Monetary Policy and the Great COVID-19 Price Level Shock*

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Abstract

We use an analytically tractable DSGE model to study the surge in the cost of living in the wake of the COVID-19 pandemic. A calibrated version of the model is used to assess the conduct of US monetary and fiscal policy over the 2020-2024 period. The model is also used to estimate the economic and welfare consequences of alternative monetary and fiscal policies. The calibrated model suggests that while the extraordinary fiscal transfers made in 2020-21 generally improved economic welfare, they were significantly larger than needed. These welfare gains came primarily in the form of insurance, not stimulus. For the observed fiscal policy, an optimal monetary policy would not have resulted in a significantly different inflation dynamic. Although monetary policy could have prevented the inflation surge with sufficient fiscal support, such a policy would have required a permanently higher real rate of interest and a permanent recession. Finally, our model suggests that while observed monetary policy muted the inflation dynamic, it did not significantly alter the total amount of inflation experienced. Finally, the COVID-19 inflation would have been mean-reverting even without an aggressive tightening of monetary policy.

Keywords: monetary policy; fiscal policy; inflation; price level; COVID-19.

JEL codes: E40, E52, E60, E63, E65

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1 Introduction

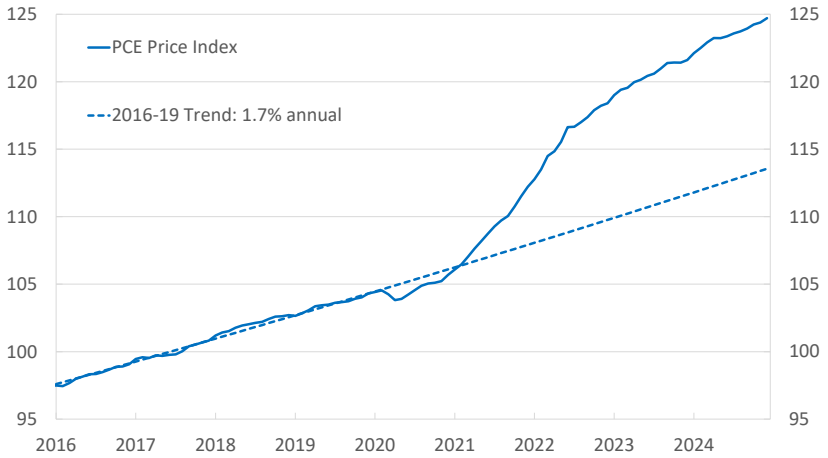
For most of the decade that followed the 2007-08 financial crisis, inflation remained below the Federal Reserve's two percent inflation target. Deflationary forces remained evident in 2020 as the COVID-19 pandemic swept across the country in the midst of a policy-induced recession. In light of this history, it is not surprising that Americans were caught off-guard as inflation began to surge in the spring of 2021. From 2021-22, PCE inflation rose roughly 500 basis points to 7 percent on a year-over-year basis. The COVID-19 inflation surge, however, proved to be transitory. Inflation declined rapidly from its peak in the summer of 2022, leaving the price level roughly 10 percent higher than its pre-pandemic trend; see Figure 1. We label this phenomenon the COVID-19 *price level shock.* This paper focuses on interpreting the COVID-19 price level shock and assessing the role of policy, both real and hypothetical, in shaping inflation dynamics.

Many are quick to blame the Federal Reserve for failing to control inflation. In his 2024 Jackson Hole speech, Fed Chair Jerome Powell implicitly acknowledged that the Fed was slow to tighten monetary policy, but only because the Fed and everyone else believed that the initial inflation surge would prove to be highly transitory. Inflation was initially concentrated in relatively few product categories driven by supply disruptions induced by the COVID-19 pandemic. It was not unreasonable to expect these forces to reverse themselves in a relatively short period of time. Moreover, Powell correctly points out that standard thinking has long supported the notion of central banks looking through a temporary increase in inflation. Inflation, however, continued to accelerate as it became more broad-based. Powell cites "pent-up demand, stimulative policies, pandemic changes in work and leisure practices, and the additional savings associated with constrained services spending all contributed to a historic surge in consumer spending on goods," among other things, as important drivers of inflation.

By October 2021, inflation was no longer perceived to be transitory, and the Fed began pivoting in November 2021, first by phasing out asset purchases and then by aggressively raising the policy rate path beginning March 2022. Inflationary pressures were exacerbated by the Russian invasion of Ukraine in February 2022 as well as continued disruptions in the global supply chain due to actions taken to curtail the pandemic in China. According to Powell, the Fed's actions were instrumental in engineering the subsequent "soft landing" by ensuring that inflation expectations remained anchored (Powell, 2024).

However, even in this favorable interpretation of Fed policy, one cannot help but notice an almost one-year-long gap between the surge in inflation that began in the spring of 2021 and the first policy rate hike that took place in the spring of 2022. In fact, there were many calls to the Fed to tighten policy well before it finally acted. Did the Fed fall behind the curve? Could the Fed have prevented, or at least mitigated, the inflation surge of 2021-22? What would the broader

Figure 1: The COVID-19 Price Level Shock



Sources: Bureau of Economic Analysis and author's calculations.

economic consequences have been had the Fed tightened policy earlier? What role did fiscal policy play in shaping the observed inflation dynamic?

We answer these and related questions using a dynamic general equilibrium model. While the model is rich enough to capture the heterogeneous experiences of households over the course of the pandemic, it is also simple enough to easily identify the economic mechanisms at work. Our goal is to qualitatively evaluate policies, both observed and hypothetical. In performing this task, we nonetheless find it useful to parameterize and calibrate the model to US data for the purpose of displaying our estimates and simulations visually.

The model incorporates two shocks. One shock negatively affects the earnings of workers in a heterogeneous way. We interpret this shock as reflecting policies designed to shut down sectors of the economy. By construction, this shock induces a sharp recession with its negative effects concentrated among a subset of households. A missing "pandemic insurance market" implies a role for fiscal policy to provide income support to households. The second shock induces some households to postpone their consumption, and so increase their desired saving. We think of this shock as a reduced form way of capturing the inability to spend money in some product categories and the desire to build precautionary savings in a highly uncertain time.

We calibrate the model's impulse response to shocks and observed policy actions to roughly match observation. We then use the calibrated model to evaluate actual policy and to perform several counterfactual experiments. Because we have a DSGE model, we can characterize a socially efficient allocation. That is, we have a benchmark by which to compare the welfare properties of actual and hypothetical policy responses. Our counterfactual experiments ask

how the economy would have evolved given: [1] No policy response; [2] An optimal monetary-fiscal policy with deficit finance; [3] An optimal monetary-fiscal policy with tax finance; [4] An optimal monetary policy given observed fiscal policy; and [5] A strict inflation target policy. We also evaluate the validity of Chair Powell's claim that monetary policy was responsible for the transitory nature of the COVID-19 inflation episode.

2 Literature Review

Our theoretical framework is based on the fiscal theory of the price level pioneered by Sargent and Wallace (1981), Aiyagari and Gertler (1985), Leeper (1991), Sims (1994), Woodford (1994), and Cochrane (2005). A central theme of this literature is that monetary-fiscal policies are inextricably linked through a consolidated government budget constraint, that monetary-fiscal policy regimes need to be modeled explicitly, and that the coordination of monetary and fiscal policy (or lack thereof) is important for interpreting historical data. The theory and arithmetic point to a decidedly more modest role for monetary policy and a correspondingly more significant role for fiscal policy in determining the price level and anchoring inflation.[1]

The 2021-22 surge in US inflation spawned a burgeoning literature trying to understand it. Given the prominent role of fiscal policy in this recent episode, it is not surprising to see several applications of the fiscal theory.[2] Bianchi, Faccini and Melosi (2023) develop a quantitative model and estimate it using US data. They find that unfunded government spending shocks account for the bulk of US inflation, including COVID-19 inflation. This finding is not uncontroversial. Smets and Wouters (2024), in contrast, estimate that over 80 percent of the fiscal implications of US business cycle shocks, including fiscal shocks, are funded. Nevertheless, they too find that expansionary fiscal policy contributed to higher inflation in 2021. Bassetto and Miller (2022) develop a model in which individuals endogenously acquire information about the prevailing fiscal regime. Their model is used to understand why inflation surged in 2021-22 instead of rising steadily as one might expect if people only gradually recognized the unfunded nature of the COVID-19 deficits.

Although there is a growing consensus that fiscal policy played a significant role in shaping the recent inflation dynamic, relatively little attention has been paid to assessing the conduct of monetary and fiscal policy during the episode. There is, of course, a large literature that casts inflationary finance in a negative light; e.g., see Hall and Sargent (2022*a*,*b*). But there is a public finance literature that casts inflation finance–in at least some circumstances–in a more favorable light; e.g., Chari and Kehoe (1999), Sims (2001), Lustig, Sleet and Yeltekin

[1] More recent explorations of the fiscal theory include Leeper and Leith (2016), Bassetto and Cui (2018), Andolfatto and Martin (2018), Cochrane (2022), Caramp and Silva (2023).

[2] More traditional monetarist explanations have also been put forward, for example, Gao and Nicolini (2023).

(2008), and more recently, Leeper and Zhou (2021). Our analysis interprets the recent inflation episode in the same light. However, we also consider counterfactual experiments that explore the properties of optimal monetary policy for a given (not necessarily optimal) fiscal policy. In this respect, our analysis is similar to Benigno and Woodford (2007), except applied to the COVID-19 inflation episode.

Our analysis draws on aspects developed in all the work cited above to reach the following three conclusions: [1] The COVID-19 price level shock was attributable to an unfunded fiscal spending shock; [2] The unfunded fiscal spending shock was welfare-improving policy, even if overdone; and [3] There was very little, if anything, that the Federal Reserve could or should have done on its own to prevent the inevitable rise in the price level.

3 The Environment

Let $t = 1, 2, ..., \infty$ denote time. The economy is populated by generations of overlapping households. There is an initial old population that lives for one period only. On every date $t \geq 1$, a new generation of young households enter the economy expecting to participate for two periods. At any given date, a constant population is evenly divided between young and old generations. The size of each new generation is normalized to one.

Households have preferences defined over lifetime consumption. Let c_t^y, c_t^o denote consumption at date t by the young and old, respectively. A young type $j \in \{L, H\}$ household has preferences

$$U_t(j) = E_t[(1 - \alpha_t)/(1/\beta_j)u(c_t^y) + c_{t+1}^o] \tag{1}$$

where $\beta_H > \beta_L > 0$, $u'' < 0 < u'$, and E_t is an expectation operator conditional on information available at date t. Let $0 < \rho < 1$ denote the fraction of *ex ante* impatient households; i.e., those households with $\beta_L < \beta_H$. The parameter $0 \leq \alpha_t \leq 1$ is an aggregate shock determining the *ex post* impatience of long-horizon decision makers (i.e., young households). A larger realization of α_t reflects a greater desire to delay consumption. The desire to delay consumption in this context can be thought of as emanating from a variety of sources. For example, during a pandemic, fear of contracting the virus may lead some households to temporarily postpone their shopping excursions. It could also capture an increased desire on the part of some households to delay spending activities because of a need to reallocate time to care for sick relatives.

The primary source of income for young households is their labor earnings, which we model here as exogenous. When the COVID-19 pandemic arrived in the United States early in 2020, it unleashed a host of forces that negatively impacted the earnings capacity of many, though not all, American households. We model this phenomenon as follows. There are two levels of real earnings,

$w_t(l) < w_t(h)$. At each date t, a fraction $0 \leq \sigma_t \leq 1$ of impatient young households experience a negative earnings shock, resulting in earnings $w_t(l) < w_t(h)$. We also allow for independent exogenous variation in $\{w_t(l), w_t(h)\}$. In this way, a recession is characterized by both its impact on average earnings and its effect on the dispersion of earnings between workers. The exogenous stochastic process that governs the evolution of $\{w_t(h), w_t(l), \sigma_t\}$ generates aggregate and idiosyncratic uncertainty. There is idiosyncratic uncertainty because impatient young workers do not know beforehand whether they will be assigned to the high- or low-wage categories; all they know is that a fraction σ_t will be assigned to the low-wage category. Assume that all shocks are realized at the beginning of period t. Aggregate earnings at date t are given by

$$w_t \equiv (1-\rho)w_t(h) + \rho[\sigma_t w_t(l) + (1-\sigma_t)w_t(h)] \tag{2}$$

As in Diamond (1965), there is a technology to transform current output into future output. For simplicity, we assume that this investment technology is operated directly by households. Each young household has access to an investment project that transforms k_t units of output at date t into $f(k_t)$ units of output at date $t+1$, where $f'' < 0 < f'$. Also, for simplicity, assume that capital investment depreciates fully after it is used in production. We assume that the pandemic shock has no direct effect on investment technology.

The economy wide resource constraint is given by,

$$\rho[c_t^y(L) + c_t^o(L)] + (1-\rho)[c_t^y(H) + c_t^o(H)] + k_t \leq w_t + f(k_{t-1}) \tag{3}$$

for all $t \geq 1$ and with $k_0 \geq 0$ given.

3.1 Efficient Allocation

We assume a social welfare function $W = E_1 \sum_{t=0}^{\infty} \delta^t \{\rho U_t(L) + (1-\rho)U_t(H)\}$, where $U_0(j) = c_1^o(j)$. That is,

$$W = E_1 \sum_{t=1}^{\infty} \delta^t \Big\{ \rho[(1-\alpha_t)(1/\beta_L)u(c_t^y(L)) + (1/\delta)c_t^o(L)] \\ + (1-\rho)[(1-\alpha_t)(1/\beta_H)u(c_t^y(H)) + (1/\delta)c_t^o(H)] \Big\}$$

where $0 < \delta < 1$ is introduced simply as a device to bound W and identify a unique efficient allocation. A planner interested in maximizing W subject to the sequence of period resource constraints would choose allocations that satisfy the following conditions on a period-by-period basis (after taking $\delta \to 1$,):

$$(1-\alpha_t)u'(\hat{c}_t^y(L)) = \beta_L; \tag{4}$$

$$(1-\alpha_t)u'(\hat{c}_t^y(H)) = \beta_H; \tag{5}$$

$$f'(\hat{k}_t) = 1; \tag{6}$$

in addition to the resource constraint (3) for all $t \geq 1$ with $k_0 \geq 0$ given.[3]

There are a few things worth noting about the optimal allocation. First, the optimal allocation can be characterized without reference to the exact properties of the stochastic properties that govern the shock processes. This convenient property is a byproduct of quasilinear preferences.

Quasilinear preferences also imply that it is efficient for old households to perfectly insure young households against their earnings risk (both idiosyncratic and aggregate risk). Specifically, $\{c_t^y(j)\}$ for $j = L, H$ are independent of all shocks to earnings $\{w_t(l), w_t(h), \sigma_t\}$. Quasilinearity also implies that the efficient level of capital spending is independent of all earning and preference shocks.

Thus, it is efficient to stabilize investment and insure young households against any loss of income attributable to the pandemic. In this case, the planner would want to divert resources from the old to the young. On the other hand, if the pandemic is also associated with an increased desire to delay consumption, the efficient transfer of purchasing power runs from young to old.[4]

The analysis above provides us with a guide to help evaluate the properties of an efficient allocation and how it should respond to a pandemic shock. An important takeaway from this analysis is that *nobody* should be better off when a pandemic hits. In other words, it is desirable to spread the pain across all members of the community. The pain itself is unavoidable. The planner must ask who in society is best able to absorb the pain and how. The same question should be asked by policymakers.

Our next task is to decentralize the economy and characterize the equilibrium allocation as a function of shocks and policies. Although we are primarily interested in using the model to evaluate the conduct of monetary policy for a given fiscal policy, we can ask a number of other interesting questions along the way. In particular, how can a decentralized economy be expected to absorb the shock of a pandemic? Do resources flow in the direction our planner above would dictate? Can we identify the properties of monetary-fiscal policies that help support efficient implementation? How do these policies compare to observed policies?

[3]Note that $\hat{c}_t^o < 0$ is permissible here since utility is transferable (think of negative consumption as labor effort).

[4]Of course, the labels *young* and *old* here should be taken as metaphors for people who, respectively, derive their purchasing power primarily from labor or financial wealth.

4 A Monetary Economy

4.1 Market Structure

Let p_t denote the price-level at date t. Assume a sequence of competitive spot markets where goods trade for money at prices $\{p_t : t \geq 1\}$. Define $\Pi_{t+1} \equiv p_{t+1}/p_t$. There are no private insurance markets.

4.2 Government Policy

Let G_t denote government spending on goods and services. Let T_t denote tax revenue and let Z_t denote money transfers to (young) households. Let M_{t-1} denote the stock of nominally risk-free debt of one period that is due at the beginning of period t. Let R_{t-1} denote the gross nominal interest rate paid on government debt. Government revenues and expenditures must satisfy,

$$T_t + M_t = G_t + Z_t + R_{t-1}M_{t-1} \tag{7}$$

Equation (7) says that the interest expense of the debt, $(R_{t-1}-1)M_{t-1}$, must be financed through some combination of the primary budget surplus $T_t - Z_t - G_t$ and debt $M_t - M_{t-1}$. For simplicity, we set $G_t = 0$ for all t. Assume that the interest expense of the debt is financed through taxes and debt, while (emergency) transfers are financed exclusively through debt; i.e.,

$$T_t = \theta_t(R_{t-1} - 1)M_{t-1} \tag{8}$$

$$M_t - M_{t-1} = Z_t + (1 - \theta_t)(R_{t-1} - 1)M_{t-1} \tag{9}$$

where $\theta_t \in [0, 1]$. When $\theta_t = 0$, both transfers and interest expense are financed exclusively with debt. When $\theta_t = 1$ all interest expense is financed with taxes, while transfers are financed with debt.

Monetary policy is determined by the interest rate rule,

$$R_t = r_t E_t \Pi_{t+1} \tag{10}$$

where r_t is a policy variable and $E_t\Pi_{t+1}$ is the rate of inflation expected by households. Let Π^* be the long-run inflation target and $R_t^* \equiv r_t\Pi^*$ be the corresponding target interest rate.[5] In what follows, we set $\Pi^* = 1$ and restrict attention to monetary-fiscal policies that deliver a zero long-run rate of inflation, consistent with the long-run target.

[5]Note that because the real interest rate is endogenous in this model, there is no unique "neutral" policy rate. However, as we shall show below, the "natural" rate (the rate consistent with the efficient allocation) is equal to one. Also note that the monetary policy rule (10) can be written equivalently as a feedback (Taylor-type) rule, $R_t = R_t^*(E_t\Pi_{t+1}/\Pi^*)^\varphi$, with $\varphi = 1$.

4.3 Household Decisions

Let $\{c_t^y(i,j), c_{t+1}^o(i,j)\}$ denote the lifetime consumption profile of a type $(i,j) \in \{l,h\} \times \{L,H\}$ household entering the economy at date t. A young type-i,j household faces the following sequence of budget constraints,

$$\begin{aligned} p_t c_t^y(i,j) &= p_t w_t(i) - m_t(i,j) - p_t k_t(i,j) + Z_t(i) \quad (11) \\ p_{t+1} c_{t+1}^o(i,j) &= p_{t+1} f(k_t(i,j)) + R_t m_t(i,j) - T_{t+1} \quad (12) \end{aligned}$$

where $m_t(i,j) \geq 0$ denotes the household's accumulation of government securities, $Z_t(i)$ denotes a government transfer, and T_t denotes a lump-sum tax. Note that government transfers may depend on earnings, but not on the degree of impatience. Define $q_t \equiv m_t/p_t$, $z_t(i) \equiv Z_t(i)/p_t$, $\tau_t \equiv T_t/p_t$ and use these expressions to rewrite the system above in real terms,

$$\begin{aligned} c_t^y(i,j) &= w_t(i) - q_t(i,j) - k_t(i,j) + z_t(i) \quad (13) \\ c_{t+1}^o(i,j) &= f(k_t(i,j)) + R_t/\Pi_{t+1} q_t(i,j) - \tau_{t+1} \quad (14) \end{aligned}$$

Substituting (13) and (14) into the household's objective function (1) yields,

$$\begin{aligned} U_t(i,j) &= (1-\alpha_t) u(w_t(i) - q_t(i,j) - k_t(i,j) + z_t(i)) \\ &+ \beta_j E_t[f(k_t(i,j)) + R_t/\Pi_{t+1} q_t(i,j) - \tau_{t+1}] + \lambda_t(i,j) q_t(i,j) \end{aligned}$$

where $\lambda_t(i,j)$ is the Lagrange multiplier associated with the non-negativity constraint, $q_t(i,j) \geq 0$. This non-negativity constraint can be expected to bind for some types in a severe recession.

Necessary conditions characterizing optimal household behavior $\{q_t(i,j), k_t(i,j)\}$ are given by

$$\begin{aligned} \beta_j f'(k_t(i,u)) &= \beta_j R_t E_t[1/\Pi_{t+1}] + \lambda_t(i,j) \quad (15) \\ (1-\alpha_t) u'(c_t^y(i,j)) &= \beta_j R_t E_t[1/\Pi_{t+1}] + \lambda_t(i,j) \quad (16) \end{aligned}$$

for $i \in \{l,h\}$ and $j \in \{L,H\}$, where the expression for $c_t^y(i,j)$ is given by (13).

4.4 Household Expectations

We assume that households form expectations as follows. Consider a stochastic process $\{x_t\}$ with an unconditional mean x. Then

$$E_t x_{t+1} = x_t^{1-\phi} x^{\phi} \quad (17)$$

where $0 \leq \phi \leq 1$. Applying this protocol to inflation expectations when the unconditional mean of inflation is equal to the inflation target, we have

$$E_t \Pi_{t+1} = \Pi_t^{1-\phi} (\Pi^*)^{\phi} \quad (18)$$

The parameter $0 \leq \phi \leq 1$ here governs how strongly household inflation expectations react to inflation data. The same parameter also governs how strongly monetary policy reacts to inflation data via equation (10). In particular, combining (10) with (18) and noting that $\Pi^* = 1$ implies

$$R_t = r_t \Pi_t^{1-\phi} \tag{19}$$

We apply the same protocol to expected inverse inflation, which is the relevant object in the household's optimality conditions. We obtain,

$$E_t[1/\Pi_{t+1}] = (1/\Pi_t)^{1-\phi} E[1/\Pi]^{\phi}$$

where $E[1/\Pi]$ is the unconditional mean of the inverse of inflation. Since we assume $E[\Pi] = \Pi^* = 1$ we obtain $E[1/\Pi] = 1/\Pi^* = 1$. Hence,

$$E_t[1/\Pi_{t+1}] = (1/\Pi_t)^{1-\phi} \tag{20}$$

4.5 Equilibrium

Combining (19) and (20) in equations (15) and (16) implies,

$$\begin{aligned} \beta_j f'(k_t(i,j)) &= \beta_j r_t + \lambda_t(i,j) & (21) \\ (1-\alpha_t) u'(w_t(i) - q_t(i,j) - k_t(i,j) + z_t(i)) &= \beta_j r_t + \lambda_t(i,j) & (22) \end{aligned}$$

for $i = l, h$ and $j = L, H$. With $q_t(i,j)$ and $k_t(i,j)$ so determined, the respective consumption demands are given by,

$$\begin{aligned} c_t^y(i,j) &= w_t(i) + z_t(i) - q_t(i,j) - k_t(i,j) & (23) \\ c_t^o(i,j) &= f(k_{t-1}(i,j)) + R_{t-1}/\Pi_t q_{t-1}(i,j) - \tau_t & (24) \end{aligned}$$

for $i \in \{l, h\}$ and $j \in \{L, H\}$ for all $t \geq 1$.

In equilibrium, the supply of nominal securities M_t/p_t must equal the demand for real balances, Q_t,

$$M_t/p_t = Q_t \tag{25}$$

for all $t \geq 1$, where Q_t consists of a weighted sum of individual money demands,

$$Q_t \equiv (1-\rho) q_t(h,H) + +\rho[\sigma_t q_t(l,L) + (1-\sigma_t) q_t(h,L)]$$

Let $\mu_t \equiv M_t/M_{t-1}$ be the growth rate of the supply of nominal securities. From (25) we can derive the following expression for the inflation rate,

$$\Pi_t = \mu_t Q_{t-1}/Q_t \tag{26}$$

Inflation depends negatively (positively) on current (past) demand for real balances.

From the government budget rules (8) and (9), plus the market-clearing condition (25), we can write:

$$\tau_t = \theta_t(R_{t-1}-1)(Q_t/\mu_t) \tag{27}$$

$$\mu_t = \frac{Q_t[1+(1-\theta_t)(R_{t-1}-1)]}{Q_t - z_t} \tag{28}$$

where $z_t \equiv \rho\sigma_t z_t(l) + (1-\rho\sigma_t)z_t(h)$.

4.6 Efficient policy

When comparing equilibrium conditions (21) and (22) with the conditions characterizing the efficient allocation, (4)–(6), it follows that to implement an efficient allocation, the policy must set $r_t = 1$ and $\lambda_t(i,j) = 0$ for all (i,j). In this case, (21) and (22) become

$$f'(k_t(i,j)) = 1 \tag{29}$$

$$(1-\alpha_t)u'(c_t^y(i,j)) = \beta_j \tag{30}$$

which imply $k_t(i,j) = \hat{k}_t$ and $c_t^y(i,j) = \hat{c}_t(j)$. From (23) we obtain

$$q_t(i,j) = w_t(i) + z_t(i) - \hat{k}_t - \hat{c}_t^y(j) \tag{31}$$

Any transfer scheme $z_t(i)$ that implements $q_t(i,j) \geq 0$ for all (i,j) implements the efficient allocation. Excess transfers are simply saved by the young and then taxed away when old. This property implies that multiple inflation rates (resulting from different transfer schemes) are consistent with the efficient allocation.

4.7 Effects of policy

Using (28) to substitute out μ_t in (26) and (27) implies

$$\Pi_t = \frac{Q_{t-1}[1+(1-\theta_t)(R_{t-1}-1)]}{Q_t - z_t} \tag{32}$$

$$\tau_t = \frac{\theta_t(R_{t-1}-1)(Q_t - z_t)}{1+(1-\theta_t)(R_{t-1}-1)} \tag{33}$$

Transfers have a direct effect on inflation and taxes, but also an indirect effect through the demand for real balances.

The following proposition states the effects of fiscal and monetary policy on households' decisions.

Proposition 1 (Effects of Fiscal and Monetary Policies)**.**

a. An increase in real transfers:

(i) has no effect on consumption or capital investment of unconstrained young households and is fully saved in real balances

(ii) increases consumption and capital investment of constrained young households

b. An increase in the real interest rate:

(i) decreases consumption and capital investment and increases the demand for real balances of unconstrained young households

(ii) has no effect on the decisions of constrained young households

The effects of fiscal and monetary policies vary depending on whether young households are debt-constrained or not. First, consider the case when all young households are unconstrained. An increase in real transfers is fully saved and thus, implies an increase in the demand for real balances; there is no effect on consumption or capital investment. An increase in the real interest rate leads to the classic Tobin effect: a decrease in consumption and capital investment and an increase in the demand for real balances.

Second, suppose there are some constrained young households. An increase in real transfers allows these households to increase their consumption and capital investment, closer to optimal levels. In this case, fiscal policy has real effects on aggregate consumption and investment. In contrast, changes in the real interest rate has no impact on constrained households. Thus, the effects of monetary policy propagate through their impact on unconstrained young households' decisions, as described above.

Proposition 2. *Assume all households are unconstrained, i.e.,* $\lambda_t(i,j) = 0$ *for for* $i = \{l, h\}$ *and* $j = \{L, H\}$*. Then:*

a. A one-time increase in real transfers has no impact on current inflation and increases inflation in the following period, i.e., $d\Pi_t/dz_t = 0$ *and* $d\Pi_{t+1}/dz_t > 0$*.*

b. A one-time increase in the real interest rate decreases current inflation, i.e., $d\Pi_t/dr_t < 0$*; when* $\theta_t = 1$*, it increases inflation in the following period, i.e.,* $d\Pi_{t+1}/dr_t > 0$*.*

A central result of our model is that, when all young households are unconstrained, the price-level effects of an expansionary fiscal policy are not felt on impact, but rather in subsequent periods. Specifically, the inflationary impact is delayed by one period. The reason is that unconstrained households save all the transfers they receive: the increase in the demand for real balances perfectly offsets the increase in the real supply of debt (which finances the increase in real transfers). In the following period, the demand for real balances returns to its previous level, while the (nominal) supply remains elevated. Hence, the price level increases to clear the market.

On impact, an increase in the real interest rate is deflationary. The channel is a Tobin-style substitution effect. Government debt becomes more attractive and hence, the demand for real balances increases. which leads to a drop in the price level. This effect is typically reverted in the following period. For the case $\theta = 1$, when all interest expense is financed with taxes, inflation in $t+1$ increases as the price level returns to its original level.

When at least some of the interest expense in financed with debt rather than taxes, there is an additional channel through which current changes in the real interest rate affect affect future inflation. This channel adds persistence to the impact of changes in the real interest rate on inflation. Combining (19) and (32), and updating one period, we obtain that Π_{t+1} depends positively on $(1-\theta_{t+1})r_t\Pi_t^{1-\phi}$. How important important this channel is depends on θ_{t+1} and the size of the impact of changes in r_t on Π_t. The impact through this channel persists over several periods, as Π_{t+2} is positively impacted by Π_{t+1} and so on. When most interest expense in financed with debt rather than taxes (i.e., then θ is low), it is even possible that the initial deflationary impact of an increase in the interest rate persists for more than one period. Eventually, however, the effect of a one-time increase in the real rate necessarily implies an inflationary period, as the price level returns to its original level.

5 Benchmark Economy

We study the U.S. economy over the five-year period 2020-2024. Period length is set to a year. We assume that the economy is on its steady-state growth path in 2019. Data for 2024 includes the latest available for each series. All variables are detrended from their estimated steady-state growth paths. All impulse-response diagrams measure responses relative to trend.

5.1 Steady state calibration

We assume the following functional forms:

$$\begin{aligned} u(c) &= \frac{c^{1-\eta}-1}{1-\eta} \\ f(k) &= k^{\gamma} \end{aligned}$$

We set these parameters at standard values in the literature: $\eta = 2$ and $\gamma = 0.3$.

We set policy targets at $R^* = \Pi^* = r^* = 1$. That is, in steady state, the real rate is equal to the natural rate and there is no inflation.[6] We assume that all young households receive the same endowment $w(h) = \omega$. That is, there are no households with low earnings ($\sigma = 0$) in steady state. We calibrate β_L so

[6] Since the (net) nominal interest rate is zero in steady state, the share of interest expense financed with taxes, θ, is irrelevant for the calibration.

that impatient households optimally choose to hold zero real balances (that is, their debt constraints are satisfied with equality but do not bind). Thus, patient young households end up accumulating all the government debt. We set β_H so that government debt equals 25% of output.[7] We set the share of impatient households to one-half, which is similar to calibrations in DSGE models with hand-to-mouth agents. Table 1 summarizes the calibration.

Table 1: Benchmark Calibration

Parameter	Value	Definition
η	2.000	curvature of utility function
γ	0.300	curvature of production function
β_H	4.000	discounting by patient households
β_L	0.302	discounting by impatient households
ρ	0.500	share of impatient households
ω	2.000	endowment

Our calibration approach implies that in 2019 the benchmark economy is implementing the efficient allocation.

5.2 Fitting 2020-2024

We now describe how we fit the model to the data for 2020-24. The comparison between data and model is presented in Figure 2. In the next section we will describe how we project the economy in subsequent years.

First, we assume that $\theta_t = 0$ for 2020-24. That is, the interest expense of the debt is financed with new debt. Hence, no taxes are levied in 2020-24, which maximizes the impact of fiscal policy on inflation. Note that this assumption allows us to directly model the fiscal assistance during the COVID period, as described below.

Second, we set σ_t so that the fraction of young impatient households in the economy subject to the low earnings shock matches the maximum drop in employment-to-population for 2020-21. In all other years, $\sigma_t = 0$. The implied values for σ_t are 0.191 and 0.067 for 2020 and 2021, respectively. When multiplied by $\rho = 0.5$ these figures yield the targeted moments.

Third, we specify the following process for transfers: $z_t(\ell) = z_t(h) + UIP_t$. The series for UIP_t corresponds to unemployment insurance payments (including PUC, PUA, PEAC and extensions), as a fraction of GDP, for 2020-21. Transfers to higher earners, $z_t(h)$ are calibrated so that the Primary Deficit /

[7] The simple structure of our model (importantly, two-period lived agents and full capital depreciation) does not allow us to target realistic levels of debt-over-GDP. Although 25% is significantly lower than the current U.S. debt-to-GDP ratio, it is as high as we can go in our calibration without distorting other properties of the allocation.

Debt implied by the model matches that of the data (including federal, state and local governments) for 2020-21. For debt we subtract foreign holdings. Transfers are set to zero in all other years. The reason we pick the deficit relative to debt rather than relative to GDP as a target is that the model cannot match debt-to-GDP ratios close to 1 and that the inflationary effects of fiscal expansions in the model are directly tied to the growth rate of government nominal liabilities. According to our model, the ultimate increase in the price level is equal to the increase in the stock of debt; hence, it is important to match the magnitude of the fiscal expansion in terms of initial debt. We accomplish this by matching how the fiscal programs deployed during COVID impacted the growth rate of debt held domestically. The top-right panel of Figure 2 shows how we fit the Primary Deficit / Debt for 2020-21 and how it compares to the data in subsequent years.

Fourth, we calibrate the earnings processes. We set $w_t(l)$ so that disposable income is the same across agents in 2020-21. That is, we assume fiscal policy insures young households across *ex post* types. Note that there are no young households type (ℓ, L) from 2022 onward. We set $w_t(h)$ to match real GDP per capita growth for 2020-24. The resulting aggregate earnings process, w_t is shown in the top-left panel of Figure 2. The top-middle panel shows that we match real GDP per capita growth exactly for all years. The model calibration implies that the economy has not quite recovered by 2024.

Fifth, the patience/demand shock α_t is set to that inflation in the model matches the annual PCE inflation rate for 2020-24. The top-left panel of Figure 2 shows the sequence of values for this shock necessary to match the data, shown in the bottom-middle panel.

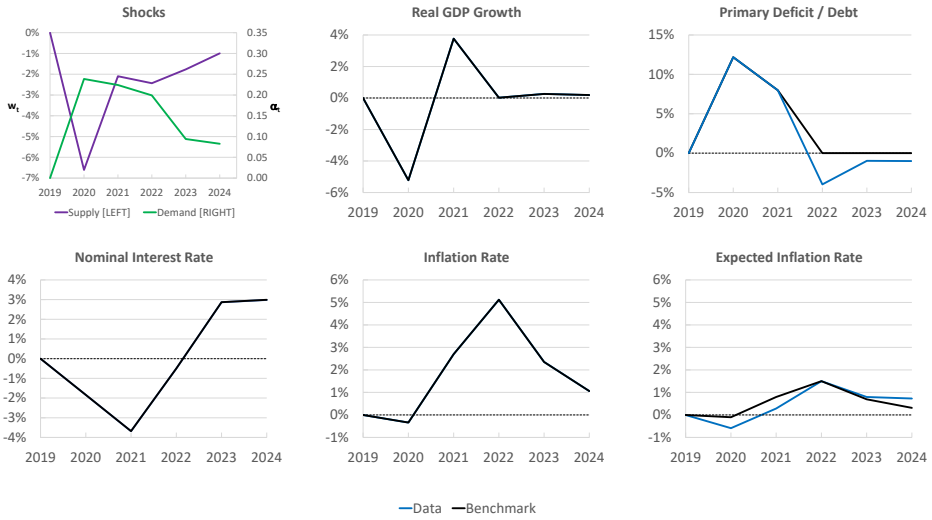
Sixth, the parameter ϕ, which anchors inflation expectations around its target, is set to 0.702 so that inflation expectations in the model match the 1-year inflation expectations published by the Cleveland Fed at its peak in 2022. The fit is presented in the bottom-right panel of Figure 2.

Finally, the sequence of real interest rates implemented by monetary policy are set so that the nominal interest rate matches the minimum if the Effective Federal Funds Rate and the Wu-Xia estimates of the Shadow Federal Funds Rate.[8]

The upper left panel in Figure 2 shows the estimated shock sequences for w_t and α_t. It is straightforward to interpret $\Delta w_t < 0$ as a negative supply shock. Since an increase in α_t induces consumers to delay spending, we can think of $\Delta\alpha_t > 0$ as a negative demand shock. Our calibrated model estimates that very large negative shocks to supply and demand were operational in 2020. Although the negative supply shock of 2020 is significantly reversed in 2021, its recovery remains incomplete even into 2024. The negative demand shock of 2020 begins to reverse itself slowly in 2021 and 2022, and then more sharply in 2023. We take this estimated shock sequence as given in all the analysis that follows.

[8] See `https://www.atlantafed.org/cqer/research/wu-xia-shadow-federal-funds-rate`.

Figure 2: Benchmark dynamics



The combined effects of the shocks and fiscal assistance implies that no households are debt-constrained throughout the simulated period. Recall that the steady state calibration implies that impatient young households hold zero debt optimally in 2019. Afterwards, the demand shock plus the fiscal assistance more than makes up for the impact of earnings loss, so that even impatient, low-earnings households are saving in real balances in 2020-21. From 2022 onward, even though there is not more fiscal assistance, the demand shock dominates the supply shock so that all impatient (and patient) households are saving.

By 2024, the price level in the benchmark economy is about 11% higher than in an economy where the COVID-19 shocks and policy response did not occur.[9] As shown in the upper left panel of Figure 2 there are demand and supply shocks still at play in 2024. In particular, positive demand shocks explain why accumulated inflation has remained below the increase in government liabilities (about 18%). If shocks were to eventually die out, then the total increase since 2019 in the price level and government debt would be 21%.

5.3 Projecting 2025-29

In the exercises we conduct below, the model dynamics are not fully resolved by 2024. Thus, we need to make some assumptions on how the economy and policy evolve in subsequent years.

[9] All changes are reported as log differences.

First, we assume that the current state of the economy is the best predictor of the future. Thus, we let aggregate shocks persist. That is, we assume that α_t and $w_t(h)$ remain at their 2024 values indefinitely.

Second, we need to specify the path for monetary policy. We take the Summary of Economic Projections released by the FOMC in December 2024. We use the projections for the federal funds rate for 2025-27 and the longer-run (2028 and beyond) and fit the path for the real rate that rationalizes this policy, given the path for inflation expectations. The procedure is similar to the calibrated path for 2020-24 but with the nominal rate implied by the Summary of Economic Projections rather than the actual rate.

By 2029 the (log) price level in the benchmark model has converged at three decimal points. The total increase in the price level between 2019 and 2029 is 0.127 log points. This is our estimated impact of the COVID shocks and the policy response on inflation.

6 Counterfactual Exercises

6.1 No Fiscal Policy Response

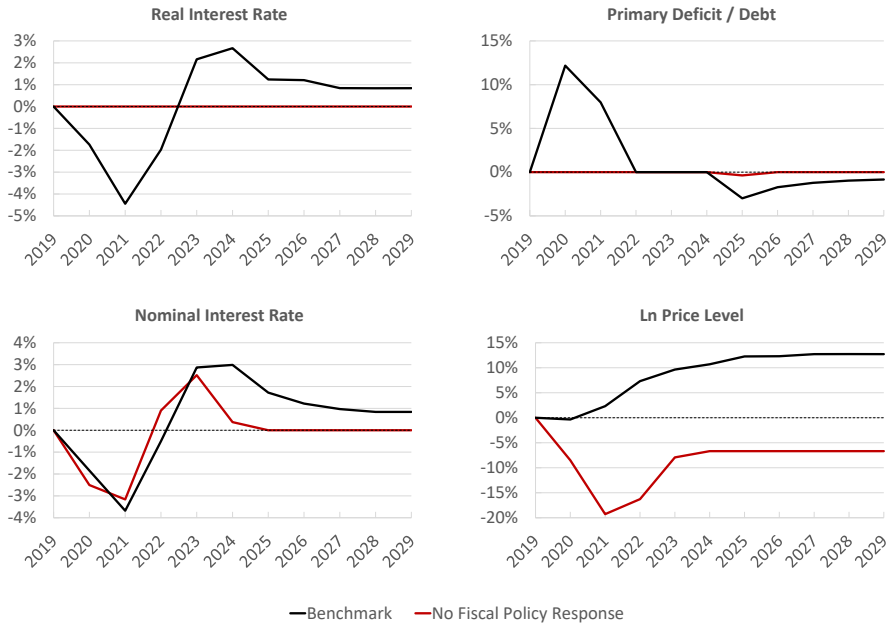
To begin our analysis, we ask how the economy would have evolved had there been no extraordinary fiscal measures taken in 2020-21. In this experiment, we assume that monetary policy keeps the real rate of interest fixed at its 2019 level and continues to adjust the nominal policy rate according to the Taylor rule (10). The result is depicted in Figure 5.

The bottom right panel of Figure 3 reveals that our calibrated model characterizes the COVID-19 pandemic as a significant deflationary event. The model predicts a massive deflation in 2020 and 2021, followed by an inflationary surge in 2022 and 2023, with the price level never fully recovering its pre-pandemic level (relative to trend). These deflationary forces were more than offset by the very large fiscal transfers of 2020-21. While it is impossible to know for sure whether or how much this was the case, this interpretation of events is supported by the evidence in Figure 1. In particular, these deflationary forces manifest themselves as disinflation in 2020, despite the very large fiscal transfers in that year.

6.2 Optimal Policy

In this section, we describe a monetary-fiscal policy that implements the optimal allocation (4)-(6) given the shock realizations and projections described in Sections 5.2 and 5.3, and shown in Figure 2. As explained in section 4.6, efficient implementation requires a monetary policy such that $r_t = 1$ and a fiscal policy such that $\lambda_t(i, j) = 0$ for $i = l, h$ and $j = L, H$. Monetary policy requires

Figure 3: No Fiscal Policy Response



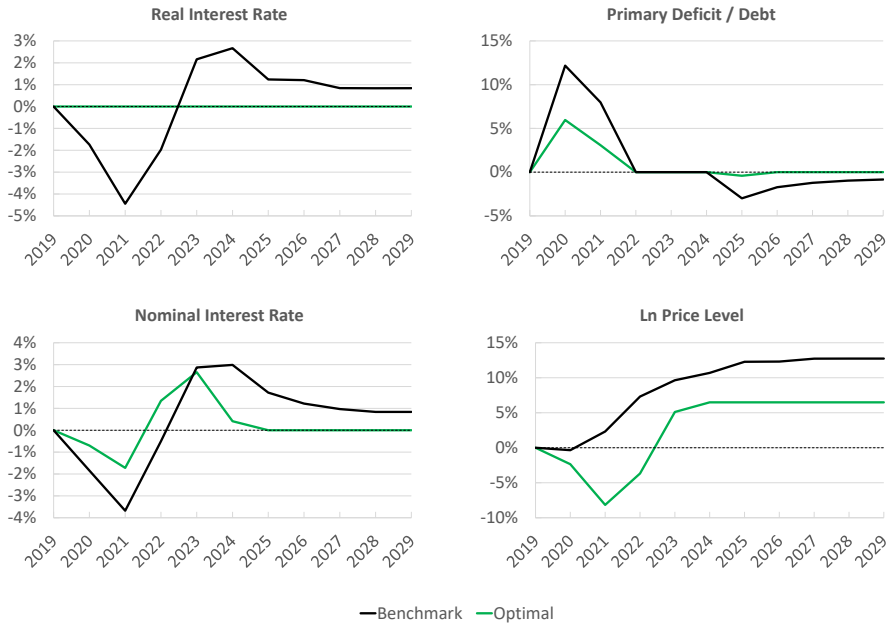
setting $r_t = 1$ for all t and adjusting the nominal rate one for one against inflation expectations, which evolve over time according to (18). The results of this counterfactual exercise are reported in Figure 4.

The upper right panel of Figure 4 suggests that while fiscal programs such as the CARES Act of 2020 and the American Rescue Plan of 2021 were desirable, they were substantially larger than required. According to our model, the spending needed to finance optimal insurance payments in both 2020 and 2021 should have generated primary deficits of around half the size of those observed.

The bottom right panel of Figure 4 depicts the price level dynamic in the benchmark economy relative to the counterfactual experiment considered here. The price level under the optimal deficit policy increases by about 8 percent (relative to trend). This is considerably smaller than the 13 percent increase generated in the benchmark economy. Thus, the model strongly suggests that the overall increase in the cost of living would have been substantially lower had fiscal policy been more restrained.

Note that the optimal price level dynamic is very different than the benchmark. In 2020, there is a modest deflation in the benchmark economy, followed by an inflation surge in 2021-22. In contrast, an optimal policy would have allowed the strong deflationary forces operating on the economy in those years

Figure 4: Benchmark vs. Optimal Policy



(Re: top left panel of Figure 2) to manifest themselves as a significant deflation (again, relative to trend) in 2020 and 2021. One beneficial consequence of deflation in this model is that it increases the purchasing power of the 2020-21 money transfers delivered to distressed households. However, the logic of our model requires the inflation tax to manifest itself at some point. Under an optimal policy, the inflation surge would have occurred in 2022-23 before rapidly tapering out in 2024 (with a lower overall increase in the price level).

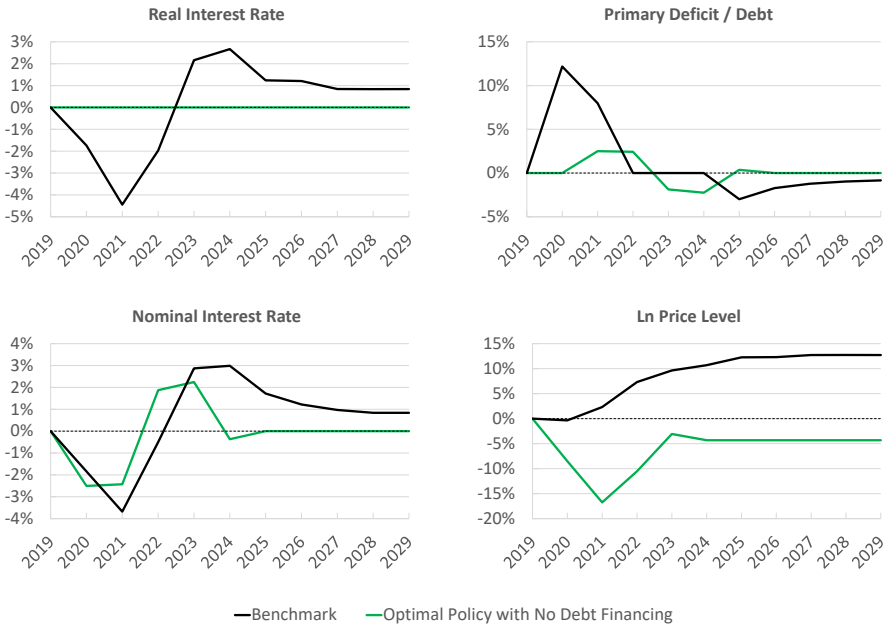
It is conceivable that the optimal inflation rate dynamic would be smoother if we had modeled households as having nonlinear preferences.[10] With quasilinear preferences, volatility in the realized rate of inflation does not affect *ex ante* welfare–it only affects the *ex post* welfare of old households. What matters for *ex ante* welfare here is how monetary policy responds to expected inflation. Expected inflation here (not depicted) is relatively smooth because expectations are adaptive and anchored around target. The optimal interest rate policy is correspondingly smooth relative to the benchmark; see the bottom left panel of Figure 4. Regarding the policy interest rate, the optimal policy involves more modest loosening in 2020-21 and less aggressive tightening in 2022-23. Under an optimal policy, the policy interest rate should have returned close to its pre-pandemic level by 2024. Because an optimal fiscal policy in our model relaxes

[10]Doing so would not have changed the conclusion pertaining to the overall amount of inflation experienced.

all credit constraints, monetary policy is free to target the "natural" real rate of interest. Our model suggests that the real rate of interest was too low (monetary policy too loose) during the period 2020-22 and too high (tight) during 2023-24.

The experiment considered above assumes that the extraordinary spending associated with the COVID-19 pandemic is deficit-financed. It is of some interest to consider the case in which the spending was instead financed through a non-distortionary tax. Figure 5 depicts the predicted dynamics relative to the benchmark.

Figure 5: Benchmark vs. Optimal Policy with No Debt Financing



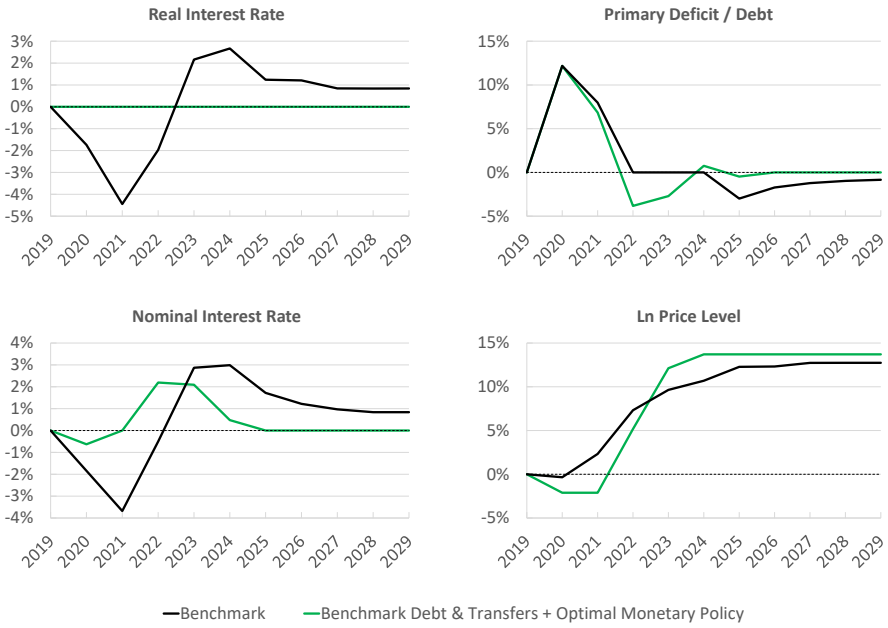
The top right panel of Figure 5 shows a moderate dynamic (relative to trend) in the primary deficit. This is owing to our assumption that in the periods following the CARES/ARP spending, the interest expense of the debt is financed through adjustments in the primary surplus. The bottom right panel displays the price level dynamic. A tax-financed spending program is predicted to be sharply deflationary in 2020 and sharply inflationary in 2021, with the inflation rebound largely sending the price level near (but still below) its steady-state path. Note that the price level here never fully recovers because we are assuming that the negative demand shock persists into the indefinite future. This latter assumption is necessary to keep the debt-to-GDP ratio elevated relative to its pre-pandemic level.

The bottom left panel of Figure 5 shows that monetary policy under a tax-financed emergency spending program would have optimally followed a path similar to the case where spending was deficit-financed. That is, while the price-level behaves very differently under these two methods of finance, the inflation dynamic is similar. This implies a similar dynamic for expected inflation and, hence, for the optimal monetary policy interest rate.

6.3 Optimal Monetary Policy Given Fiscal Policy

The Federal Open Market Committee of the US Federal Reserve views fiscal policy as beyond its control when formulating its interest rate policy. Our analysis above suggests that the fiscal transfers and primary deficits during 2021-22 were larger than necessary (at least in hindsight). In other words, the inflationary impulse of fiscal policy was greater than it should have been. How should monetary policy have responded to this larger than necessary inflationary impulse?

Figure 6: Optimal Monetary Policy Given Fiscal Policy



Because the smaller fiscal transfer program described in the previous section is sufficient to relax credit constraints, the larger program considered here achieves the same result–albeit, through overkill. The monetary authority in our

model is therefore left to target the natural rate of interest, which we continue to assume remained constant throughout the episode. The resulting dynamics are displayed in Figure 6

To achieve the monetary policy goal of targeting the expected natural rate of interest, our model suggests that the policy rate should have been cut only modestly in 2020 and returned to its pre-pandemic level by 2021. The Fed should have raised its policy rate by 200bp in 2022, keeping it at this level throughout 2023, before lowering it back near its pre-pandemic level in 2024; see bottom left panel of Figure 6. This relatively modest undulation in the policy rate path essentially follows the path of inflation expectations.

The bottom right panel of Figure 6 shows that given fiscal policy, an optimal monetary policy would have made very little difference in the total amount of inflation experienced in the economy.[11] Without fiscal support, interest rate policy in our model can only determine the timing of inflation. As in the earlier experiment (see Figure 4), the optimal policy backloads the inflation surge. According to our model, the Fed should have allowed disinflation to persist throughout 2020-21. Doing so would have implied an even stronger inflation surge in 2022. This is the inflation tax that is necessary to finance the given fiscal expenditures.

6.4 Strict Inflation Targeting

Our economic environment is one in which the long-term inflation target is ultimately determined by the fiscal authority.[12] However, because the monetary authority can influence the real interest rate in the short term, it also has the power to determine the path of the price level in the short term. In the following experiment, we provide a counterfactual experiment in which monetary policy uses all of its power to keep inflation on target assuming the observed fiscal policy over 2020-24 and assuming full fiscal support for the inflation-targeting policy beyond 2024. As in the benchmark economy, we set $\theta_t = 0$ for 2020-24 and $\theta_t = 1$ from 2025 onward. The dynamics from this counterfactual experiment are recorded in Figure 7.

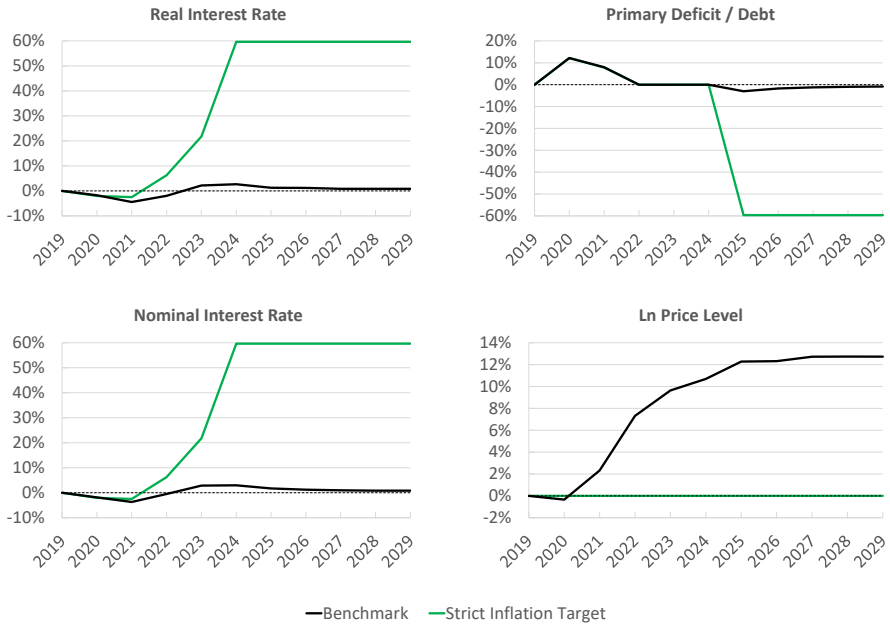
As Figure 7 reveals, strict inflation targeting appears to be feasible for a central bank, but only for a limited period of time. In Figure 7, the real interest rises to astronomical levels and remains there only due to the assumed primary surplus that becomes operational in 2025. Without this fiscal support, the real interest rate would collapse back to zero in 2025 via a corresponding jump in the rate of inflation. The sharp increase in the real interest rate would have sent the economy into a permanent recession.[13]

[11] The reader will notice that the price level is lower in the benchmark economy. This is because the real interest rate is higher, which serves to increase the level demand for real money balances.

[12] In most economic models, fiscal support for the assumed inflation target is implicit.

[13] In the model, this occurs through a contraction in capital investment. But in richer models

Figure 7: Strict Inflation Target without Fiscal Support in 2020-24



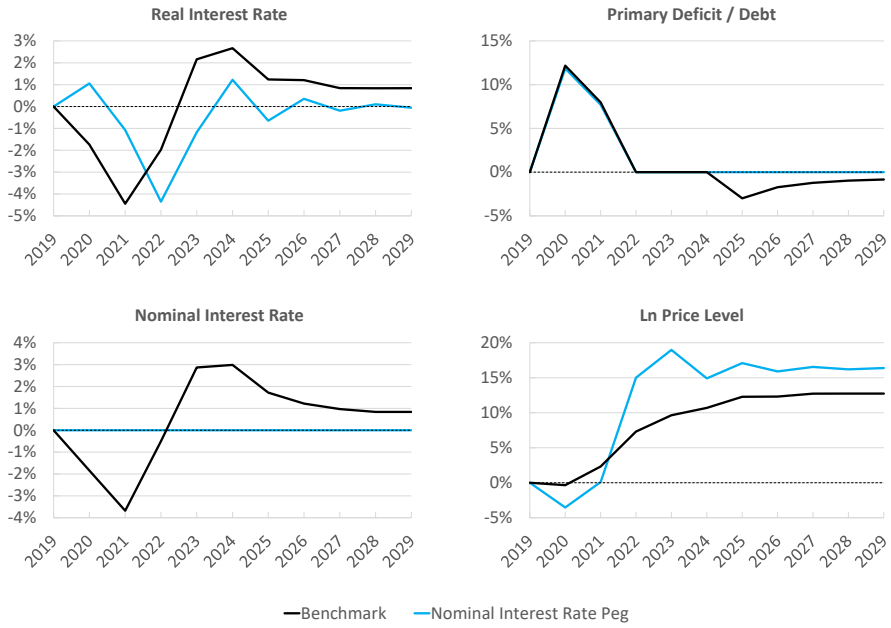
6.5 Transitory Inflation With a Nominal Interest Rate Peg

In his speech at Jackson Hole, Fed Governor Jerome Powell took credit for the rapid disinflation that occurred soon after inflation peaked in the summer of 2022 (Powell, 2024). To evaluate this claim, we compute the model dynamics assuming that the Fed keeps its policy rate at its 2019 level throughout the entire episode. The results are reported in Figure 8. The bottom right panel of Figure 8 supports Chair Powell's claim in one sense, but not in another. Our model supports the notion that active Fed policy mitigated the inflation surge relative to what would have transpired had the Fed kept its policy rate unchanged. In fact, the overall increase in the price level is lower than it otherwise would have been. The reason for this latter result has to do with the fact that the Fed is keeping the real rate of interest elevated relative to its pre-pandemic level (and relative to what is optimal in the model). However, our model rejects the claim that an aggressive Fed policy was necessary to anchor inflation expectations; e.g., see Bundick, Smith and der Meer (2024).

Figure 9 reports the dynamics of expected inflation under the two mone-

and in reality, this would occur through a variety of other channels.

Figure 8: Nominal Interest Rate Peg

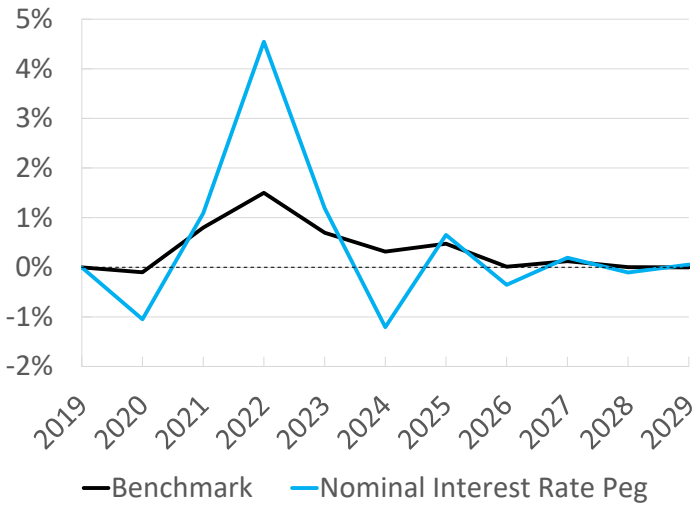


tary policies considered here. Aggressive monetary policy did serve to smooth expectations of inflation, but was not necessary to anchor these expectations. The results of our experiment are not inconsistent with the way that elevated inflation during the Korean War eventually dissipated without any aggressive monetary policy tightening. The basic intuition for this result is that a one (or two) time helicopter drop of money should only generate a transitory burst of inflation and a permanent increase ithe price level, even for a fixed interest rate policy.

7 Conclusions

The COVID-19 pandemic disrupted the earning capacity of American households in a heterogeneous manner. It also induced an economy-wide change in economic behavior, including a desire to postpone spending. Our model suggests that US fiscal policy during the COVID-19 pandemic was, on the whole, desirable, if somewhat excessive. It was almost surely better than doing nothing at all. However, an equally effective income support program financed with a surtax could have been implemented with less inflation.

Figure 9: Expected Inflation



Given the observed fiscal policy and the COVID-19 shock, the Federal Reserve should have lowered and then raised its policy rate as it did, although in a less dramatic manner. Doing so would only have delayed the inflation surge. Although the Fed could have prevented the inflation surge, doing so would have required an ever-increasing real rate of interest that would have contracted real economic activity. There is no way the Fed could have prevented the COVID-19 price level shock through interest rate policy alone. And while the Fed helped smooth inflation and inflation expectations through its aggressive monetary policy tightening, such an action was not necessary to keep inflation expectations anchored.

This interpretation of events runs counter to many popular narratives. Although our analysis was performed in the context of a very simple model, we have reason to believe that the qualitative results reported above will remain robust to more elaborate extensions of the model. Our implications are important for the Federal Reserve's upcoming review of its policy framework. When the economy is inflicted by a large shock, such as a war or a pandemic, monetary policy should suspend its usual concern for inflation over the near term. At the same time, Congress needs to ensure that fiscal policy remains anchored. The Federal Reserve's long-run inflation target cannot be achieved without fiscal support.

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A Efficient allocation

Household type $j = \{L, H\}$ has preferences

$$U_t(j) = E_t[(1-\alpha_t)(1/\beta_j)u(c_t^y) + c_{t+1}^o] \tag{34}$$

The social welfare function is $W = E_1 \sum_{t=0}^{\infty} \delta^t \{\rho U_t(L) + (1-\rho)U_t(H)\}$, where $U_0(j) = c_1^o(j)$. That is,

$$W = E_1 \sum_{t=1}^{\infty} \delta^t \Big\{ \rho[(1-\alpha_t)(1/\beta_L)u(c_t^y(L)) + (1/\delta)c_t^o(L)] \\ + (1-\rho)[(1-\alpha_t)(1/\beta_H)u(c_t^y(H)) + (1/\delta)c_t^o(H)] \Big\}$$

The resource constraint is given by,

$$w_t + f(k_{t-1}) - \rho[c_t^y(L) + c_t^o(L)] - (1-\rho)[c_t^y(H) + c_t^o(H)] - k_t \geq 0$$

for all $t = 1, \ldots, \infty$. Initial capital, k_0 is given.

With Lagrange multiplier $\delta^t \lambda_t$ on the resource constraints, the first-order conditions of the planner's problem are

$$\begin{aligned}
\delta^t \rho(1-\alpha_t)(1/\beta_L)u'(c_t^y(L)) - \delta^t \rho \lambda_t &= 0 \\
\delta^t (1-\rho)(1-\alpha_t)(1/\beta_H)u'(c_t^y(H)) - \delta^t (1-\rho)\lambda_t &= 0 \\
\delta^{t-1}\rho - \delta^t \rho \lambda_t &= 0 \\
\delta^{t-1}(1-\rho) - \delta^t (1-\rho)\lambda_t &= 0 \\
-\delta^t \lambda_t + \delta^{t+1} f'(k_t) E_t \lambda_{t+1} &= 0
\end{aligned}$$

for all $t = 1, \ldots, \infty$. The system simplifies to

$$\begin{aligned}
(1-\alpha_t)u'(c_t^y(j)) &= \beta_j \lambda_t \\
1 &= \delta \lambda_t \\
\lambda_t &= \delta f'(k_t) E_t \lambda_{t+1}
\end{aligned}$$

for $j = \{L, H\}$ and all $t = 1, \ldots, \infty$. Hence, $\lambda_t = 1/\delta$ and so,

$$\begin{aligned}
(1-\alpha_t)u'(c_t^y(j)) &= \beta_j/\delta \\
f'(k_t) &= 1/\delta
\end{aligned}$$

When $\delta = 1$ we obtain (4)–(6).

Note that the planner's problem does not pin-down $c_t^o(L)$ and $c_t^o(H)$ but rather $c_t^o \equiv \rho c_t^o(L) + (1-\rho)c_t^o(H)$. This follows from quasi-linearity: as shown in the equations above, the FOCs wrt $c_t^o(j)$ are the same for both types, so we lose one equation. The efficient allocation is silent about how consumption is allocated among the old. Hence, it is sufficient to show that an equilibrium implements the allocation $(\hat{c}_t^y(L), \hat{c}_t^y(H), \hat{k}_t)$ to show that it is efficient.

B Alternative specifications

B.1 Consumption tax

In this section, we assume the government no longer has access to lump-sum taxes and, instead, relies on distortionary consumption taxes to finance the deficit. Specifically, assume that tax revenue is given by $T_t = \tau_t^c p_t (c_t^y + c_t^o)$ and so, the government budget constraint (8) becomes

$$\tau_t^c p_t c_t = \theta_t (R_{t-1} - 1) M_{t-1} \tag{35}$$

where $c_t \equiv (1-\sigma_t)c_t^y(h) + \sigma_t c^y(l) + (1-\sigma_{t-1})c_t^o(h) + \sigma_{t-1}c_t^o(l)$.

The budget constraints of a type-i household are now

$$\begin{aligned} (1+\tau_t^c)c_t^y(i) &= w_t(i) - q_t(i) - k_t(i) + z_t(i) & (36)\\ (1+\tau_{t+1}^c)c_{t+1}^o(i) &= f(k_t(i)) + R_t/\Pi_{t+1} q_t(i) & (37) \end{aligned}$$

Necessary conditions characterizing optimal household behavior $\{q_t(i), k_t(i)\}$ are given by,

$$\begin{aligned} \beta f'(k_t(i)) E_t\left[\frac{1}{1+\tau_{t+1}^c}\right] &= \beta R_t E_t\left[\frac{1}{\Pi_{t+1}(1+\tau_{t+1}^c)}\right] + \lambda_t(i) & (38)\\ \frac{(1-\alpha_t)u'(c_t^y(i))}{1+\tau_t^c} &= \beta R_t E_t\left[\frac{1}{\Pi_{t+1}(1+\tau_{t+1}^c)}\right] + \lambda_t(i) & (39) \end{aligned}$$

for $i = l, h$.

Expectations are formed according the rule (17). As with inflation, there is a tax rate τ^* which is consistent with steady state and anchors the expectations for future taxes. Hence,

$$\begin{aligned} E_t[\Pi_{t+1}] &= \Pi_t^{1-\phi}(\Pi^*)^{\phi} \\ E_t\left[\frac{1}{1+\tau_{t+1}^c}\right] &= \left[\frac{1}{(1+\tau_t^c)}\right]^{1-\phi}\left[\frac{1}{(1+\tau^*)}\right]^{\phi} \\ E_t\left[\frac{1}{\Pi_{t+1}(1+\tau_{t+1}^c)}\right] &= \left[\frac{1}{\Pi_t(1+\tau_t^c)}\right]^{1-\phi}\left[\frac{1}{\Pi^*(1+\tau^*)}\right]^{\phi} \end{aligned}$$

The Taylor Rule (10) implies

$$r_t = \frac{R_t}{\Pi_t^{1-\phi}(\Pi^*)^{\phi}}$$

Then, (38) and (39) become

$$\begin{aligned} \beta f'(k_t(i)) &= \beta r_t + \lambda_t(i) & (40)\\ (1-\alpha_t)u'(c_t^y(i))\left(\frac{1+\tau^*}{1+\tau_t^c}\right)^{\phi} &= \beta r_t + \lambda_t(i) & (41) \end{aligned}$$

where

$$c_t^y(i) = \frac{w_t(i) - q_t(i) - k_t(i) + z_t(i)}{1 + \tau_t^c} \tag{42}$$

Combining (35) with the resource constraint (3) and the market clearing condition (25), we can solve for the tax rate in equilibrium

$$\tau_t^c = \frac{\theta_t(R_{t-1} - 1)Q_t}{c_t \mu_t} \tag{43}$$

In a steady state, $R^* = \Pi^* = r^* = 1$ and so $\tau^* = 0$.

B.2 Single government budget constraint

In the benchmark model, transfers are always financed with new debt and the policy parameter θ_t determines how much of the interest expense is financed with taxes. This specification implies two government budget constraints that need to be satisfied in equilibrium, (8) and (9).

Alternatively, we could allow for transfers to be financed with taxes. In real terms, the consolidated government budget constraint, (7) becomes:

$$\tau_t = z_t + (R_{t-1}/\mu_t - 1)Q_t \tag{44}$$

Now τ_t and μ_t satisfy a single equation, so one fiscal instrument is free to support a particular policy objective. For example, fiscal policy could support the inflation target, for a given monetary policy. In this case, μ_t could be set to ensure $\Pi_t = \Pi^*$ and τ_t would adjust passively to satisfy (44).

B.3 Adaptive nominal anchor

Inflation expectations in the benchmark model are anchored by the long-run inflation target, Π^*. Here, we relax this assumption and allow the anchor to move away from target if inflation is different than target. Consider the following process for the anchor: Π_1^* is given and for $t \geq 2$,

$$\Pi_t^* = \Pi^* \prod_{j=1}^{t-1} (\Pi_j/\Pi^*)^{\delta^{t-j}} \tag{45}$$

with $\delta \in [0, 1)$. The benchmark case, $\Pi_t^* = \Pi^*$, assumes $\delta = 0$. When $\delta \in (0, 1)$ agents account for past inflation misses to form expectations. If $\Pi_t = \hat{\Pi}$ for all t and $\delta = 1/2$ then Π_t^* converges to $\hat{\Pi}$. In general, Π_t^* converges to values below or above $\hat{\Pi}$, depending on whether $\hat{\Pi}$ is above or below Π^* and δ is above or below $1/2$.

When $\Pi^* = 1$, as we assume in the benchmark model, (45) simplifies to

$$\Pi_t^* = \prod_{j=1}^{t-1} \Pi_j^{\delta^{t-j}}$$

Recall that expectations are formed according the rule (17). We modify this rule slightly to allow for a moving target. Specifically,

$$\begin{aligned} E_t[\Pi_{t+1}] &= \Pi_t^{1-\phi}(\Pi_t^*)^{\phi} \\ E_t\left[\frac{1}{\Pi_{t+1}}\right] &= \left[\frac{1}{\Pi_t}\right]^{1-\phi}\left[\frac{1}{\Pi_t^*}\right]^{\phi} \end{aligned}$$

where Π_t^* is determined by (45).

The Taylor Rule (10) now implies

$$r_t = \frac{R_t}{\Pi_t^{1-\phi}(\Pi_t^*)^{\phi}}$$

Optimal household behavior is still characterized by (21) and (22).