t(\lambda)\} + \dot{v}_t(x).$$

The solution to the problem is a value function $v_t(x)$, an adjustment hazard function $\lambda_t(x)$ solving

$$\lambda_t(x) = \frac{1}{\gamma_0}\left[\frac{v_t(\hat{x}_t) - v_t(x)}{\gamma_0(1+\gamma_1)}\right]^{\frac{1}{\gamma_1}}$$

and a reset price gap solving

$$v_t'(\hat{x}_t) = 0.$$

The treatment that follows closely mirrors Cavallo et. al (2024) but considers a non-stationary equilibrium.

Aggregation. Given an initial distribution of price gaps $\mu_0^f(x)$, the distribution of price gaps evolves as

$$\dot{\mu}_t^f(x) = \frac{\dot{P}_{I,t}}{P_{I,t}} \mu_t^{f\prime}(x) + \frac{\sigma^2}{2}\mu_t^{f\prime\prime}(x) - \lambda_t(x)\mu_t^f(x), \quad \text{for each } x \neq \hat{x}_t.$$

The stationary distribution of price gaps is characterized by

$$0 = \frac{\dot{P}_t}{P_t}\mu^{f\prime}(x) + \frac{\sigma^2}{2}\mu^{f\prime\prime}(x) - \lambda(x)\mu^f(x), \quad \text{for each } x \neq \hat{x},$$

with boundary conditions $\lim_{x\downarrow\hat{x}} \mu^f(\hat{x}) = \lim_{x\uparrow\hat{x}} \mu^f(\hat{x})$, $\int_{-\infty}^{\infty} \mu^f(x)\,dx = 1$ and $\lim_{\pm\infty} \mu^f(x) = 0$. Note that the stationary increase in intermediate input prices is solely because of aggregate price increases. In this stationary equation we use $\lambda(x)$ and $\hat{x}$ which are the stationary counterparts to the time-varying policy functions.

In the aggregate shocks exercises in the main text we initialize the distribution of price gaps at the stationary distribution.

Frequency of price adjustments The frequency of price adjustments Λ_t is given by

$$\Lambda_t = \int_{-\infty}^{\infty} \lambda_t(x)\, \mu_t^f(x)\, dx.$$

This equation keeps track of the number of price changes per unit of time by multiplying the adjustment intensity $\lambda_t(x)$ with the density of firms with a given price gap $\mu_t^f(x)$.

Similarly, the frequency of price increases or decreases is further obtained by multiplying the integrand by an indicator function for the event $1\{x < \hat{x}_t\}$ or otherwise.

Distribution of price adjustments. As noted before, the size of a log price change equals the size of a price gap change. Define $\Delta p = \hat{x}_t - x$, then the distribution of price changes is given by

$$q_t(\Delta \log p) = \frac{\lambda_t(x)\, \mu_t^f(x)}{\Lambda_t}.$$

A.2 Details of Funded and Unfunded Government Budget

Outside of steady-state, the government keeps track of two budgets, one unfunded b_t^u and one funded b_t^f,

$$b_t = b_t^u + b_t^f, \tag{24}$$

with corresponding nominal values B_t^u and B_t^f.

The unfunded component of government debt b_t^u is debt backed only by surpluses raised from the steady-state tax function $\bar{\mathcal{T}}(x)$. Unfunded debt evolves as

$$db_t^u = r_t b_t^u - \bar{\mathcal{T}}(Y_t) + (1-\varphi)\mathcal{E}_t^{\tau}. \tag{25}$$

where φ is the fraction of fiscal stimulus that are explicitly backed by new taxes. We assume that the steady-state debt is unfunded so that after a shock $b_0^u = \bar{b}, b_0^f = 0$. This means that fiscal policy is active in the language of Leeper (1991).

The funded component of government debt b_t^f is debt backed by commitments to raise additional future surpluses sufficient to eventually repay it. When steady-state debt is unfunded, funded debt arises when $\varphi > 0$ meaning that the government finances part of a fiscal stimulus policy $\mathcal{E}_t^{\tau}$ by issuing new debt that it commits to repay. We assume that outside steady-state, the government raises these surpluses by lowering lump-sum transfers according to the rule

$$\varsigma_{0,t} = \begin{cases} \bar{\varsigma}_0 & \text{if } t \le t^* \\ \bar{\varsigma}_0 - \phi_b b_t^f & \text{if } t > t^*, \end{cases} \tag{26}$$

or by raising proportional taxes according to the rule

$$\varsigma_{1,t} = \begin{cases} \bar{\varsigma_1} & \text{if } t \leq t^* \\ \bar{\varsigma_1} - \phi_b b_t^f & \text{if } t > t^*, \end{cases} \tag{27}$$

In both cases we assume that with $\phi_b > \bar{r}$.

Starting from steady-state with $b_t^f = 0$, funded debt accrues from the funded component of fiscal stimulus, $\varphi \mathcal{E}_t^\tau$. The rule implies that the government starts to raise surpluses after a delay of t^*, after which it lowers the level of lump-sum transfers or raises the proportional tax rate in proportion to the amount of funded debt outstanding. Hence funded debt evolves as

$$db_t^f = \begin{cases} r_t b_t^f + \varphi \mathcal{E}_t^\tau & \text{if } t \leq t^* \\ (r_t - \phi^b) b_t^f & \text{if } t > t^*. \end{cases} \quad . \tag{28}$$

Since $\phi_b > \bar{r}$, the rule guarantees that funded debt always return to zero, so that the funded component of stimulus transfers $\varphi \mathcal{E}^\tau$ is always repaid.

Note that even when all stimulus payments are unfunded $\varphi = 0$, our formulation of the tax revenue function allows for the possibility of partial self-financing, in the language Angeletos et al. (2024), since it is the steady-state tax *function* rather than *revenues* which back unfunded debt, and actual tax revenues depend endogenously on output.

A.3 Long-Run Price Effect of a Fiscal Helicopter Drop

In this appendix we summarize the effects of a one-time fiscal helicopter drop on the price level. Consider a policy in which the government issues an amount of new nominal debt equivalent in value to a fraction Δ of its outstanding debt, and uses the proceeds to make a one-time lump sum transfer to households. We assume that at the time of the transfer the government announces that it does *not* plan to repay the new debt and will keep the primary surplus unchanged from its steady-state level of $\bar{s}$. We also assume that monetary policy holds the nominal rate constant throughout at $i_t = \bar{i}$.

A Useful Integral Equation Integrating the government budget constraint (21) forward in time from an initial condition $b_0 > 0$, yields an integral restriction on the joint time path of inflation, nominal rates and primary surpluses that turns out to be useful for understanding many of the results that follow,

$$\frac{b_0}{b_\infty} = \int_{t=0}^{\infty} \omega(t)\, e^{-\int_{j=0}^{t} (\hat{i}_j - \hat{\pi}_j) d\tau} e^{\hat{s}_j}\, dt, \tag{29}$$

where $\hat{i}_t$ and $\hat{\pi}_t$ are paths of deviations of nominal interest rates and inflation from steady-state, $\hat{s}_t$ are log deviations of the primary surplus from steady-state, and $\omega(t) \coloneqq r^* e^{-r^* t}$ is a non-negative, decreasing weighting function that integrates to 1. Equation (29) assumes a positive steady-state real rate, $r^* > 0$. With $r^* < 0$ an analogous equation holds for any economy that returns to steady state, with similar implications. One can also integrate forward the log-linearized version of (21) to obtain an equivalent integral restriction that holds for small deviations from steady-state,

$$\log \frac{b_0}{b_\infty} = \int_{t=0}^{\infty} \omega(t) \left(\hat{\pi}_t - \hat{i}_t + \hat{s}_t \right) dt, \tag{30}$$

Representative agent, flexible prices Consider a flexible price endowment economy with a representative household. The amount of *nominal* debt immediately after the policy is $B_0 = B^*(1+\Delta)$. Since prices are flexible, the real interest rate remains unchanged at $r^* = \rho$. And since the nominal rate is unchanged, the inflation rate is therefore unaffected by the policy and remains constant at $\bar{\pi} = \bar{i} - \rho$. Therefore there is is a one-time jump in the price level. To compute the size of the jump in the price level, note that the steady-state of the government budget constraint (21) requires that the real value of government debt is $b^* = \frac{\bar{s}}{\rho}$, and so is unaffected by the fiscal stimulus program, and is therefore the same before and after the change and is given by

$$b^* = \frac{B^*}{P^*} = \frac{B^*(1+\Delta)}{P_0}, \tag{31}$$

where P_0 is the price level immediately after the stimulus. The effect of the stimulus is therefore an immediate jump in the price level of size Δ so that $P_0 = P^*(1+\Delta)$, with no change in any real variables or inflation.

Representative agent, sticky prices With sticky prices the same forces manifest as an inflationary boom in which inflation temporarily rises above its steady state level, and the cumulative increase in the price level is close to Δ. To see why, set $\hat{i}_t = \hat{s}_t = 0$ in equation (30) (by assumption the nominal rate and primary surpluses are both unchanged by the policy). Since prices are sticky, there is no change in the price level on impact, and so the real value of debt immediately after the transfer is $b_0 = (1+\Delta) b^*$. Moreover, because the economy returns to the same real steady-state, $b_\infty = b^*$ and so equation (30) implies

$$\log(1+\Delta) \approx \int_{t=0}^{\infty} \omega(t) \hat{\pi}_t dt. \tag{32}$$

To relate this to the long-run increase in the price level, note that

$$\begin{aligned}\frac{P_\infty}{P_0} &\approx 1+\int_{t=0}^{\infty}\hat{\pi}\left(t\right)dt\\ &=1+\int_{t=0}^{\infty}\omega\left(t\right)\hat{\pi}\left(t\right)dt-\int_{t=0}^{\infty}\left[\omega\left(t\right)-1\right]\hat{\pi}\left(t\right)dt\\ &=1+\log\left(1+\Delta\right)-\int_{t=0}^{\infty}\left[\omega\left(t\right)-1\right]\hat{\pi}\left(t\right)dt\\ &=1+\Delta-\varepsilon_1-\varepsilon_2. \end{aligned} \tag{33}$$

Equation (33) says that for small shocks, the cumulative increase in the long-run price level is approximately Δ. The first term in the approximation, $\varepsilon_1 := \Delta - \log\left(1+\Delta\right)$ is the log approximation error and is negative. When inflation is declining monotonically over time, the second term in the approximation $\varepsilon_2 = \int_{t=0}^{\infty}\left[\omega\left(t\right)-1\right]\hat{\pi}\left(t\right)dt$ is positive. In practice, for small shocks both discrepancies are small, and the cumulative price increase is well approximated by $1+\Delta$.

Heterogeneous agents, flexible prices Consider the case of a flexible price, endowment economy. The stimulus program gives each household an additional amount of nominal resources ΔB^*. If the price level were to immediately jump to $P_0 = P^*\left(1+\Delta\right)$ as it does in the RANK economy, then households with higher initial wealth than the average would suffer a fall in real wealth, and vice-versa. Intuitively, the stimulus program gives real resources to households in an additive way, but the rise in the price level takes real resources away from households in a multiplicative way. A household with the average wealth in the economy would be unaffected for the same reason that the representative agent is unaffected by the same experiment in a RANK model.

However, in a HANK model this would result in real redistribution from high-wealth households to low-wealth households. Moreover, because low-wealth households have higher MPCs than high-wealth households, overall spending would increase, putting additional upward pressure on the price level. For the goods market to clear, a period of higher real interest rates is required to offset this additional spending pressure. This means that equation (31) no longer holds.With no change in the nominal rate, the higher real rate comes about via lower future inflation, implying that the price level jumps higher on impact than in the representative agent economy and so $P_0 > P^*\left(1+\Delta\right)$. For small shocks, the long-run price increase $P_\infty$is well approximated by Δ.

Heterogeneous agents, sticky prices With sticky prices, this higher initial price jump manifests as an overshooting of inflation in the immediate wake of the stimulus, followed by lower subsequent inflation. For small shocks, the formula in equation (32) is a good approximation to the long-run effect, but for a large stimulus it is not a good approximation. The corresponding

formula for large shocks, which comes from setting $B_0 = (1+\Delta) B^*$ in equation (29) is

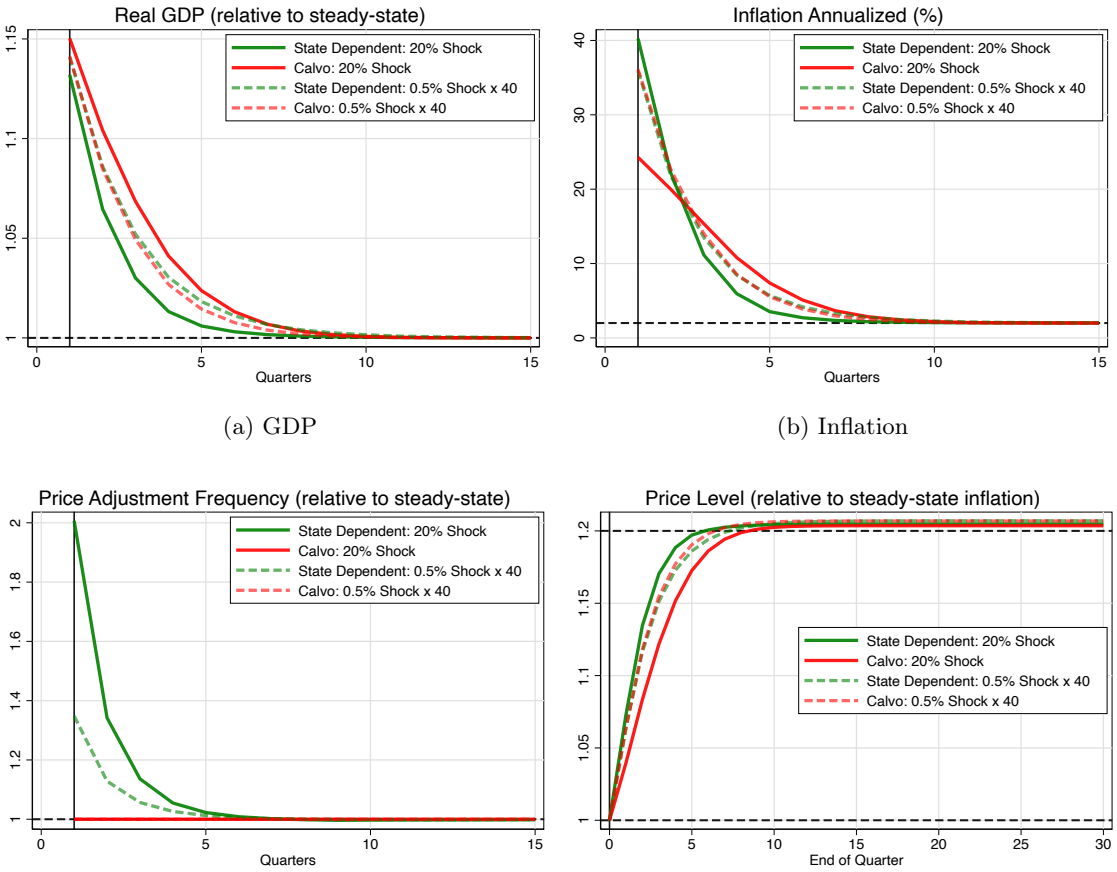
$$1 + \Delta = \int_{t=0}^{\infty} \omega(t) \frac{P_t}{P_0} dt. \tag{34}$$

Equation (34) shows that a weighted average of cumulative price increases at all horizons equals the size of the stimulus Δ. When there is a large amount of overshooting of prices from the real redistribution described above, the non-monotonic path of prices means that the lower future inflation is not enough to offset the higher inflation early on, and the cumulative increase in the price level is larger than Δ.

B Appendix Calibration Details

TO BE ADDED

C Appendix Figures



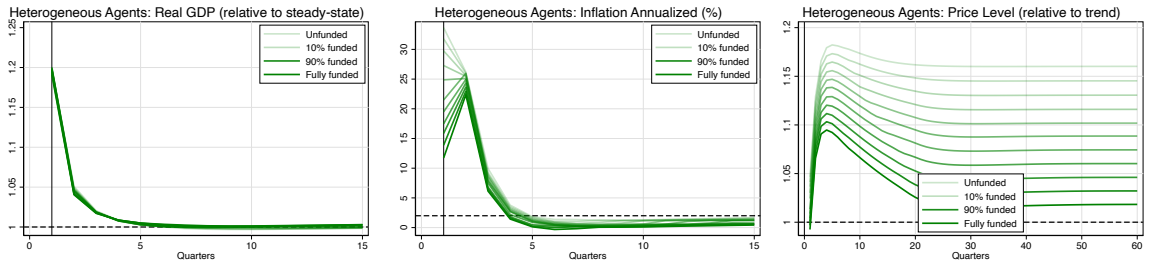
(a) GDP

(b) Inflation

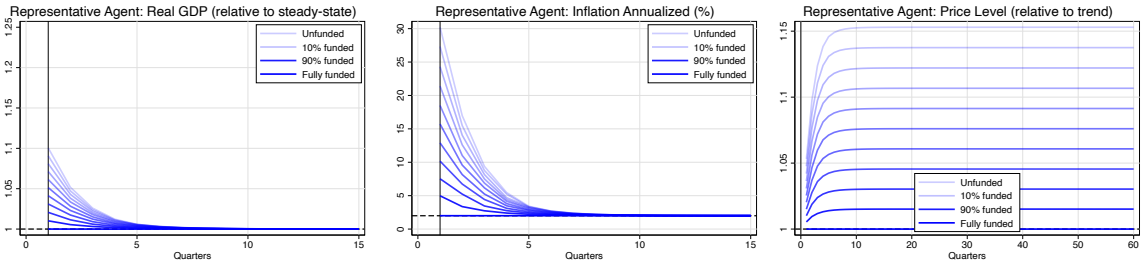
(c) Frequency of price adjustment

(d) Price level relative to steady-state)

Figure 17: Impulse response to a large and small unfunded increase in uniform lump-sum transfers in representative agent economy. Large shock is 13% of outstanding steady-state debt, small shock is 1%. Figures for small shocks are multiplied by 13 for comparability.

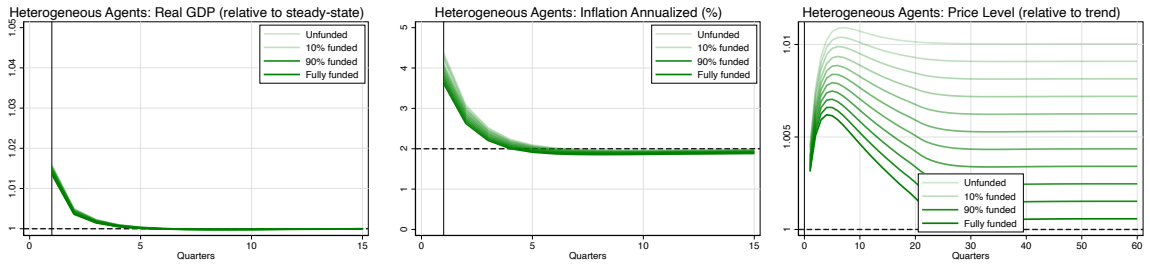


(a) Heterogeneous agents: GDP (b) Heterogeneous agents: inflation (c) Heterogeneous agents: price level

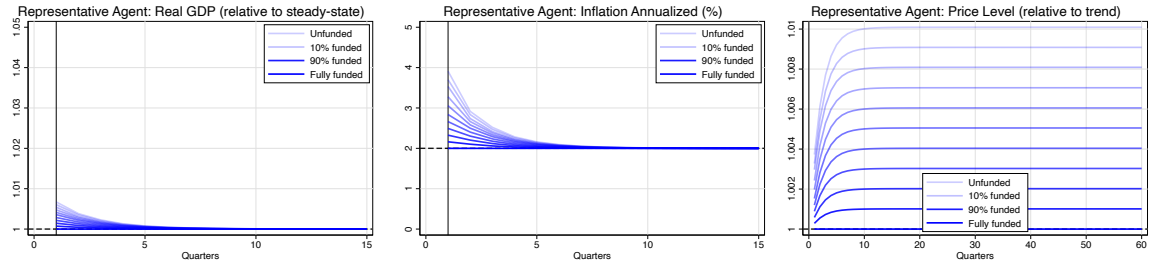


(d) Representative agent: GDP (e) Representative agent: inflation (f) Representative agent: price level

Figure 18: 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.

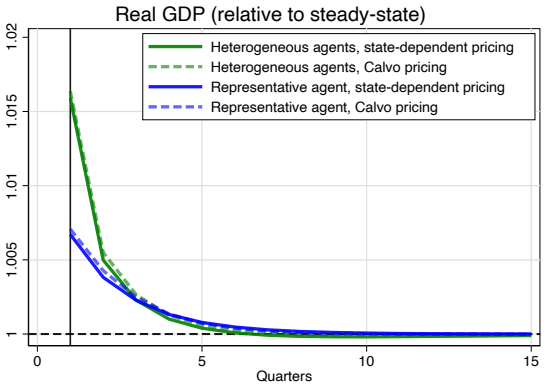


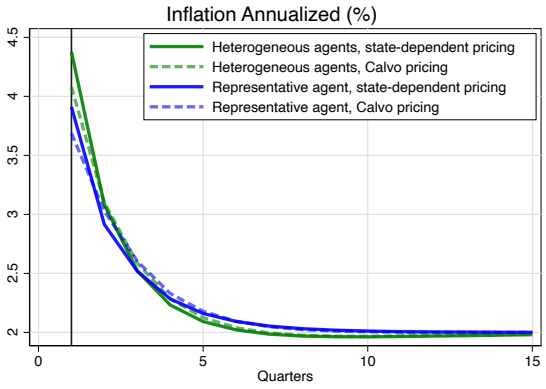
(a) Heterogeneous agents: GDP (b) Heterogeneous agents: inflation (c) Heterogeneous agents: price level



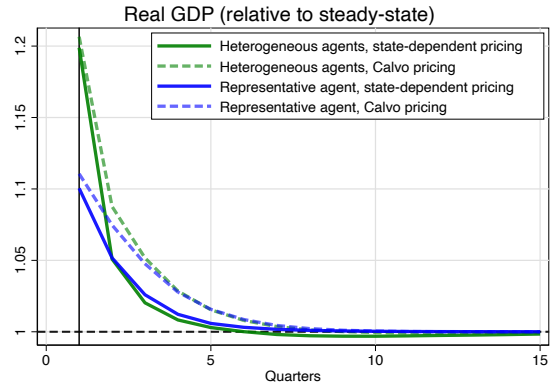
(d) Representative agent: GDP (e) Representative agent: inflation (f) Representative agent: price level

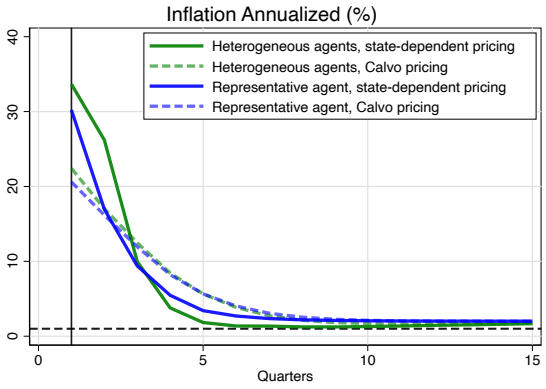
Figure 19: Impulse response to an increase in uniform lump-sum transfers, equivalent to 1% of outstanding government debt, for different degrees of funding in 10% increments from unfunded to fully funding. Funding is implemented by reductions in lump-sum transfers commencing after 5 years.





(a) Small fiscal stimulus: GDP

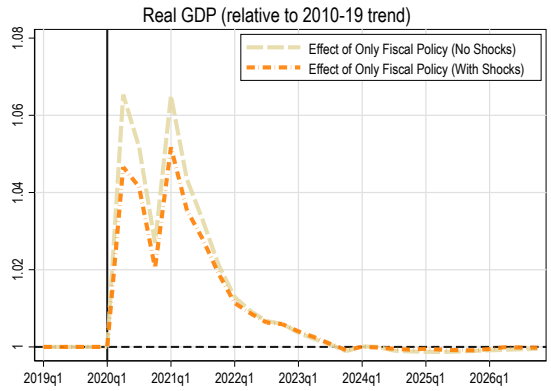




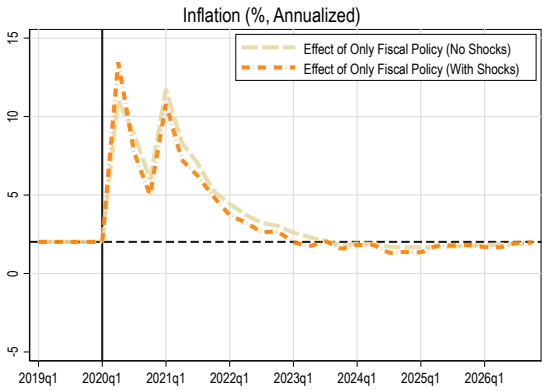
(c) Large fiscal stimulus: GDP

(d) Large fiscal stimulus: inflation

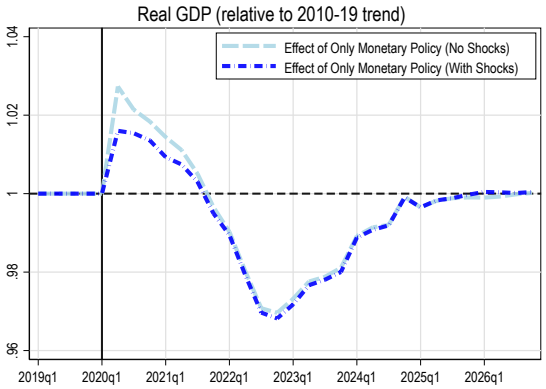
Figure 20: Impulse response to an unfunded increase in uniform lump-sum transfers under different pricing models and heterogenous vs representative agent. Panels (a) and (b) show a small stimulus equivalent to 1% of outstanding government debt. Panels (c) and (d) show a large stimulus equivalent to 13% of outstanding government debt.



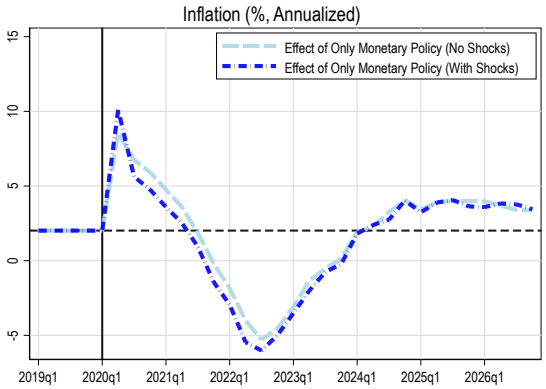
(a) Effect of fiscal stimulus on GDP with and without shocks



(b) Effect of fiscal stimulus on inflation with and without shocks

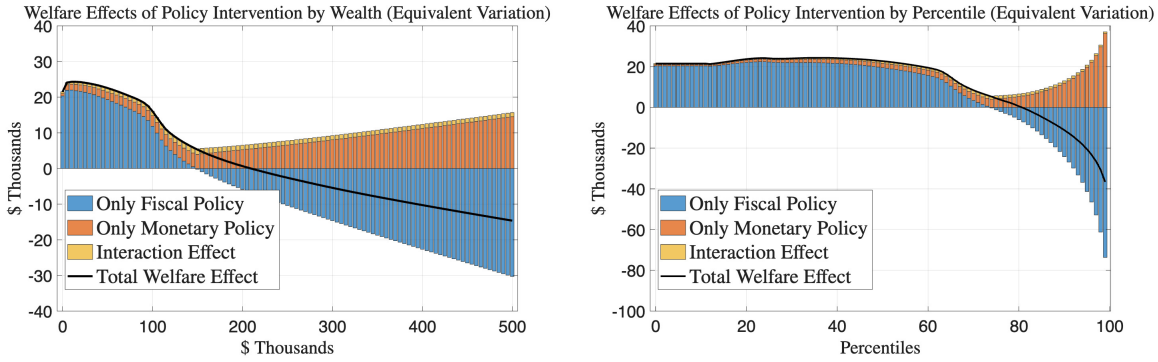


(c) Effect of monetary policy on GDP with and without shocks



(d) Effect of monetary policy on GDP with and without shocks

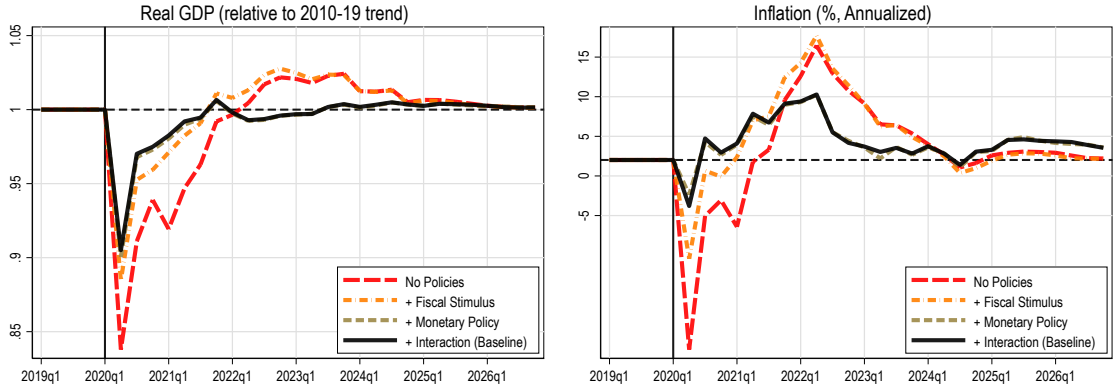
Figure 21: Effects of the policy interventions with and without the large pandemic shocks. Lines with shocks are baseline impulse responses to the two policies in isolation. Lines without shocks show the effects of the same policy interventions starting from steady-state. Top panels show fiscal stimulus, bottom panels show monetary policy; left panels show GDP, right panels show inflation.



(a) Welfare effects by wealth level

(b) Welfare effects by wealth percentile

Figure 22: 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, evaluated using preferences that abstract from the demand shock over this period ($\mathcal{E}_t^C = 0$). Left panel by dollars, right panel by percentiles



(a) TFP GDP

(b) Consumption utility shock

Figure 23: Interaction between the fiscal and monetary policy responses in the presence of the aggregate shocks.