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Monetary Policy and the COVID-19 Inflation Shock*

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Abstract

We study the surge in U.S. inflation following the COVID-19 pandemic using a small-scale dynamic general equilibrium model calibrated to the 2020–2024 period. The framework emphasizes the interaction among fiscal transfers, monetary policy, and the government's intertemporal budget constraint in an economy with heterogeneous households, incomplete insurance and borrowing constraints.

We evaluate what monetary policy could realistically have achieved given the observed stance of U.S. fiscal policy. While the model implies that monetary policy was late relative to the optimum, earlier tightening would mainly have altered the timing of inflation rather than the cumulative increase in the price level. More aggressive attempts to smooth the inflation burst through monetary policy alone would have required an unsustainable path for the real interest rate and produced a deep and prolonged recession.

We also show that, absent extraordinary fiscal support, the COVID-19 shock would have generated deflationary pressures, binding borrowing constraints and sizable welfare losses for adversely affected households. In this context, the inflation surge of 2021–2022 is best understood as the consequence of large unfunded fiscal transfers implemented in 2020–2021. Although these transfers were likely larger than necessary, they were nonetheless welfare-improving relative to inaction, with the resulting price-level adjustment serving as a second-best means of financing a broadly desirable social insurance response.

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

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

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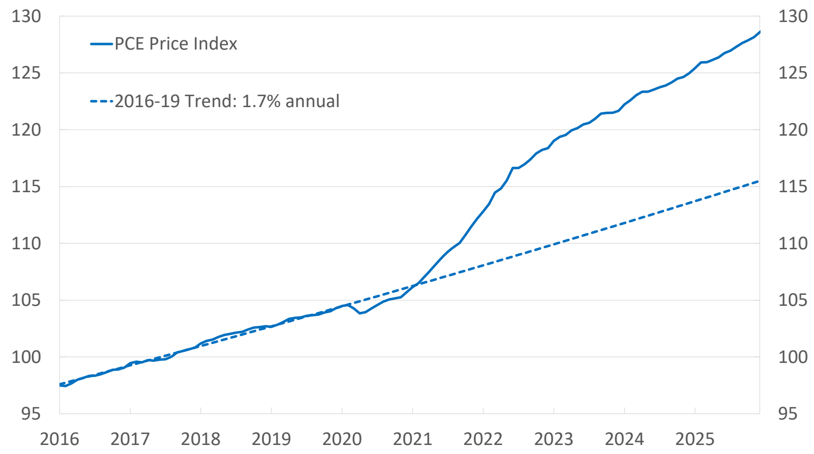
1 Introduction

The surge in U.S. inflation following the COVID-19 pandemic has generated considerable discussion and debate about the proper conduct of monetary policy in those extraordinary times. Between early 2021 and mid 2022, inflation rose sharply before declining, leaving the price level permanently elevated relative to its pre-pandemic trend—see Figure 1. A common narrative attributes this episode to a combination of supply disruptions, strong demand and a monetary policy that remained accommodative for too long. In this view, the Federal Reserve fell behind the curve.

Figure 1: The COVID-19 Price Level Shock



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

Conventional "behind-the-curve" critiques often rely on historically estimated Taylor rules and implicitly assume that fiscal policy is Ricardian—i.e., that future primary surpluses adjust to support the price level implied by monetary policy. That assumption is untenable in the COVID-19 episode. The pandemic shock prompted large, deficit-financed transfers, designed to assist households with little or no contemporaneous means to offset its budgetary effects. In this environment, it is unrealistic to expect tighter monetary policy alone to reverse the resulting price level shift without imposing significant real costs. Indeed, Sims (2011) shows that when nominal government debt is not fully backed by future taxes, policy-induced increases in the interest rate can actually raise rather than reduce inflation. By raising the interest expense of the debt, aggressive rate hikes may lead to increased issuance of nominal debt and thereby intensify inflationary pressure. In such circumstances, the central bank risks "stepping on a rake".

This observation motivates our contribution. Many critiques assume that the Federal Reserve could have contained the pandemic-era price surge simply by raising rates more aggressively, leaving fiscal policy in the background. Yet without a general-equilibrium framework that endogenizes the interaction between monetary and fiscal policy, one cannot know whether sharper rate hikes would have tamed inflation or compounded economic hardship. Our goal is to fill this gap by constructing a tractable dynamic general-equilibrium model with heterogeneous households, incomplete insurance and borrowing constraints. In this setting, pandemic fiscal transfers are interpreted as social insurance against concentrated income losses, and the model's simplicity yields transparent comparative statics. Calibrated to the actual paths of monetary and fiscal policy during the COVID-19 episode, our framework allows us to run counterfactuals—such as earlier monetary tightening or withholding fiscal support—and to evaluate the resulting trade-offs among inflation, output and welfare.

The main results of our analysis are as follows. First, we show that, absent extraordinary fiscal support, the COVID-19 shock would have generated *deflationary* pressures accompanied by binding borrowing constraints and welfare losses for adversely affected households. In our model, pandemic fiscal transfers complete a missing insurance market and raise our measure of social welfare. How these transfers are financed determines the associated paths of interest rates and inflation.

A non-inflationary, welfare-improving tax-transfer scheme is feasible in the model. Deficit-financed transfers backed by future primary surpluses constitute another feasible policy and could have insured households with limited inflationary consequences. By contrast, transfers financed without future fiscal backing are inflationary but remain welfare-enhancing relative to inaction. In this sense, the resulting inflation surge can be interpreted as Pareto-improving *ex ante*. This conclusion is largely absent from standard analyzes and commentary, which typically explain the price-level consequences of unfunded fiscal expansions but abstract from welfare comparisons across policy regimes.

The central contribution of our paper speaks to the debate over whether the Federal Reserve should have tightened policy sooner. Consistent with critiques based on historically estimated Taylor rules, our model implies that monetary policy was indeed late relative to standard reaction functions. However, while earlier tightening may have improved welfare, the gains in our framework are small. More importantly, earlier tightening would mainly have shifted the timing of inflation rather than its ultimate magnitude. Given the observed fiscal stance, any attempt to substantially smooth the inflationary burst without fiscal adjustment would have required an ever-increasing real interest rate path, resulting in a deep and prolonged recession.

In this environment, monetary policy can, at most, influence the timing of inflation, not eliminate the underlying price-level adjustment implied by fiscal policy. At worst, an aggressive interest rate policy without fiscal support may raise the interest expense of the debt and thereby add to the inflationary pressure it is intended to contain.

Our analysis therefore reframes the policy debate in two important ways. First, it challenges the view that the post-COVID inflation episode primarily reflects a monetary-policy mistake; instead, it emphasizes the limited scope of interest rate policy in the presence of large, unfunded fiscal transfers. Second, it highlights a fundamental trade-off: attempting to strictly stabilize inflation through monetary policy alone may impose severe real costs, while allowing a temporary inflation surge may dominate feasible alternatives in welfare terms.

In summary, the COVID-19 price level increase is best interpreted as the equilibrium response to a large, unfunded fiscal expansion. The associated fiscal intervention was likely excessive but nonetheless welfare-improving relative to inaction, and—given the fiscal stance—there was little scope for the Federal Reserve acting alone to prevent the resulting rise in the price level without inducing a deep and prolonged recession.

2 Related literature

Our theoretical framework builds on the fiscal theory of the price level (FTPL), pioneered by Sargent and Wallace (1981), Aiyagari and Gertler (1985), Leeper (1991), Sims (1994), Woodford (1994) and Cochrane (2005). A central insight of this literature is that monetary and fiscal policies are jointly constrained by a consolidated government budget constraint. As a result, the determination of the price level depends critically on the specification of monetary–fiscal regimes and on the degree of coordination between policy authorities. This perspective implies a more limited role for monetary policy, and a correspondingly larger role for fiscal policy, in anchoring the price level and inflation expectations. Recent contributions extending and refining these insights include Leeper and Leith (2016), Bassetto and Cui (2018), Andolfatto and Martin (2018), Cochrane (2022) and Caramp and Silva (2023).

The surge in U.S. inflation during 2021–2022 has generated a rapidly growing literature seeking to explain its origins. Given the scale of fiscal interventions during the pandemic, it is not surprising that several studies apply the FTPL framework to this episode.[1] Bianchi, Faccini and Melosi (2023) develop and estimate a quantitative model in which unfunded government spending shocks account for a substantial portion of U.S. inflation, including the COVID-19 episode. This conclusion is not uncontroversial. Using an estimated New Keynesian model, Smets and Wouters (2024) find that most fiscal implications of U.S. business-cycle shocks are ultimately funded, though they also conclude that expansionary fiscal policy contributed meaningfully to the 2021 inflation surge. Similarly, Barro and Bianchi (2025) document a significant role for fiscal expansions in recent inflation episodes across OECD countries. Bassetto and Miller (2025) emphasize information frictions about fiscal regimes and use them to explain why inflation rose sharply in 2021–2022 rather than gradually as deficits accumulated.

While there is growing agreement that fiscal policy played an important role in shaping recent inflation dynamics, relatively little attention has been devoted to the normative evaluation of monetary and fiscal policy during this episode. Much of the existing literature treats inflationary finance as undesirable, emphasizing its distortionary and redistributive costs; see, for example, Hall and Sargent (2022*a*,*b*). At the same time, a public finance tradition recognizes that inflationary finance may be welfare-improving under certain circumstances, particularly when it relaxes binding constraints or substitutes for more distortionary taxes; see Chari and Kehoe (1999), Sims (2001), Lustig, Sleet and Yeltekin (2008), and more recently Leeper and Zhou (2021). Our analysis interprets the COVID-19 inflation episode through this latter lens.

In addition, we conduct counterfactual experiments that evaluate the scope of monetary policy for a given, and not necessarily optimal, fiscal policy. In this respect, our approach is related to Benigno and Woodford (2007), though applied to the COVID-19 inflation episode and to an environment in which fiscal policy plays a central role in determining the price level.

Our analysis complements the recent work of Alves and Violante (2026) and Kaplan and Miyahara (2026) who, as in our paper, perform a set of counterfactual experiments designed to evaluate the conduct of monetary and fiscal policy during the COVID-19 pandemic. Consistent with our findings, the welfare gains associated with pandemic-era fiscal policies arise through the provision of insurance rather than aggregate demand stimulus. The authors also find, as in our paper, that a coordinated monetary-fiscal policy would have achieved these gains with less inflation. Our paper complements this literature by developing a streamlined, analytically transparent model that allows for explicit welfare comparisons, recasting the pandemic-era inflation surge as a deliberate policy trade-off between a one-off price-level increase and deeper real-economy costs.

A summary of our contribution is as follows. To be clear, the contribution of this paper is

[1] More traditional monetarist explanations have also been proposed; see, for example, Gao and Nicolini (2023).

not to restate the fiscal theory of the price level, but to extend it along three dimensions that have received relatively little attention in the context of the COVID-19 inflation episode.

First, the paper provides an explicit welfare ranking of feasible policy alternatives. Existing FTPL analyses explain why inflation occurs under unfunded fiscal expansions, but typically stop short of comparing inflationary outcomes to alternatives such as deflation, binding borrowing constraints, or policy-induced recessions. This paper shows that, relative to inaction, the inflationary fiscal response was welfare-improving.

Second, the paper evaluates the practical limits of monetary policy using realistic counterfactuals. Rather than asking whether inflation is theoretically preventable, the analysis asks whether it was feasibly preventable given the observed fiscal stance. The results show that earlier or more aggressive monetary tightening primarily shifts the timing of inflation and that materially smoothing the inflation path would have required a persistently rising real interest rate and a deep recession.

Third, the paper directly engages critiques of Federal Reserve policy based on historically estimated Taylor rules. While the model implies that monetary policy was late relative to such rules, it also shows that this timing difference had little effect on cumulative inflation outcomes in a fiscally driven episode. This reframes the post-COVID policy debate by emphasizing the limits of monetary policy in the absence of fiscal adjustment.

3 The Environment

Let $t = 1, 2, ..., \infty$ denote time. The economy is populated by overlapping generations of 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 enters 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 equal a unit mass.

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* patience 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 U.S. 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,

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

where $0 < \delta < 1$ is introduced simply as a device to bound W. 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.[2]

The restriction to quasilinear preferences buys us much in the way of analytical tractability. First, the optimal allocation can be characterized without reference to the exact properties of the stochastic process that govern the shock processes. This restriction also implies that it is efficient for old households to perfectly insure young households

[2]Note that $\hat{c}_t^o < 0$ is permissible here since utility is transferable (think of negative consumption as labor effort). See Appendix A for a detail of the derivations of (4)–(6).

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 $\{w_t(l), w_t(h), \sigma_t\}$. Finally, quasi-linearity 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.[3]

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?

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 government liabilities (debt) at prices p_t. Define inflation at date t as the growth rate in the price level with respect to the preceding period, i.e., $\Pi_t \equiv p_t/p_{t-1}$.

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 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 new 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 transfers are financed exclusively

[3] 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.

through debt. That is,

$$
\begin{aligned}
T_t &= \theta_t(R_{t-1}-1)M_{t-1} &(8)\\
M_t - M_{t-1} &= Z_t + (1-\theta_t)(R_{t-1}-1)M_{t-1} &(9)
\end{aligned}
$$

where $\theta_t \in [0,1]$. When $\theta_t = 0$, both transfers and interest expenses are financed exclusively with debt. When $\theta_t = 1$, all interest expenses are financed with taxes, while transfers are financed with debt. We call θ_t the degree of fiscal support. Note that (8) and (9) imply (7) given $G_t = 0$.

Government transfers are sent to young households and may depend on earnings type $i = \{l, h\}$, but not on the degree of impatience. Importantly, there are no private insurance markets. Let $Z_t(i)$ denote transfers to a household of type i. Then, given that there is a measure $\rho\sigma_t$ of type-l households, we obtain

$$
Z_t = (1-\rho\sigma_t)Z_t(h) + \rho\sigma_t Z_t(l) \tag{10}
$$

Taxes T_t are lump-sum and imposed on old households.

It is convenient to express (8), (9) and (10) in real terms. To this end, define $\tau_t \equiv T_t/p_t$, $z_t \equiv Z_t/p_t$, $z_t(i) \equiv Z_t(i)/p_t$, $\hat{Q}_t \equiv M_t/p_t$ and $\mu_t \equiv M_t/M_{t-1}$, and rewrite the expressions above as,

$$
\begin{aligned}
\tau_t &= \theta_t(R_{t-1}-1)(\hat{Q}_t/\mu_t) &(11)\\
(1-1/\mu_t)\hat{Q}_t &= z_t + (1-\theta_t)(R_{t-1}-1)(\hat{Q}_t/\mu_t) &(12)\\
z_t &= (1-\rho\sigma_t)z_t(h) + \rho\sigma_t z_t(l) &(13)
\end{aligned}
$$

Monetary policy follows a Taylor-type rule,

$$
R_t = r_t\Pi^*(E_t\Pi_{t+1}/\Pi^*)^{\nu} \tag{14}
$$

where r_t is a monetary policy variable, $E_t\Pi_{t+1}$ is the rate of inflation expected by households and Π^* is the long-run target for inflation. The policy variable r_t indicates the desired impact of monetary policy on the real economy. The parameter $\nu \geq 0$ specifies how aggressively the central bank reacts to deviations of inflation expectations from the inflation target.

In what follows, government policy is modeled as stochastic processes. In any given period, the exogenous component of policy consists of the triple $\{r_t, \theta_t, z_t(i)\}$. The endogenous component of policy consists of fiscal instruments, $\{\mu_t, \tau_t, z_t\}$, that adjust to satisfy the government budget rules, (11)–(13), the nominal interest rate, R_t, which is determined by the monetary policy rule (14), and the supply of government debt expressed in real terms, $\hat{Q}_t$, which will be determined in equilibrium to satisfy market clearing for debt.

4.3 Household Decisions

Households take the exogenous shock process for $\{w_t(i), \sigma_t, \alpha_t\}$ as given. They also take government actions $\{r_t, \theta_t, z_t(i), \mu_t, \tau_t, z_t, R_t\}$ as given. Given two-period lives, quasilinear preferences and full capital depreciation, the only future variables entering a young household's decision-making problem are expectations for the inflation rate and taxes. Since taxes are lump-sum and utility when old is linear, expectations about future taxes will not affect the decisions of young households. As we shall see below, the expected real return on government debt will affect a young household's demand for government liabilities. This real return will depend on the current nominal rate, R_t, which itself will depend on expected future inflation by (14), and expectations about the inverse of future inflation, $E_t[1/\Pi_{t+1}]$. For the moment, we take the stochastic processes for expected inflation and its inverse as exogenous. As we shall explore below, this representation accommodates various assumptions on how expectations are formed by households, including rational expectations and adaptive expectations.

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. Recall that only impatient (L) households may experience the low-earnings shock, σ_t. Hence, there are no households of type (l,H).

A young type-(i,j) household faces the following sequence of budget constraints,

$$\begin{aligned} p_t c_t^y(i,j) &= p_t w_t(i) - m_t(i,j) - p_t k_t(i,j) + Z_t(i) && (15) \\ p_{t+1} c_{t+1}^o(i,j) &= p_{t+1} f(k_t(i,j)) + R_t m_t(i,j) - T_{t+1} && (16) \end{aligned}$$

where $m_t(i,j) \geq 0$ denotes the household's accumulation of government securities.

Define $q_t \equiv m_t/p_t$ to rewrite the system above in real terms,

$$\begin{aligned} c_t^y(i,j) &= w_t(i) - q_t(i,j) - k_t(i,j) + z_t(i) && (17) \\ c_{t+1}^o(i,j) &= f(k_t(i,j)) + R_t/\Pi_{t+1} q_t(i,j) - \tau_{t+1} && (18) \end{aligned}$$

Substituting (17) and (18) into the household's objective function (1) yields,

$$\begin{aligned} U_t(i,j) &= (1-\alpha_t) u(w_t(i) - q_t(i,j) - k_t(i,j) + z_t(i)) \\ &+ \beta_j E_t[f(k_t(i,j)) + R_t/\Pi_{t+1} q_t(i,j) - \tau_{t+1}] + \lambda_t(i,j) q_t(i,j) && (19) \end{aligned}$$

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

$$\begin{aligned} (1-\alpha_t) u'(w_t(i) - q_t(i,j) - k_t(i,j) + z_t(i)) &= \beta_j R_t E_t[1/\Pi_{t+1}] + \lambda_t(i,j) && (20) \\ (1-\alpha_t) u'(w_t(i) - q_t(i,j) - k_t(i,j) + z_t(i)) &= \beta_j f'(k_t(i,j)) && (21) \end{aligned}$$

for $i = \{l,h\}$ and $j = \{L,H\}$. Notice that the portfolio-saving decision does not depend on the expected future tax liability τ_{t+1}. As mentioned earlier, however, this decision does depend on forming an expectation about (the inverse of) future inflation.

4.4 Characterization

We now further characterize the interaction between the private economy and government policy. Household optimization together with monetary policy requires combining (14), (20) and (21), which implies,

$$f'(k_t(i,j)) = r_t \Pi^* (E_t \Pi_{t+1}/\Pi^*)^\nu E_t[1/\Pi_{t+1}] + \lambda_t(i,j)/\beta_j \tag{22}$$

for $i = \{l,h\}$ and $\{j = L,H\}$. With $q_t(i,j)$ and $k_t(i,j)$ determined by (21), (22) and the complementary slackness condition, $\lambda_t(i,j) q_t(i,j) = 0$, the corresponding consumption demands are given by,

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

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

In equilibrium, the supply of nominal securities $\hat{Q}_t \equiv M_t/p_t$ 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,

$$Q_t \equiv (1-\rho)q_t(h,H) + \rho[\sigma_t q_t(l,L) + (1-\sigma_t)q_t(h,L)] \tag{26}$$

From (25) we can derive the following expression for the inflation rate,

$$\Pi_t = \mu_t Q_{t-1}/Q_t \tag{27}$$

where, recall, $\mu_t \equiv M_t/M_{t-1}$ is the growth rate of the supply of nominal securities. Equation (27) states that inflation depends negatively (positively) on current (past) demand for real balances.

As mentioned above, we assume that transfers, $z_t(i)$, and fiscal support, θ_t, are fiscal policy parameters. Hence, taxes, τ_t, and the growth rate of nominal liabilities, μ_t, evolve endogenously. From the government budget rules (11) and (12), plus the market-clearing condition (25), we can write:

$$\begin{aligned} \tau_t &= \theta_t(R_{t-1}-1)(Q_t/\mu_t) && (28)\\ \mu_t &= \frac{Q_t[1+(1-\theta_t)(R_{t-1}-1)]}{Q_t - z_t} && (29) \end{aligned}$$

where $z_t \equiv \rho\sigma_t z_t(l) + (1-\rho\sigma_t)z_t(h)$. Using (29) to substitute μ_t in (27) and (28) implies

$$\begin{aligned} \Pi_t &= \frac{Q_{t-1}[1+(1-\theta_t)(R_{t-1}-1)]}{Q_t - z_t} && (30)\\ \tau_t &= \frac{\theta_t(R_{t-1}-1)(Q_t - z_t)}{1+(1-\theta_t)(R_{t-1}-1)} && (31) \end{aligned}$$

4.5 Perfect-foresight equilibrium

To simplify exposition, in this section we will focus on defining an equilibrium for the case with no uncertainty. Assume the sequences for aggregate parameters $\{w_t(i), \sigma_t, \alpha_t\}$ and policy $\{r_t, \theta_t, z_t(i)\}$ are known. Furthermore, suppose there is perfect foresight for inflation and hence, $E_t\Pi_{t+1} = \Pi_{t+1}$ and $E_t[1/\Pi_{t+1}] = 1/\Pi_{t+1}$. In this case, the monetary policy rule (14) becomes,

$$R_t = r_t\Pi^*(\Pi_{t+1}/\Pi^*)^\nu \tag{32}$$

while the Euler equation (22) simplifies to

$$f'(k_t(i,j)) = r_t(\Pi_{t+1}/\Pi^*)^{\nu-1} + \lambda_t(i,j)/\beta_j \tag{33}$$

Definition 1. *Given individual initial portfolios $(k_0(i,j), q_0(i,j))$, aggregate initial conditions (Q_0, R_0), sequences for aggregate parameters $\{w_t(i), \sigma_t, \alpha_t\}$ and policy $\{r_t, \theta_t, z_t(i)\}$, a* ***perfect-foresight equilibrium*** *consists of individual allocations $\{c_t^y(i,j), c_t^o(i,j)\}$, individual portfolio decisions $\{q_t(i,j), k_t(i,j)\}$, aggregate real balances $\{Q_t\}$, policy actions $\{\tau_t, R_t\}$ and inflation rates $\{\Pi_t\}$ for all i, j and $t \geq 1$, such that:*

a. *Given policy actions $\{\tau_t, R_t\}$ and inflation $\{\Pi_t\}$, individual allocations $\{c_t^y(i,j), c_t^o(i,j)\}$ and portfolio decisions $\{q_t(i,j), k_t(i,j)\}$ solve (21), (23), (24) and (33), with $q_t(i,j) \geq 0$, $\lambda_t(i,j) \geq 0$ and $\lambda_t(i,j)q_t(i,j) = 0$;*

b. *Given individual demand for real balances* $\{q_t(i,j)\}$, *aggregate real balances* $\{Q_t\}$ *solve* (26)*;*

c. *Given aggregate real balances* $\{Q_t\}$, *policy actions* $\{\tau_t, R_t\}$ *and inflation* $\{\Pi_t\}$ *solve* (30), (31) *and* (32).

We can compute the equilibrium sequence for the growth rate of nominal liabilities, $\{\mu_t\}$, from (29). Then, given an initial condition for nominal liabilities, $M_0 > 0$, we can recover equilibrium prices $\{p_t\}$ from (26). We obtain

$$p_t = (M_0/Q_t) \prod_{h=1}^{t} \mu_h$$

An important special case occurs when $\nu = 1$. From (33) we now obtain

$$f'(k_t(i,j)) = r_t + \lambda_t(i,j)/\beta_j \tag{34}$$

One important implication is that the equilibrium now comprises two independent blocks. Given sequences for aggregate parameters $\{w_t(i), \alpha_t\}$ and policy $\{r_t, z_t(i)\}$, we can solve for the equilibrium sequences for $\{c_t^y(i,j), q_t(i,j), k_t(i,j)\}$ using (21), (23) and (34), plus the complementary-slackness conditions. These equilibrium sequences are independent from initial conditions. From there, given initial conditions and the remaining exogenous sequences, $\{\sigma_t, \theta_t\}$, we can recover the equilibrium sequences for consumption when old $\{c_t^o(i,j)\}$, aggregate real balances $\{Q_t\}$, policy actions $\{\tau_t, R_t\}$ and inflation rates $\{\Pi_t\}$, using the corresponding conditions. Finally, the equilibrium sequences for $\{\mu_t, p_t\}$ can be recovered as explained above.

In Appendix C, we further explore the case with rational expectations and compare it to our benchmark case with adaptive expectations, which we characterize in Section 5 below.

4.6 Efficient policy

For an arbitrary government policy $\{r_t, \theta_t, z_t(i)\}$, the equilibrium will be inefficient relative to the planner's allocation, as characterized by conditions (4)–(6). We will study actual and hypothetical policies below, with the goal of comparing them to an optimal policy. In this section, we characterize an optimal monetary-fiscal policy for any given shock process for the aggregate parameters $\{w_t(i), \sigma_t, \alpha_t\}$.

When comparing equilibrium conditions (21) and (22) with the conditions characterizing the efficient allocation, (4)–(6), it follows that, to implement an efficient allocation, government policy must relax debt constraints and target the appropriate real interest rate. Debt constraints are slack when $\lambda_t(i,j) = 0$ for all (i,j). Because there is no population or productivity growth, the (gross) "natural" real rate of interest in this environment is equal to one.

When debt-constraints are slack and the marginal product of capital is equal to one, (22) implies the policy parameter r_t must satisfy,

$$r_t = \{\Pi^*(E_t\Pi_{t+1}/\Pi^*)^\nu E_t[1/\Pi_{t+1}]\}^{-1} \tag{35}$$

By the monetary policy rule (14), this implies a nominal interest rate,

$$R_t = \{E_t[1/\Pi_{t+1}]\}^{-1} \tag{36}$$

Note that in a perfect-foresight equilibrium, $E_t\Pi_{t+1} = \Pi_{t+1}$, condition (36) implies $R_t = \Pi_{t+1}$. Furthermore, if $\nu = 1$ then $r_t = 1$, equal to the natural real rate.

The role of optimal monetary policy is to stabilize the real rate. Note that optimal monetary policy only responds to aggregate shocks indirectly, through their effect on inflation expectations.

Under the optimal monetary policy, (21) and (22) become

$$\begin{aligned} (1-\alpha_t)u'(c_t^y(i,j)) &= \beta_j & (37)\\ f'(k_t(i,j)) &= 1 & (38) \end{aligned}$$

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

$$q_t(i,j) = w_t(i) + z_t(i) - \hat{k}_t - \hat{c}_t^y(j) \tag{39}$$

Any transfer scheme $z_t(i)$ that implements $q_t(i,j) \geq 0$ for all (i,j) implements the efficient allocation. Transfers sent to young households in excess of those required to relax debt constraints are simply saved. As shown in Appendix A, due to our assumption of quasilinear preferences, the planner's problem only pins down average consumption when old, not how it is distributed across impatient and patient households. Hence, different transfer schemes, as long as debt constraints remain slack, correspond to different planner allocations for the old across types (the average remains the same). This property implies that multiple inflation rates (resulting from different transfer schemes) are consistent with the efficient allocation.

4.7 Steady state

Suppose there are no shocks and that government policy implements the long-run targets, $\{r^*, \Pi^*, \theta^*\}$. Assume $\alpha_t = \sigma_t = 0$ and $w_t(h) = w(h) = w$. Since there are no l-type households, agents in steady state are either impatient (L) or patient (H). All young households receive the same transfers, z. Finally, assume that inflation expectations are equal to actual inflation (in this case, equal to the inflation target): $E_t\Pi_{t+1} = \Pi_{t+1} = \Pi^*$. This final assumption is consistent with households holding either rational or adaptive expectations.

The steady state allocation $\{c^y(j), c^o(j), q(j), k(j), \lambda(j)\}_{j=\{L,H\}}$ is characterized by

$$\begin{aligned} u'(w - q(j) - k(j) + z) &= \beta_j f'(k(j))\\ f'(k(j)) &= r^* + \lambda(j)/\beta_j\\ c^y(j) &= w - q(j) - k(j) + z\\ c^o(j) &= f(k(j)) + r^* q(j) - \tau \end{aligned}$$

and $\lambda(j)q(j) = 0$, for $j = \{L, H\}$.

Let $Q \equiv (1-\rho)q(H) + \rho q(L)$. From (30) we obtain

$$\Pi = \frac{Q[1 + (1-\theta^*)(r^*\Pi^* - 1)]}{Q - z}$$

Importantly, steady state inflation is determined by both fiscal and monetary policies. Fiscal policy affects the long-run inflation rate through transfers, z. Monetary policy affects the long-run inflation rate through the real interest rate, r which, together with transfers, z, determines the demand for real balances, Q.

Assume that fiscal policy is consistent with the inflation target, i.e., let z be set so that $\Pi = \Pi^*$. Then,

$$\begin{aligned}
\mu &= \Pi^* \\
z &= \left[1 - (1-\theta^*)r^* - \theta^*/\Pi^*\right] Q \\
\tau &= \theta^*(r^* - 1/\Pi^*)Q
\end{aligned}$$

When $r^* = \Pi^* = 1$ we obtain, $\mu = 1$ and $z = \tau = 0$. For this steady state to be efficient, it must be the case that earnings are large enough so that debt constraints do not bind. Specifically, $w \geq \hat{c}^y(L) + \hat{k}$.

5 Equilibrium under adaptive inflation expectations

In this section, we derive analytical results under the assumption that households form inflation expectations using an adaptive rule anchored to the long-run inflation target, consistent with evidence that inflation expectations adjust sluggishly and incompletely to realized inflation (e.g., Coibion and Gorodnichenko, 2015; Gabaix, 2020; Weber, D'Acunto, Gorodnichenko and Coibion, 2022). As a result, expected inflation adjusts gradually and less than proportionally to realized inflation.

This assumption serves several purposes. First, in combination with quasi-linear preferences, adaptive expectations simplify household decision-making during the pandemic episode. In particular, household choices can be expressed as functions of current policy alone, without requiring assumptions about beliefs regarding the future path of the pandemic or government policy. This allows us to isolate the effects of contemporaneous policy while preserving analytical tractability, which, in turn, permits a tractable characterization of the monetary equilibrium and yields transparent comparative statics for the response of inflation to policy changes and aggregate shocks.

Second, it captures a salient empirical feature of recent data: since the onset of the pandemic, inflation expectations rose only gradually and lagged behind realized inflation, rather than adjusting one-for-one as in standard forward-looking models. Accordingly, we adopt adaptive expectations as the maintained assumption in both the analytical and quantitative analyzes. Later, we perform sensitivity analysis to assess the robustness of our main results to the alternative assumption of rational expectations.

Note that, as previously indicated, the steady state characterized in Section 4.7 also applies to the case with adaptive expectations.

5.1 Inflation Expectations

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

$$E_t x_{t+1} = x_t^{1-\phi} x^{\phi} \tag{40}$$

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

$$E_t \Pi_{t+1} = \Pi_t^{1-\phi} (\Pi^*)^{\phi} \tag{41}$$

The parameter $0 \leq \phi \leq 1$ here governs how strongly inflation expectations react to inflation data. We assume that households and monetary policymakers share the same inflation expectations. Moreover, assume $\nu = 1$, i.e., monetary policy reacts one-to-one to deviations of inflation expectations from target. As a consequence, the "Taylor rule" (14) can be written as,

$$R_t = r_t \Pi_t^{1-\phi} (\Pi^*)^{\phi} \tag{42}$$

We apply the same protocol to expected inverse inflation, which is the relevant object in the household's optimality condition (22). In doing so, we derive

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

As a consequence, the household's Euler equation (22) simplifies to

$$f'(k_t(i,j)) = r_t + \lambda_t(i,j)/\beta_j \tag{43}$$

for $i = \{l, h\}$ and $j = \{L, H\}$. This is convenient as we can now characterize the equilibrium outcomes in period t as functions of the contemporaneous policy variables governing the real interest rate r_t, the set of real transfers $z_t(i)$, and the level of fiscal support θ_t.

5.2 Equilibrium

Under adaptive expectations, the processes governing the aggregate parameters $\{w_t(i), \sigma_t, \alpha_t\}$ and policy $\{r_t, \theta_t, z_t(i)\}$ do not affect how households make decisions. Thus, we can define an equilibrium for particular realizations of these variables.

Definition 2. *Given individual initial portfolios $(k_0(i,j), q_0(i,j))$, aggregate initial conditions (Q_0, R_0), sequences for aggregate parameters $\{w_t(i), \sigma_t, \alpha_t\}$ and policy $\{r_t, \theta_t, z_t(i)\}$, an **adaptive expectations equilibrium** consists of individual allocations $\{c_t^y(i,j), c_t^o(i,j)\}$, individual portfolio decisions $\{q_t(i,j), k_t(i,j)\}$, aggregate real balances $\{Q_t\}$, policy actions $\{\tau_t, R_t\}$ and inflation rates $\{\Pi_t\}$ for all i, j and $t \geq 1$, such that:*

a. Individual decisions $\{c_t^y(i,j), q_t(i,j), k_t(i,j)\}$ solve (21), (23) and (43), with $q_t(i,j) \geq 0$, $\lambda_t(i,j) \geq 0$ and $\lambda_t(i,j)q_t(i,j) = 0$;

b. Given policy actions $\{\tau_t, R_t\}$ and inflation $\{\Pi_t\}$, individual allocations $\{c_t^o(i,j)\}$ solve (24);

c. Given individual demand for real balances $\{q_t(i,j)\}$, aggregate real balances $\{Q_t\}$ solve (26);

d. Given aggregate real balances $\{Q_t\}$, policy actions $\{\tau_t, R_t\}$ and inflation $\{\Pi_t\}$ solve (30), (31) and (42).

As in the perfect-foresight equilibrium when $\nu = 1$, the equilibrium definition with adaptive expectations comprises two independent blocks. The equilibrium under adaptive expectations can be minimally defined by the solution to $\{c_t^y(i,j), q_t(i,j), k_t(i,j)\}$ from conditions (21), (23) and (43), plus the complementary-slackness conditions. The remaining equilibrium variables can then be recovered from the corresponding conditions. We shall exploit this property in the theoretical analysis and quantitative exercises below.

Furthermore, when $\nu = 1$ we can establish an equivalence result between the equilibria under perfect-foresight and adaptive expectations.

Proposition 1. *Assume $\nu = 1$. (i) Given sequences for aggregate parameters $\{w_t(i), \sigma_t, \alpha_t\}$ and policy $\{r_t, \theta_t, z_t(i)\}$, the perfect foresight equilibrium and the equilibrium under adaptive expectations feature the same individual decisions $\{c_t^y(i,j), q_t(i,j), k_t(i,j)\}$ and aggregate real balances $\{Q_t\}$ for all i, j and $t \geq 1$. (ii) The two equilibria generically differ* *in policy actions* $\{\tau_t, R_t\}$ *and inflation rates* $\{\Pi_t\}$*. (iii) When* $\theta_t = 1$*, inflation rates* $\{\Pi_t\}$ *are identical under perfect foresight and adaptive expectations.*

In other words, when $\nu = 1$, the real allocation block in equilibrium is the same under perfect foresight and adaptive expectations.[4] The differences lie in policy outcomes: tax rates, nominal interest rates and inflation rates. The proof is in Appendix B.

In addition, when there is full fiscal support, $\theta = 1$, the paths for inflation are the same under perfect foresight and adaptive expectations. In this case, the key difference would be in the path for inflation expectations and the nominal interest rate, which would also imply a different sequence of taxes.

In Appendix C we further explore how the economy responds to changes in policy and aggregate shocks under rational and adaptive expectations.

5.3 Policy effects

In this section, we study the effects of monetary and fiscal policy on allocations and prices.

The following proposition states the effects of fiscal and monetary policy on households' decisions. We consider the impact of a change in current transfers, z_t, and the real interest rate, r_t, on the consumption and savings decisions of the current generation of young households, $c^y(i,j)$, $q_t(i,j)$ and $k_t(i,j)$. The effects of policy changes depend on whether households are debt-constrained or not. All proofs are in Appendix B.

Proposition 2. ***Effects of Fiscal and Monetary Policies on Young Households***

a. An increase in real transfers:

- *(i) for unconstrained young households, has no effect on consumption or capital investment, and is fully saved in real balances;*
- *(ii) for constrained young households, increases consumption and capital investment.*

b. An increase in the real interest rate:

- *(i) for unconstrained young households, decreases consumption and capital investment and increases holdings of real balances;*
- *(ii) for constrained young households, has no effect.*

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, a change 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.

[4] Note that while average (and aggregate) consumption when old is the same under perfect foresight and adaptive expectations, individual consumption when old is not generically the same. Due to quasilinear preferences, this distinction has no welfare consequences.

We now turn to the effects of fiscal and monetary policies, z_t and r_t, respectively, on current and future inflation. We focus on one-time changes to transfers and the real interest rate, that revert in the following period. The starting point is an economy where all young households are unconstrained and there are no transfers. These circumstances will also characterize the initial conditions in our quantitative analyses below. These assumptions can be relaxed and we discuss the impact of this whenever relevant.

Proposition 3. ***Effects of Fiscal and Monetary Policies on Inflation***

Consider an equilibrium in which all young households are unconstrained and transfers are zero, i.e., $\lambda_t(i,j) = 0$ for $i = \{l,h\}$, $j = \{L,H\}$ and $z_t = 0$, for all $t \geq 1$.

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

b. A one-time increase in the real interest rate decreases current inflation, $d\Pi_t/dr_t < 0$, and increases inflation in the following period, $d\Pi_{t+1}/dr_t > 0$.

Transfers are inflationary. An important property 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.

As shown in Proposition 2, transfers going to constrained young households would have no impact on their demand for real balances. Hence, the associated expansion in nominal liabilities, used to finance the transfers to constrained households, would have a positive impact on current (as well as future) inflation.

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 reverts in the following period and inflation consequently increases.

The impact of the real interest rate on future inflation can be persistent when at least some of the interest expense is financed with debt rather than taxes, i.e., when $\theta_{t+1} < 1$. In such a case, the higher nominal interest rate in t results in an expansion of nominal liabilities in $t+1$ (the fraction of interest expenses financed with debt rather than taxes), which increases the inflationary impact in $t+1$. This channel is still active in subsequent periods, adding persistence to the impact of changes in the current real interest rate on future inflation.

5.4 Inflation targeting

Modern central banks have adopted inflation-targeting strategies to pursue their price stability mandate. Here, we can let monetary policy set the real rate, r_t, to implement inflation equal to target, conditional on adequate fiscal support. In Section 4.7 we showed how the long run inflation rate depends on both fiscal and monetary policies. Proposition 3 showed that debt-financed fiscal expansions (here, an increase in real transfers) are inflationary. Now, we shall analyze how (and whether) monetary policy can unilaterally maintain inflation at target when facing a fiscal expansion.

Condition (30) implicitly determines the demand for real balances consistent with maintaining inflation at target, Q_t^*. When $\Pi_t = \Pi^* = 1$ we obtain,

$$Q_t^* = z_t + Q_{t-1}[1 + (1 - \theta_t)(R_{t-1} - 1)] \tag{44}$$

Suppose we start from initial conditions consistent with a steady state with inflation at target and all households unconstrained. From Section 4.7, we get $r^* = 1$, $z = \tau = 0$. Note that $R^* = r^*\Pi^* = 1$. Let Q^* be the corresponding demand for real balances. Suppose there is a one-time increase in real transfers in the first period, i.e., $z_1 = \zeta > 0$ and $z_t = 0$ for $t > 1$. Then, (44) implies

$$Q_1^* = \zeta + Q^* \tag{45}$$

As shown in Proposition 3, a one-time increase in real transfers to unconstrained young households is fully saved in real balances and does not increase current inflation, i.e., $\Pi_1 = 1$. Thus, on impact, monetary policy remains unchanged, $r_1 = 1$. What happens afterwards depends on fiscal support, θ_t.

Full fiscal support

When $\theta_t = 1$, all interest expense is financed with taxes. Then, given $z_2 = 0$, (44) and (45) imply $Q_2^* = \zeta + Q^*$. Note that $Q_2^* > Q^*$ even though transfers are back to zero. This means the real interest rate $r_2^* > 1$ to induce the higher demand for real balances. The same argument applies to any $t \geq 2$. The result is a higher permanent real interest rate, $r_t > 1$, which induces a higher demand for real balances and lower young-consumption and capital investment than in the initial steady state. Maintaining inflation at target in response to a one-time fiscal expansion leads to a permanent contraction in output.

Partial fiscal support

Now suppose $\theta_t < 1$, i.e., some interest expense is debt-financed. Then, given $r_1^* = 1$ and $z_2 = 0$, (44) and (45) imply $Q_2^* = \zeta + Q^*$, same as with full fiscal support. Hence, we get the same increase in the real interest rate, $r_2^* > 1$.

In the following period, we obtain $Q_3^* = (\zeta + Q^*)[1 + (1 - \theta_3)(r_2^* - 1)]$. Since $Q_3^* > \zeta + Q^* = Q_2^*$, we need $r_3^* > r_2^*$. That is, the real interest rate needs to increase even more to maintain inflation at target. The reason is that the unfunded interest expense implies an additional fiscal expansion, which needs to be sterilized. Specifically, the real rate needs to increase to induce the higher demand for real balances necessary to maintain inflation at target.

The same argument can be applied to subsequent periods. That is, $r_t^* > r_{t-1}^*$ when $\theta_t < 1$ for $t \geq 2$. Clearly, without fiscal support the real rate consistent with inflation at target is on an ever-increasing path. At the same time, consumption and capital investment by young households decrease over time. To put an end to this dynamic, the interest expense needs to eventually be fully financed with taxes. That is, there needs to be a period $t = T$ such that $\theta_T = 1$. In this case, the real rate stabilizes at a level higher than had there been full fiscal support from the start. The permanent recession from that point on is correspondingly deeper.

5.5 Aggregate shocks

We now study the effects of aggregate shocks. Recall that there are three sources of aggregate uncertainty: the degree of patience of young households, α_t; earnings by type, $w_t(i)$; and the measure of young households with low earnings, σ_t. The following proposition establishes how aggregate shocks impact households' decisions. As in Proposition 2, we consider the impact of aggregate shocks on the consumption and savings decisions of the current generation of young households, which depend on whether households are debt-constrained or not.

Proposition 4. ***Impact of Aggregate Shocks on Young Households***

a. An increase in patience:

(i) for unconstrained young households, decreases consumption, has no effect on capital investment and increases holdings of real balances;

(ii) for constrained young households, decreases consumption and increases capital investment.

b. An increase in earnings:

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

(ii) for constrained young households, increases consumption and increases capital investment.

An increase in patience, what we may label a negative *demand* shock, decreases the consumption of all young households. The effect on desired savings depends on whether young households are debt-constrained or not. For unconstrained young households, optimal capital spending is independent of the demand shock. In this latter case, a negative demand shock simply increases holdings of real balances. For constrained households, greater patience implies a substitution from consumption to capital investment. On aggregate, consumption from young households decreases, while capital investment and holdings of real balances increase.

An increase in earnings, regardless of type, which we may label a positive *supply* shock, also has a disparate impact, depending on whether young households are debt-constrained or not. For unconstrained households, consumption and capital investment are at optimal, so higher earnings are fully saved in real balances. For constrained households, higher earnings lead to increases in consumption and capital investment. On aggregate, consumption, capital investment, and holdings of real balances all increase.

The last result has implications for the impact of the low-earnings shock, σ_t, which we may also label a *supply* shock. This shock changes the measure of young households that receive low earnings. Importantly, an increase in the measure of low earners implies a decrease in the demand for reak balances. This has implications for inflation, which we investigate below.

The following proposition establishes the impact of aggregate shocks to patience and earnings on current and future inflation. Again, we focus on policy changes to an economy where all young households are unconstrained and there are no transfers, though more general results can be derived.

Proposition 5. ***Impact of Aggregate Shocks on Inflation***

Consider an equilibrium in which all young households are unconstrained and transfers are zero, i.e., $\lambda_t(i,j) = 0$ *for* $i = \{l, h\}$, $j = \{L, H\}$ *and* $z_t = 0$, *for all* $t \geq 1$.

a. A one-time increase in patience decreases current inflation, $d\Pi_t/d\alpha_t < 0$, *and increases inflation in the following period,* $d\Pi_{t+1}/d\alpha_t > 0$.

b. A one-time increase in earnings decreases current inflation, $d\Pi_t/dw_t < 0$, *and increases inflation in the following period,* $d\Pi_{t+1}/dw_t > 0$.

c. If some impatient young households hold positive amounts of real balances, then a one-time increase in the measure of low-earning young households increases current inflation and decreases inflation in the following period, i.e., $d\Pi_t/d\sigma_t > 0$ *and* $d\Pi_{t+1}/d\sigma_t < 0$.

d. If no impatient young household holds real balances, then a one-time increase in the measure of low-earning young households has no impact on inflation, $d\Pi_t/d\sigma_t = \Pi_{t+1}/d\sigma_t = 0$.

As we shall describe in the next section, we are going to characterize the COVID-19 shock as a combination of an increase in patience, a decrease in earnings for all types, and an increase in the measure of low-earning households. The demand shock is deflationary, while the supply shocks are both inflationary. The net effect of these shocks on inflation depends on their relative strength. We investigate this further below using a numerical version of our model calibrated to the U.S. economy.

6 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. All variables are detrended from their estimated steady-state growth paths. All impulse-response diagrams measure responses relative to trend.

6.1 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.[5] 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 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, which matches holdings of the non-bank domestic sector in 2019.[6] 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.

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

[5] 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.

[6] That is, we subtract the holdings of the Federal Reserve Banks, depository institutions, money market mutual funds and the foreign sector. The simple structure of our model (importantly, two-period lived agents and full capital depreciation) does not allow us to target total issuance of debt, which was about 80% of GDP in 2019. We instead target the holdings of a subset of the economy that resembles the households in our model.

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

6.2 Fitting 2020-2024

We now describe how we fit the model to the data for 2020-24. Targeted moments in the data are all expressed as deviations from 2019. The comparison between data and model is presented in Figure 2. In the next section, we describe how the model projections beyond 2024 are formed.

We assume that $\theta_t = 0$ for 2020-24. That is, the interest expense of the debt is financed entirely with new debt over this time frame.

We set σ_t so that the fraction of young impatient households 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.

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 all the expansions and extensions provided by the CARES act and the American Rescue Plan), as a fraction of GDP, for 2020-21.

Next, calibrate ϕ, which anchors inflation expectations around the inflation target. We can solve for ϕ using (41) for a particular year. We choose to target the year when inflation expectations peak. We use the 1-year inflation expectations published by the Cleveland Fed, which peaks in 2022. For inflation, we use the annual PCE inflation rate. The value of ϕ that allows the model to match the peak in inflation expectations is 0.702.

Condition (42) establishes a path for the real rate for 2020-24, given inflation and nominal interest rate targets. As mentioned above, for inflation we use the annual PCE inflation rate. For the nominal interest rate we use the minimum of the Effective Federal Funds Rate and the Wu-Xia estimates of the Shadow Federal Funds Rate.[7]

The remaining parameters are jointly estimated to match selected moments as described below. For 2020-24, we need to specify sequences for the high earnings process, $w_t(h)$ and the patience shocks, α_t. For 2020-21, which is the period of the COVID-19 shock and fiscal assistance, we need sequences for the low earnings process $w_t(l)$, and transfers to high-earning households, $z_t(h)$. Recall that transfers to low-earning households, $z_t(l)$, follow the rule specified above, which adds UIP benefits, specific to those affected by the σ_t shock in 2020-21. In all, we have 14 parameters to estimate, so we target a corresponding number of moments.

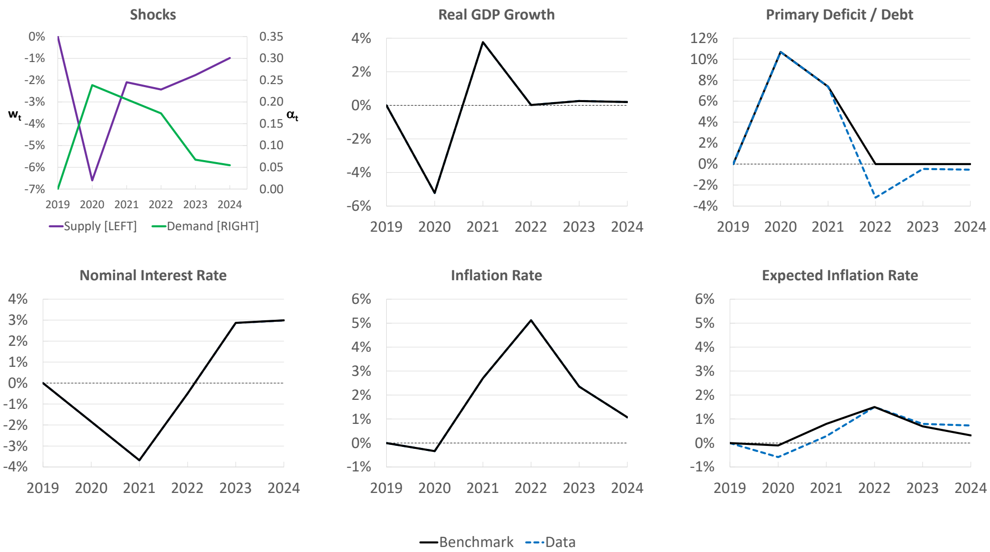
For 2020-24 we target the nominal interest rate, R_t, and the real GDP per capita growth rate. Given our target for the nominal interest rate and the calibrated path for the real rate, as described above, we also match the inflation rate, Π_t.

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

We target the Primary Deficit over Debt for 2020-21. We use the consolidated primary deficit for the general government (i.e., federal, state, and local) from the flow of funds; the measure of debt includes Treasuries and municipal securities, net of foreign holdings.[8] Transfers are normalized to zero in all other years.

Next, we target the same disposable income (earnings plus transfers minus taxes) for all young households in 2020-21. That is, we assume fiscal policy insures young households across *ex post* types.[9] Recall that there are no young households of type (ℓ, L) from 2022 onward. That makes 14 data moments that are fitted with the estimated parameters we described above.

Figure 2: Benchmark dynamics relative to trend



The upper left panel in Figure 2 shows the estimated shock sequences for the aggregate earnings process, w_t, and the patience shock, 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 negative shocks to supply and demand were operational in 2020. Although the negative supply shock of 2020 reverses in 2021, its recovery is estimated to remain 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.

The top-center, bottom-left and bottom-center panels show that we match real GDP growth, the nominal interest rate and the inflation rate exactly for 2020-24. The top- and bottom-right panels show that we match the primary deficit to debt ratio for 2020-21 and the peak of expected inflation, which occurs in 2022. Recall that all these moments are expressed as deviations from 2019.

The combined effects of the shocks and fiscal assistance imply that no households are debt-constrained throughout the simulation period. Recall that the steady state cal-

[8] Looking at the consolidated government during this period is important, as transfers from the federal government to state governments were not immediately spent.

[9] As argued by Ganong, Noel and Vavra (2020) the median replacement ratio from unemployment insurance may have exceed 100% during the initial round of fiscal assistance in 2020.

ibration implies that impatient young households optimally hold zero debt 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 as extraordinary fiscal assistance is removed, the demand shock dominates the supply shock so that all impatient (and patient) households are saving.

By 2024, the (log) 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.[10] As shown in the upper left panel of Figure 2 demand and supply shocks are still at play in 2024. In particular, negative demand shocks (i.e., $\alpha_t > 0$) explain why accumulated inflation has remained below the increase in government liabilities (about 16% in log differences). If these shocks were to eventually die out, then the total growth in the price level since 2019 would equal the growth in government debt.

6.3 Projections over 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 are expected to evolve in subsequent years.

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.

By 2029 the price level in the benchmark model has converged at three decimal points. The total increase in the price level between 2019 and 2029 is 13.7%. This is our estimated impact on inflation of the COVID-19 shocks and the associated fiscal and monetary policy response.

7 Counterfactual Exercises

7.1 No Fiscal Policy Response

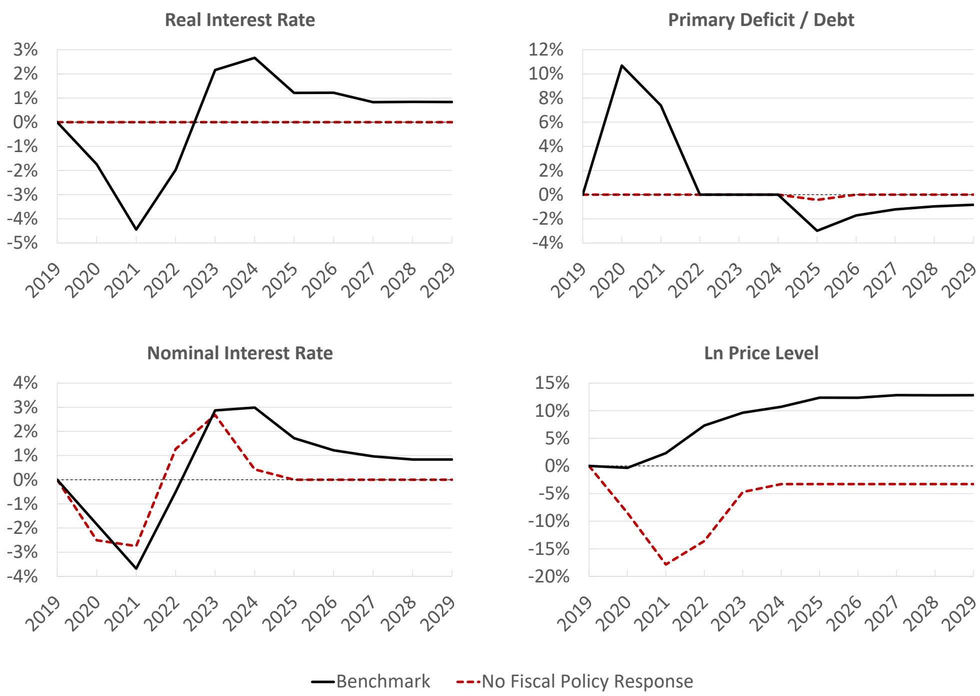
To begin our analysis, we ask how the economy would have evolved had there been no extraordinary fiscal measures taken in 2020-21. In this experiment, we assume that monetary policy keeps the real rate of interest fixed at its 2019 level and continues to adjust the nominal policy rate according to the interest rule (14). The result is depicted in Figure 3.

The bottom right panel of Figure 3 reveals that our calibrated model characterizes the COVID-19 pandemic as a deflationary event. The model predicts a 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). Evidence of this deflationary impulse can be seen in Figure 1. In particular, note the disinflation that occurred in 2020, despite very large fiscal transfers in that year.

[10] We report the price level in logs and changes as log differences. These differences should be interpreted as deviations from trend.

While the absence of a fiscal response keeps the national debt in check, hidden in the aggregate dynamics described in Figure 3 is the hardship experienced by young households experiencing losses to their earnings capacity. In particular, in 2020-21 a fraction of impatient young households are hit by the low-earnings shock. Because these households have no accumulated savings to draw on, without fiscal assistance, their consumption and investment levels fall below what our planner above would dictate.

Figure 3: No Fiscal Policy Response



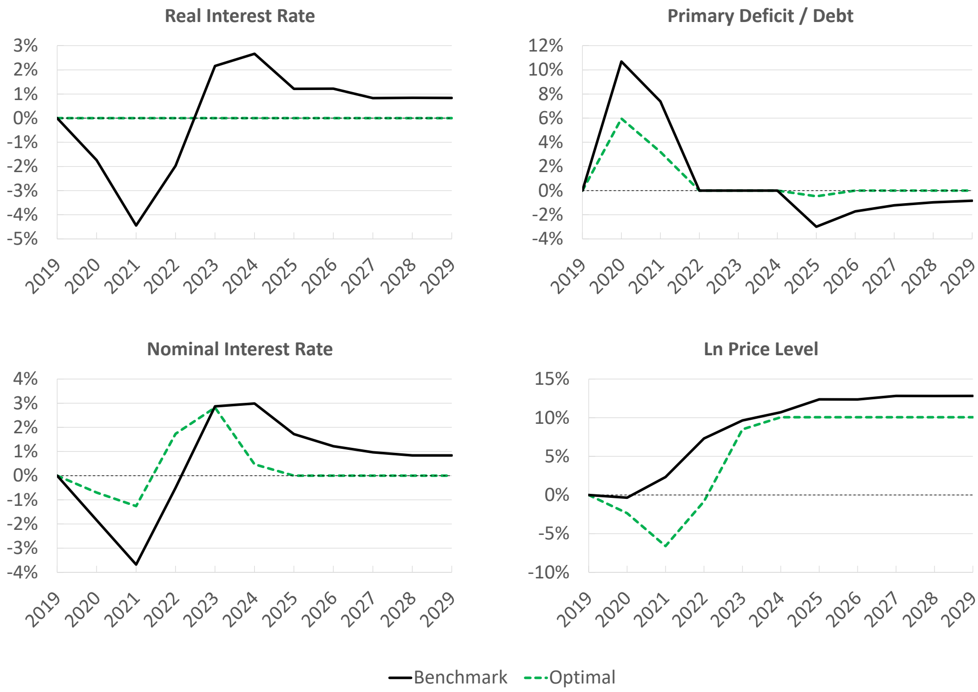
7.2 Optimal Policy

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 6.2 and 6.3, 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 sets $r_t = 1$ for all t by adjusting the nominal rate one for one against inflation expectations, which evolve over time according to (41). Optimal fiscal policy involves transfers just large enough to relax debt constraints.[11] 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 roughly half the size of those observed. Consequently, the optimal policy involves a smaller expansion of the debt than in the benchmark economy (12% instead of 16%).

[11] As noted previously, larger-than-needed transfers also implement the optimal allocation, as they are saved, but result in higher inflation.

Figure 4: Benchmark vs. Optimal Policy



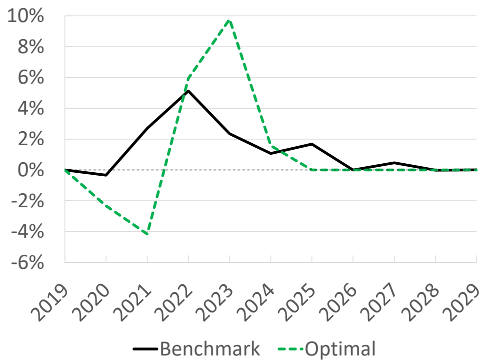
The bottom right panel of Figure 4 depicts the price level dynamic in the benchmark economy relative to the counterfactual experiment considered here. The price level under the optimal deficit policy increases by 10% (log-difference, relative to trend). This is very close to the increase of almost 11% in the benchmark economy by 2024, but somewhat smaller than the almost 13% increase generated in the benchmark economy by 2029. Thus, the model predicts that the overall increase in the cost of living would have been lower had fiscal policy been more restrained. The difference would be larger if the real interest rate in the benchmark economy were to return to its 2019 value instead of remaining elevated.

Note that the optimal price level dynamic in this case is very different than the benchmark. Figure 5 compares the inflation dynamics under the benchmark and optimal policies. 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 (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.[12] 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

[12] In a model with sticky nominal wages, deflation would also increase the real wage, an effect that could be expected to discourage the recovery dynamic. Thus, a rationale for smoothing inflation could arise if nominal wages are slow to adjust.

Figure 5: Inflation Rate



modeled households as having nonlinear preferences and/or sticky nominal wages.[13] 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 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.

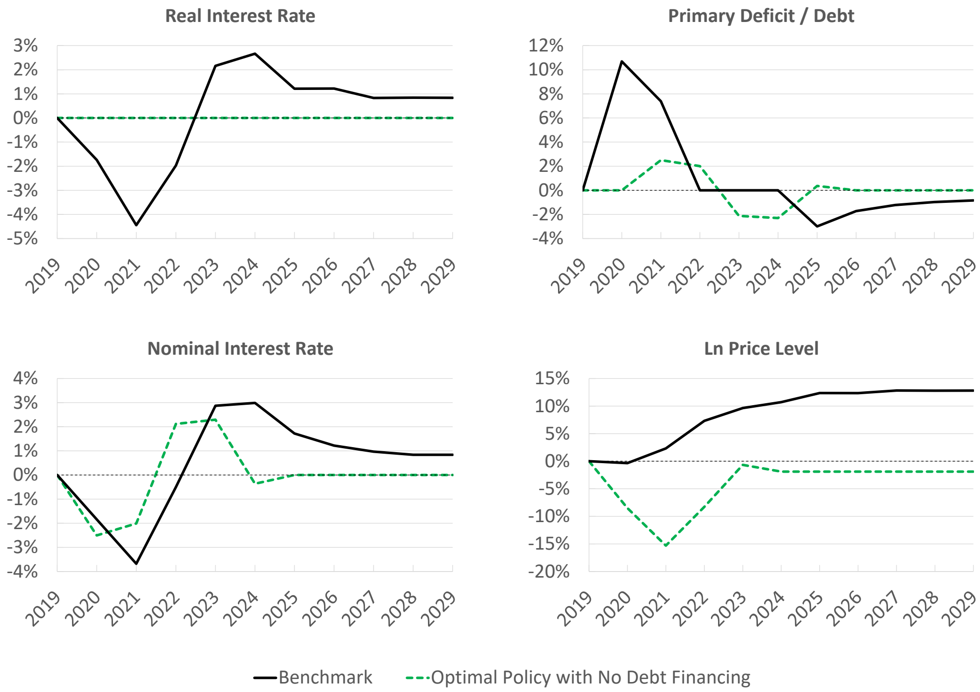
The experiment considered above assumes that the extraordinary spending associated with the COVID-19 pandemic is deficit-financed. It is of some interest to consider the case in which the spending was instead financed through a non-distortionary tax. Figure 6 depicts the predicted dynamics relative to the benchmark.

The top right panel of Figure 6 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 deflationary in 2020 and 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 never fully recovers because we assume that the negative demand shock persists into the indefinite future.

The bottom left panel of Figure 6 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.

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

Figure 6: Benchmark vs. Optimal Policy with No Debt Financing



7.3 Optimal Monetary Policy Given Fiscal Policy

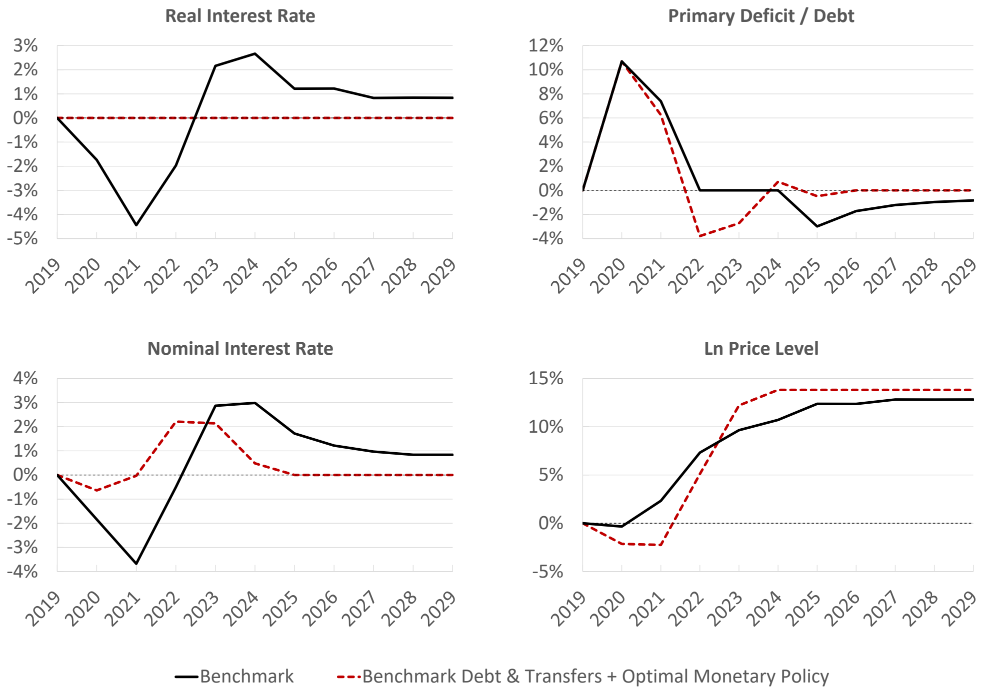
The Federal Open Market Committee of the Federal Reserve views fiscal policy as beyond its control when formulating its interest rate policy. Our analysis above suggests that the fiscal transfers and primary deficits during 2021-22 were larger than necessary (at least in hindsight). In other words, the 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?

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 7

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 7. This relatively modest undulation in the policy rate path essentially follows the path of inflation expectations. It is also a policy path that is consistent with the Fed critics arguing for an earlier and more aggressive tightening of monetary policy.

While our model agrees with Fed critics on monetary policy, it disagrees over the effect this counterfactual policy would have had. The bottom right panel of Figure 7 shows that given fiscal policy, an optimal monetary policy would have made very little difference

Figure 7: Optimal Monetary Policy Given Fiscal Policy



in the total amount of inflation experienced in the economy.[14] 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 simply backloads the inflation surge without eliminating it. 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 unfunded fiscal expenditures.

7.4 Inflation Targeting

Our economic environment is one in which the long-term inflation target is ultimately determined by the fiscal authority.[15] 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. It is worth stressing that in this model, the real interest level influences the price level, not the inflation rate, as shown by condition (25). The real interest rate affects the demand for nominal government liabilities, which given nominal supply, determines the price level. It is the *path* of the real interest rate that influences the inflation rate. In Section 5.4 we characterized the real interest rate policy necessary for maintaining inflation at target in response to a one-time increase in transfers and how this policy depended on fiscal support.

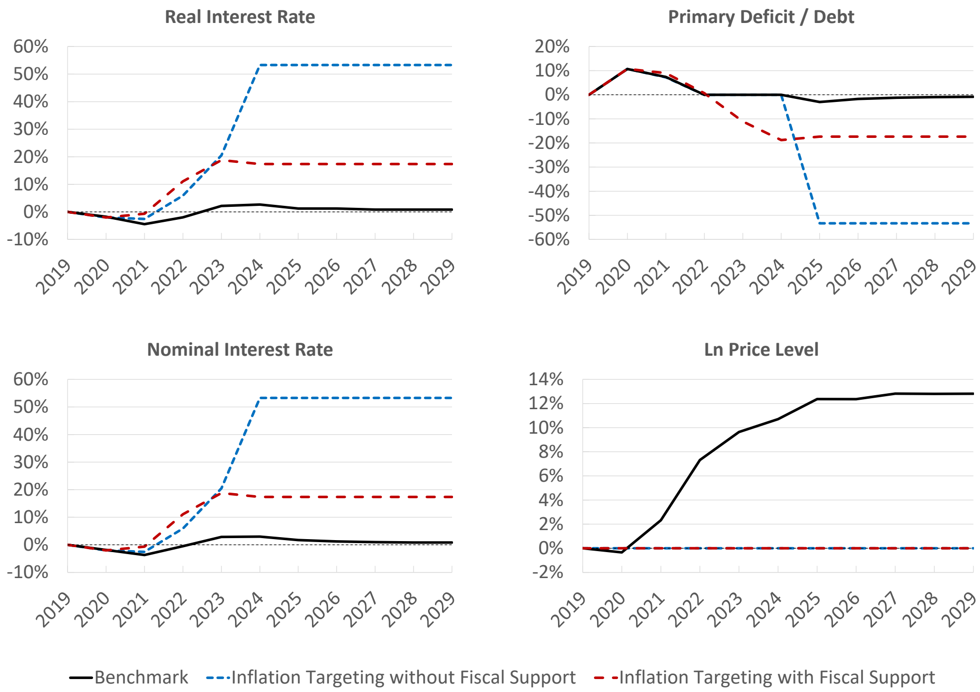
In the following experiment, we provide a counterfactual experiment in which monetary policy uses all of its power to keep inflation on target assuming the observed fiscal policy over 2020-24 and assuming full fiscal support for the inflation-targeting policy

[14]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.

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

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 the square-dotted blue lines in Figure 8.

Figure 8: Inflation Targeting conditional on Fiscal Support for 2020-24



As Figure 8 reveals, strict inflation targeting appears to be feasible for a central bank, but only for a limited period of time. In Figure 8, 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, maintaining inflation at target would require an ever-increasing real interest rate. Eventually, either fiscal policy provides support by taxing the interest expense or monetary policy abandons the inflation target, in which case the real interest rate would collapse back to zero and there would be a jump in the price level proportional to the accumulated increase in debt. The sharp and persistent increase in the real interest rate would have sent the economy into a sustained recession.[16]

Figure 8 also presents an alternative counterfactual scenario, the red dashed lines, in which the fiscal authority supports monetary policy by financing the entire expense of the debt with taxes, i.e., setting $\theta_t = 1$ throughout. The qualitative dynamics are similar as in the case when such fiscal support comes up in 2025, except that fiscal support materializes sooner. However, the quantitative effects can be significant. Now, the fiscal authority finances the budgetary impact of monetary policy and so, the required real interest rate that implements the inflation target has a significantly lower terminal point when compared to the previous counterfactual. The economy still suffers a permanent recession, albeit a milder one.

[16]In the model, this occurs through a contraction in capital investment. But in richer models and in reality, this would occur through a variety of other channels.

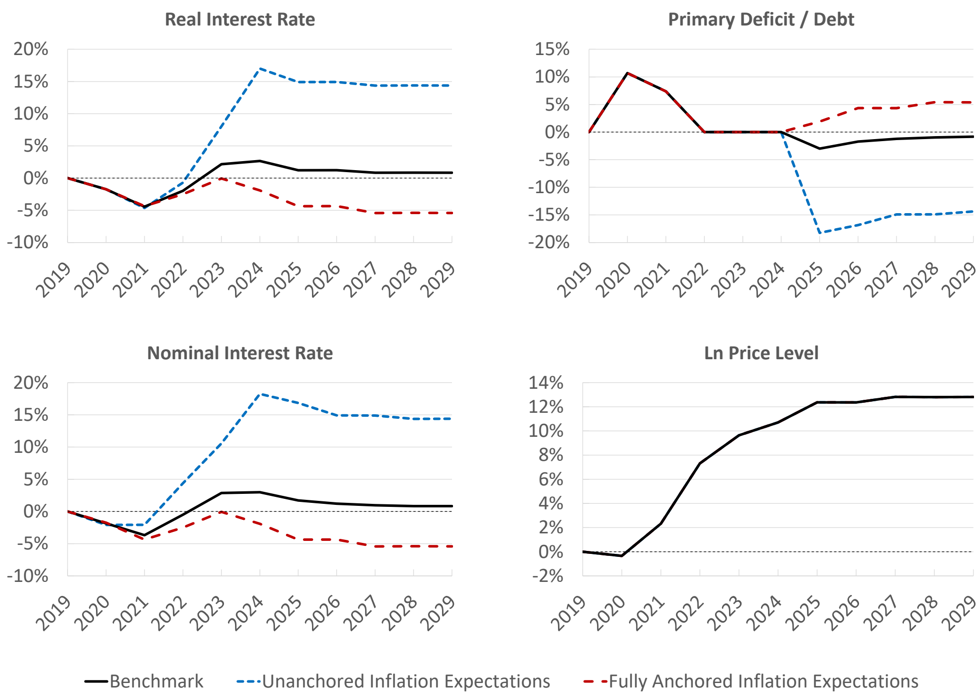
7.5 The role of anchored inflation expectations

Our benchmark calibration assumes some degree of anchoring in inflation expectations that rationalizes the fact that expectations rose far less than observed inflation. As mentioned above, an important part of the official narrative is that ensuring inflation expectations remained well-anchored was critical to achieving a "soft landing." We evaluate this assertion by varying the degree to which inflation expectations are anchored.

First, suppose inflation expectations are unanchored in the sense that $\phi = 0$. In this case, inflation expectations are equal to observed inflation. Second, suppose that inflation expectations are fully anchored in the sense that $\phi = 1$. In this case, inflation expectations are always equal to the target.

Figure 9 shows how monetary policy would have looked like if it was designed to achieve the same inflation dynamic as in the benchmark, when facing the observed fiscal policy but either without an anchor on inflation expectations or with fully anchored inflation expectations. As with the benchmark case, in both counterfactual exercises we assume full fiscal support, $\theta_t = 1$, from 2025 onward.

Figure 9: Anchored vs. Unanchored Inflation Expectations



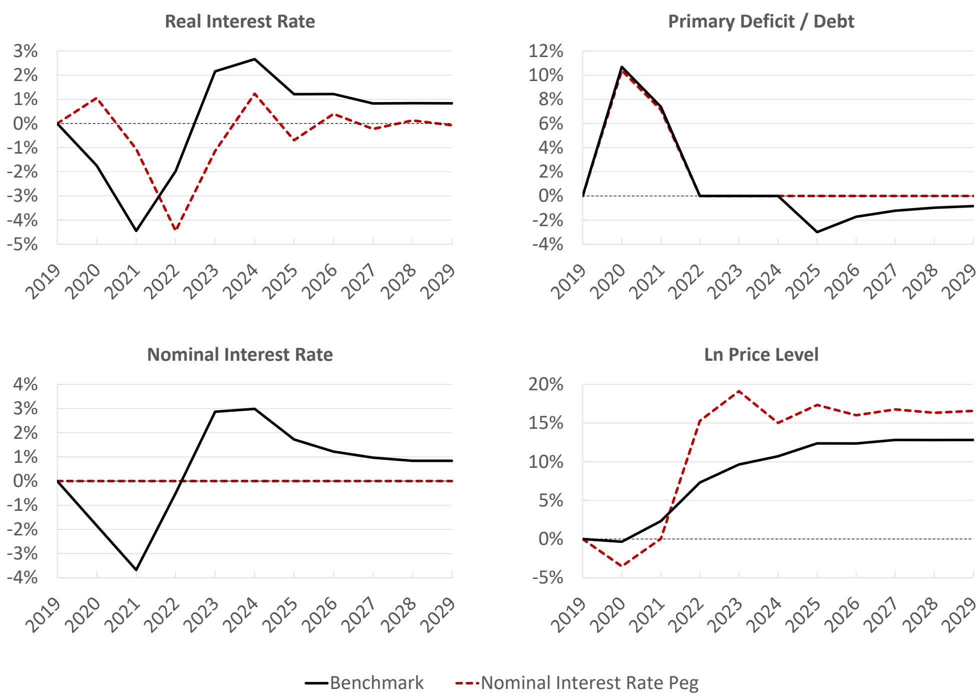
For the case with unanchored inflation expectations, Figure 9 shows that the real and nominal interest rates would have had to increase more than if inflation expectations had not been anchored. In addition, the lack of anchor also implies that the terminal real rate is higher as well, necessitating larger fiscal support and implying a higher adverse impact on economic activity. In contrast, if inflation expectations were fully anchored, then the real and nominal interest rates would have kept below the benchmark, though following a similar dynamic. In this case, lower interest rates have a benign effect on the primary deficit, as the expansion of the debt due to the interest expense is correspondingly smaller than in the benchmark. Overall, our model is compatible with the narrative that well-anchored inflation expectations were critical in achieving the disinflation at a low economic cost, for a given desired inflation path.

There are two important caveats to the narrative. First, the anchor is not critical for the return of actual inflation to the target; this is achieved via the appropriate fiscal support. Second, with unanchored inflation expectations, the Fed could have instead implemented the same real interest rate path (and thus, kept the economic impact the same) and let inflation rise higher than in the benchmark.

7.6 Transitory Inflation With a Nominal Interest Rate Peg

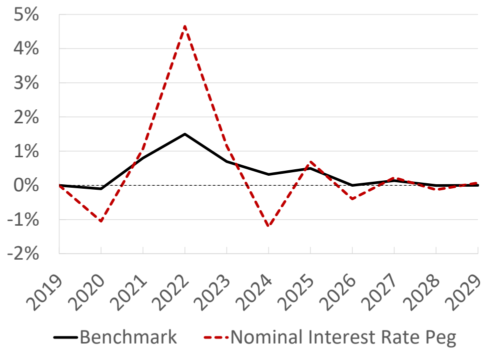
In his speech at Jackson Hole, Fed Governor Jerome Powell took credit for the rapid disinflation that occurred soon after inflation peaked in the summer of 2022 (Powell, 2024). To evaluate this claim, we compute the model dynamics assuming that the Fed keeps its policy rate at its 2019 level throughout the entire episode. The results are reported in Figure 10.

Figure 10: Nominal Interest Rate Peg



The bottom right panel of Figure 10 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 11 reports the dynamics of expected inflation under the two monetary policies considered here. Aggressive monetary policy did serve to

Figure 11: Expected Inflation Rate



smooth expectations of inflation, but was not necessary to anchor these expectations.

8 Conclusions

The COVID-19 pandemic generated highly uneven disruptions to household earnings and induced significant shifts in economic behavior, including a widespread increase in precautionary saving and deferred consumption. Our analysis suggests that the fiscal response in the U.S. functioned as an effective form of social insurance against these disruptions and was broadly welfare-improving relative to inaction, though likely excessive in scale. A similarly effective income-support program financed through temporary taxation could, in principle, have delivered comparable welfare gains while exerting less upward pressure on the price level.

Given the scale and financing of the fiscal response, our results imply that monetary policy had limited scope to materially alter the cumulative increase in the price level. While the Federal Reserve likely lowered its policy rate too aggressively and delayed subsequent tightening relative to historically estimated reaction functions, a more responsive interest rate path would primarily have shifted the timing of inflation rather than prevented it. Eliminating the inflation surge through monetary policy alone would have required a persistently rising real interest rate path, at the cost of a deep and prolonged recession and a materially weaker recovery. In this sense, the COVID-era price-level adjustment should be understood as largely outside the control of monetary policy acting in isolation.

At the same time, our analysis suggests that observed monetary policy actions played a meaningful role in shaping the inflation path and in supporting the anchoring of inflation expectations. While aggressive tightening was not strictly necessary to preserve credibility in this environment, it likely contributed to smoothing the transition back toward the long-run inflation objective.

These conclusions contrast with narratives that attribute the post-COVID inflation episode primarily to monetary policy mistakes. While our analysis is based on a stylized model, the qualitative insights are robust to a range of plausible extensions. The broader policy implication is that, in response to large exogenous shocks such as pandemics or wars, short-run inflation stabilization may need to be temporarily deprioritized by monetary policy, while fiscal policy must remain credibly anchored. Sustaining long-run price stability ultimately requires fiscal backing, and the effectiveness of monetary policy depends critically on the fiscal environment in which it operates.

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A Efficient allocation

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

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

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,

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

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 Proofs

Proof of Proposition 1.

Assume $\nu = 1$ and fix sequences for aggregate parameters $\{w_t(i), \sigma_t, \alpha_t\}$ and policy $\{r_t, \theta_t, z_t(i)\}$.

(i) Consider the equilibrium with perfect foresight from Definition 1. When $\nu = 1$, equation (33) is equivalent to (43), which is the relevant condition in the equilibrium under adaptive expectations from Definition 2. Hence, the sequences of decisions $\{c^y_t(i,j), q_t(i,j), k_t(i,j)\}$ are characterized by the same equations under perfect foresight and adaptive expectations. Similarly, $\{Q_t\}$ is determined by (26) in both cases and is thus the same under both assumptions for expectations.

(ii) The equation determining the nominal interest rate is either (32) or (42), depending on the assumption on expectations. Under perfect foresight, R_t depends on Π_{t+1}; under adaptive expectations, R_t depends on Π_t. Hence, if inflation Π_t follows a non-trivial path, the sequences of interest rates will differ. In turn, $\{R_t\}$ determines taxes and actual inflation, through conditions (30) and (31). Hence, they will generically differ as well.

(iii) Suppose $\theta_t = 1$. Then, (30) simplifies to

$$\Pi_t = \frac{Q_{t-1}}{Q_t - z_t}$$

Since $\{Q_t\}$ is the same under perfect foresight and adaptive expectations, the inflation sequence $\{\Pi_t\}$ is the same as well.

□

Proof of Proposition 2.

a. (i) Suppose $\lambda_t(i,j) = 0$. Then, (43) implies

$$f''(k_t(i,j))\frac{dk_t(i,j)}{dz_t(i)} = 0 \tag{B.1}$$

and so, $\frac{dk_t(i,j)}{dz_t(i)} = 0$. From (21) we obtain

$$(1-\alpha_t)u''(c^y_t(i,j))\frac{dc^y_t(i,j)}{dz_t(i)} = \beta_j f''(k_t(i,j))\frac{dk_t(i,j)}{dz_t(i)} \tag{B.2}$$

Combining (B.1) and (B.2) we get $\frac{c^y_t(i,j)}{dz_t(i)} = 0$. From (23) we obtain

$$\frac{dc^y_t(i,j)}{dz_t(i)} = -\left[\frac{dq_t(i,j)}{dz_t(i)} + \frac{dk_t(i,j)}{dz_t(i)}\right] + 1 \tag{B.3}$$

Given $\frac{c^y_t(i,j)}{dz_t(i)} = \frac{k_t(i,j)}{dz_t(i)} = 0$, (B.3) implies $\frac{dq_t(i,j)}{dr_t} = 1$.

(ii) Suppose $\lambda_t(i,j) > 0$. Then $q_t(i,j) = 0$ and so, $\frac{dq_t(i,j)}{dr_t} = 0$. Hence, (B.3) implies

$$\frac{dc^y_t(i,j)}{dz_t(i)} + \frac{dk_t(i,j)}{dz_t(i)} = 1 \tag{B.4}$$

and from (B.2) we obtain

$$[(1-\alpha_t)u''(c_t^y(i,j))+\beta_j f''(k_t(i,j))]\frac{dc_t^y(i,j)}{dz_t(i)}=\beta_j f''(k_t(i,j)) \tag{B.5}$$

Hence, $\frac{dc_t^y(i,j)}{dz_t(i)}>0$. Similarly, combining (B.4) and (B.5) implies

$$(1-\alpha_t)u''(c_t^y(i,j))=[\beta_j f''(k_t(i,j))+(1-\alpha_t)u''(c_t^y(i,j))]\frac{dk_t(i,j)}{dz_t(i)} \tag{B.6}$$

and so, $\frac{dk_t(i,j)}{dz_t(i)}>0$.

b. (i) Suppose $\lambda_t(i,j)=0$. Then, (43) implies

$$f''(k_t(i,j))\frac{dk_t(i,j)}{dr_t}=1 \tag{B.7}$$

and so, $\frac{dk_t(i,j)}{dr_t}=\frac{1}{f''(k_t(i,j))}<0$. From (21) we obtain

$$(1-\alpha_t)u''(c_t^y(i,j))\frac{dc_t^y(i,j)}{dr_t}=\beta_j f''(k_t(i,j))\frac{dk_t(i,j)}{dr_t} \tag{B.8}$$

Combining (B.7) and (B.8) we get $\frac{c_t^y(i,j)}{dr_t}=\frac{\beta_j}{(1-\alpha_t)u''(c_t^y(i,j))}<0$. From (23) we obtain

$$\frac{dc_t^y(i,j)}{dr_t}=-\left[\frac{dq_t(i,j)}{dr_t}+\frac{dk_t(i,j)}{dr_t}\right] \tag{B.9}$$

and hence, $\frac{dq_t(i,j)}{dr_t}=-\left[\frac{\beta_j}{(1-\alpha_t)u''(c_t^y(i,j))}+\frac{1}{f''(k_t(i,j))}\right]>0$.

(ii) Suppose $\lambda_t(i,j)>0$. Then $q_t(i,j)=0$ and so, $\frac{dq_t(i,j)}{dr_t}=0$. Hence, (B.9) implies

$$\frac{dc_t^y(i,j)}{dr_t}=-\frac{dk_t(i,j)}{dr_t} \tag{B.10}$$

and so (B.8) implies

$$(1-\alpha_t)u''(c_t^y(i,j))\frac{dc_t^y(i,j)}{dr_t}=-\beta_j f''(k_t(i,j))\frac{dc_t^y(i,j)}{dr_t} \tag{B.11}$$

which can only be satisfied if $\frac{dc_t^y(i,j)}{dr_t}=0$. Thus, $\frac{dc_t^y(i,j)}{dr_t}=\frac{dk_t(i,j)}{dr_t}=0$. $\square$

Proof of Proposition 3.

a. From (30) we obtain

$$\frac{d\Pi_t}{dz_t}=-\left(\frac{\Pi_t}{Q_t-z_t}\right)\left(\frac{dQ_t}{dz_t}-1\right) \tag{B.12}$$

From Proposition 2, $\frac{dq_t(i,j)}{dz_t(i)}=1$ if $\lambda_t(i,j)=0$. Hence, $\frac{dQ_t}{dz_t}=1$ and so, $\frac{d\Pi_t}{dz_t}=0$.

Updating (30) one period, imposing $z_{t+1} = 0$ and combining with (42) implies

$$\Pi_{t+1} = \frac{Q_t[1 + (1 - \theta_{t+1})(r_t \Pi_t^{1-\phi} - 1)]}{Q_{t+1}} \tag{B.13}$$

The impact of a one-time increase in transfers has no impact on Q_{t+1}. Then, given $\frac{dQ_t}{dz_t} = 1$ and $\frac{d\Pi_t}{dz_t} = 0$ we obtain

$$\frac{d\Pi_{t+1}}{dz_t} = \frac{1 + (1 - \theta_{t+1})(r_t \Pi_t^{1-\phi} - 1)}{Q_{t+1}} \tag{B.14}$$

and so, $\frac{d\Pi_{t+1}}{dz_t} > 0$.

b. From (30) we obtain

$$\frac{d\Pi_t}{dr_t} = -\frac{\Pi_t}{Q_t}\frac{dQ_t}{dr_t} \tag{B.15}$$

From Proposition 2, $\frac{dq_t(i,j)}{dr_t} > 0$ if $\lambda_t(i,j) = 0$. Hence, $\frac{dQ_t}{dr_t} > 0$ and so, $\frac{d\Pi_t}{dr_t} < 0$.

The impact of a one-time increase in r_t has no impact on Q_{t+1}. Then, from (B.13) and (B.15) we obtain

$$\frac{d\Pi_{t+1}}{dr_t} = \frac{1}{Q_{t+1}}\left\{\left[\theta_{t+1} + (1 - \theta_{t+1})\phi r_t \Pi_t^{1-\phi}\right]\frac{dQ_t}{dr_t} + Q_t(1 - \theta_{t+1})\Pi_t^{1-\phi}\right\} \tag{B.16}$$

Given $\frac{dQ_t}{dr_t} > 0$, (B.16) implies that $\frac{d\Pi_{t+1}}{dr_t} > 0$. □

Proof of Proposition 4.

a. (i) Suppose $\lambda_t(i,j) = 0$. Then, (43) implies

$$f''(k_t(i,j))\frac{dk_t(i,j)}{d\alpha_t} = 0 \tag{B.17}$$

and so, $\frac{dk_t(i,j)}{d\alpha_t} = 0$. Given this result, from (21) we obtain

$$(1 - \alpha_t)u''(c_t^y(i,j))\frac{dc_t^y(i,j)}{d\alpha_t} = u'(c_t^y(i,j)) \tag{B.18}$$

Hence, $\frac{dc_t^y(i,j)}{d\alpha_t} = \frac{u'(c_t^y(i,j))}{(1-\alpha_t)u''(c_t^y(i,j))} < 0$. From (23) we obtain

$$\frac{dc_t^y(i,j)}{d\alpha_t} = -\frac{dq_t(i,j)}{d\alpha_t} \tag{B.19}$$

and so, $\frac{dq_t(i,j)}{d\alpha_t} > 0$.

(ii) Suppose $\lambda_t(i,j) > 0$. Then $q_t(i,j) = 0$ and so, $\frac{dq_t(i,j)}{d\alpha_t} = 0$. From (21) we obtain

$$(1 - \alpha_t)u''(c_t^y(i,j))\frac{dc_t^y(i,j)}{d\alpha_t} - u'(c_t^y(i,j)) = \beta_j f''(k_t(i,j)\frac{dk_t(i,j)}{d\alpha_t} \tag{B.20}$$

and, given $\frac{dq_t(i,j)}{d\alpha_t} = 0$, (23) implies

$$\frac{dc_t^y(i,j)}{d\alpha_t} = -\frac{dk_t(i,j)}{d\alpha_t} \tag{B.21}$$

Combining (B.20) and (B.21) implies

$$[(1-\alpha_t)u''(c_t^y(i,j)) + \beta_j f''(k_t(i,j)]\frac{dc_t^y(i,j)}{d\alpha_t} = u'(c_t^y(i,j)) \tag{B.22}$$

and so, $\frac{dc_t^y(i,j)}{d\alpha_t} < 0$ and $\frac{dk_t(i,j)}{d\alpha_t} > 0$.

b. (i) Suppose $\lambda_t(i,j) = 0$. Then, (43) implies

$$f''(k_t(i,j))\frac{dk_t(i,j)}{dw_t(i)} = 0 \tag{B.23}$$

and so, $\frac{dk_t(i,j)}{dw_t(i)} = 0$. Given this result, from (21) we obtain

$$(1-\alpha_t)u''(c_t^y(i,j))\frac{dc_t^y(i,j)}{dw_t(i)} = 0 \tag{B.24}$$

Hence, $\frac{dc_t^y(i,j)}{dw_t(i)} = 0$. Then, (23) implies $\frac{dq_t(i,j)}{d\alpha_t} = 1$.

(ii) Suppose $\lambda_t(i,j) > 0$. Then $q_t(i,j) = 0$ and so, $\frac{dq_t(i,j)}{d\alpha_t} = 0$. From (21) we obtain

$$(1-\alpha_t)u''(c_t^y(i,j))\frac{dc_t^y(i,j)}{dw_t(i)} = \beta_j f''(k_t(i,j)\frac{dk_t(i,j)}{dw_t(i)} \tag{B.25}$$

and, given $\frac{dq_t(i,j)}{d\alpha_t} = 0$, (23) implies

$$\frac{dc_t^y(i,j)}{dw_t(i)} = 1 - \frac{dk_t(i,j)}{dw_t(i)} \tag{B.26}$$

Combining (B.25) and (B.26) implies

$$[(1-\alpha_t)u''(c_t^y(i,j)) + \beta_j f''(k_t(i,j)]\frac{dc_t^y(i,j)}{d\alpha_t} = \beta_j f''(k_t(i,j) \tag{B.27}$$

and so, $\frac{dc_t^y(i,j)}{d\alpha_t} > 0$. Similarly,

$$(1-\alpha_t)u''(c_t^y(i,j)) = [(1-\alpha_t)u''(c_t^y(i,j)) + \beta_j f''(k_t(i,j)]\frac{dk_t(i,j)}{d\alpha_t} \tag{B.28}$$

and so, $\frac{dk_t(i,j)}{d\alpha_t} > 0$. $\square$

Proof of Proposition 5.

a. From (30) we obtain

$$\frac{d\Pi_t}{d\alpha_t} = -\frac{\Pi_t}{Q_t}\frac{dQ_t}{d\alpha_t} \tag{B.29}$$

From Proposition 4, $\frac{dq_t(i,j)}{d\alpha_t} > 0$ if $\lambda_t(i,j) = 0$. Hence, $\frac{dQ_t}{d\alpha_t} > 0$ and so, $\frac{d\Pi_t}{d\alpha_t} < 0$.

From (B.13) and (B.29) we obtain

$$\frac{d\Pi_{t+1}}{d\alpha_t} = \frac{1}{Q_{t+1}}\left[\theta_{t+1} + (1-\theta_{t+1})\phi r_t \Pi_t^{1-\phi}\right]\frac{dQ_t}{d\alpha_t} \tag{B.30}$$

Given $\frac{dQ_t}{d\alpha_t} > 0$, $\frac{d\Pi_{t+1}}{d\alpha_t} > 0$.

b. From (30) we obtain

$$\frac{d\Pi_t}{dw_t} = -\frac{\Pi_t}{Q_t}\frac{dQ_t}{dw_t} \tag{B.31}$$

From Proposition 4 we have $\frac{dq(i,j)}{dw(i)} = 1$ when $\lambda(i,j) = 0$. Hence, $\frac{dQ_t}{dw_t} > 0$ and so, $\frac{d\Pi_t}{dw_t} < 0$.

From (B.13) and (B.31) we obtain

$$\frac{d\Pi_{t+1}}{d\alpha_t} = \frac{1}{Q_{t+1}}\left[\theta_{t+1} + (1-\theta_{t+1})\phi r_t \Pi_t^{1-\phi}\right]\frac{dQ_t}{dw_t} \tag{B.32}$$

Given $\frac{dQ_t}{dw_t} > 0$, $\frac{d\Pi_{t+1}}{dw_t} > 0$.

c. From (26),

$$\frac{dQ_t}{d\sigma_t} = \rho[q_t(l,L) - q_t(h,L)] \tag{B.33}$$

From Proposition 4 we have $\frac{dq(i,j)}{dw(i)} = 1$. Hence, given $w(l) < w(h)$ we get $q_t(l,L) < q_t(h,L)$. Therefore, if $q_t(h,L) > 0$ then (B.33) implies $\frac{dQ_t}{d\sigma_t} < 0$.

From (30) and (B.33) we obtain

$$\frac{d\Pi_t}{d\sigma_t} = -\frac{\Pi_t \rho[q_t(l,L) - q_t(h,L)]}{Q_t} \tag{B.34}$$

which implies $\frac{d\Pi_t}{d\sigma_t} > 0$.

From (B.13), (B.33) and (B.34) we obtain

$$\frac{d\Pi_{t+1}}{d\sigma_t} = \frac{\rho[q_t(l,L) - q_t(h,L)]}{Q_{t+1}}\left[\theta_{t+1} + (1-\theta_{t+1})\phi r_t \Pi_t^{1-\phi}\right] \tag{B.35}$$

and so, $\frac{d\Pi_{t+1}}{d\sigma_t} < 0$.

d. Suppose $q_t(l,L) = q_t(h,L) = 0$. A change in the measure of low- vs. high-earning impatient young households keeps the overall demand for real balances the same and hence, has no impact on inflation. □

C Robustness to Rational Expectations

The baseline analysis assumes adaptive expectations, a parsimonious device that captures gradual belief updating and delivers tractable transition dynamics. A natural question is whether our main results hinge on this assumption.

To address this, we reconsider the model under rational expectations. Specifically, we solve the deterministic perfect-foresight equilibrium defined in Section 4.5 and calculate the impulse-response dynamics when the model economy is subjected to an unexpected shock. Agents are assumed to form expectations consistent with the model's equilibrium law of motion, and transitions are computed under perfect foresight following unexpected one-period shocks. This alternative specification replaces the backward-looking updating rule with a forward-looking equilibrium condition, allowing expectations to adjust immediately to new information. Two points are worth emphasizing at the outset.

First, under full fiscal support ($\theta_t = 1$), the long-run price level is pinned down by fiscal fundamentals and is therefore invariant to the expectations formation mechanism. In particular, for one-off transfer shocks, the cumulative price-level effect is identical under adaptive and rational expectations. Any differences that arise reflect only the timing of adjustment, not its magnitude.

Second, as shown in Proposition 1, the knife-edge case $\nu = 1$ in the monetary policy rule (14) provides a useful benchmark. In this case, realized inflation dynamics are identical across the two expectation regimes, and differences appear only in expected inflation and the nominal interest rate. Departures from $\nu = 1$ introduce forward-looking feedback through expected inflation, amplifying or dampening the initial response depending on whether $\nu < 1$ or $\nu > 1$.

Taken together, the results below show that the central qualitative findings of the paper are robust to the expectations specification. Rational expectations alter the timing and, in some cases, the front-loading of inflation and interest rate responses, but leave the underlying fiscal determination of the price level unchanged. Partial fiscal support of interest payments, $\theta_t < 1$, opens the door for an endogenous mechanism through which assumptions on expectations alter the ultimate quantitative impact of policy changes and aggregate shocks on the price level. The key is how the monetary policy response alters debt accumulation through different assumptions on inflation expectations.

C.1 The impact of a one-time-transfer

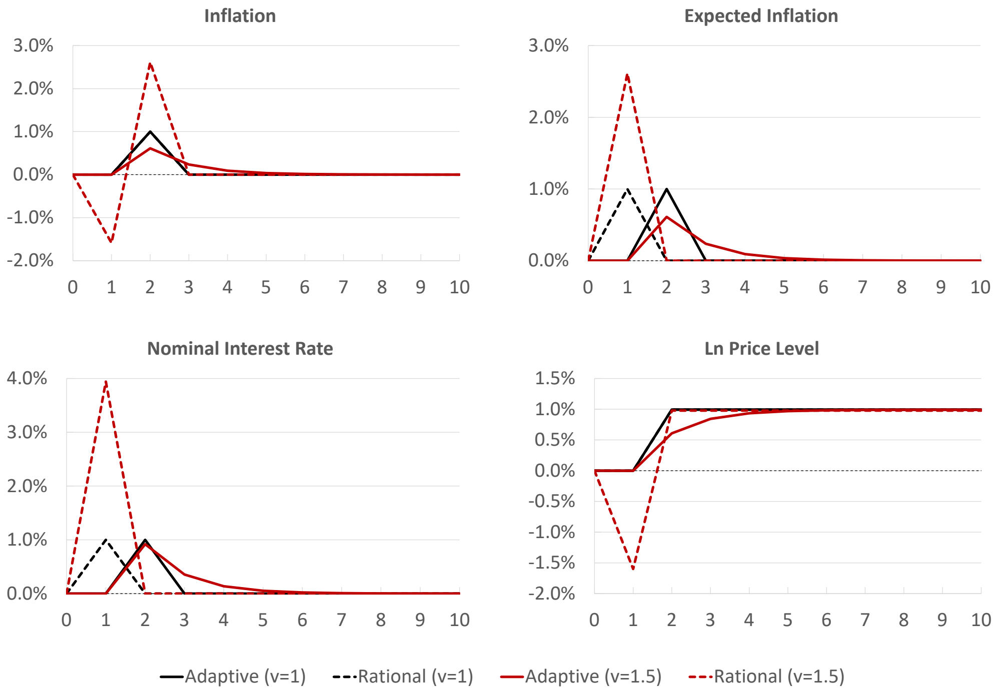
In Figure 12, we plot the response of inflation, expected inflation, the nominal interest rate and the price-level following a one-time but permanent transfer. For a one-off transfer shock to z_t with $\theta_t = 1$ and $\nu = 1$, the impact on inflation at $t = 1$ is zero because the transfer is absorbed by real balances on impact. We therefore normalize the experiment by calibrating the one-off transfer size so that the first nonzero inflation response in the $\nu = 1$ case is exactly 1 percentage point. The same transfer size is then used for $\nu = 1.5$. All other parameters are set to their calibrated values, as presented in Table 1.

The long-run price level is normalized to the same nonzero terminal value across all experiments, consistent with the theoretical implication that changing ν affects the timing of inflation, expected inflation and the nominal interest rate, but not the cumulative price-level effect of a one-off transfer.

As shown in Figure 12, when $\nu = 1$, inflation dynamics are the same under rational and adaptive expectations, consistent with Proposition 1. Expected inflation and the nominal interest rate move once and by the same amount, but the timing is different. Under rational expectations, both variables increase on impact, while under adaptive expectations, they increase after one period.

Making monetary policy more responsive to expected inflation, i.e., increasing ν, has different effects depending on how expectations are formed. Under adaptive expectations, $\nu > 1$ adds persistence to the hike in the nominal rate. As a result, the increase in the price level is more gradual. Under rational expectations, $\nu > 1$ increases the

Figure 12: Impact of a one-time transfer with full fiscal support



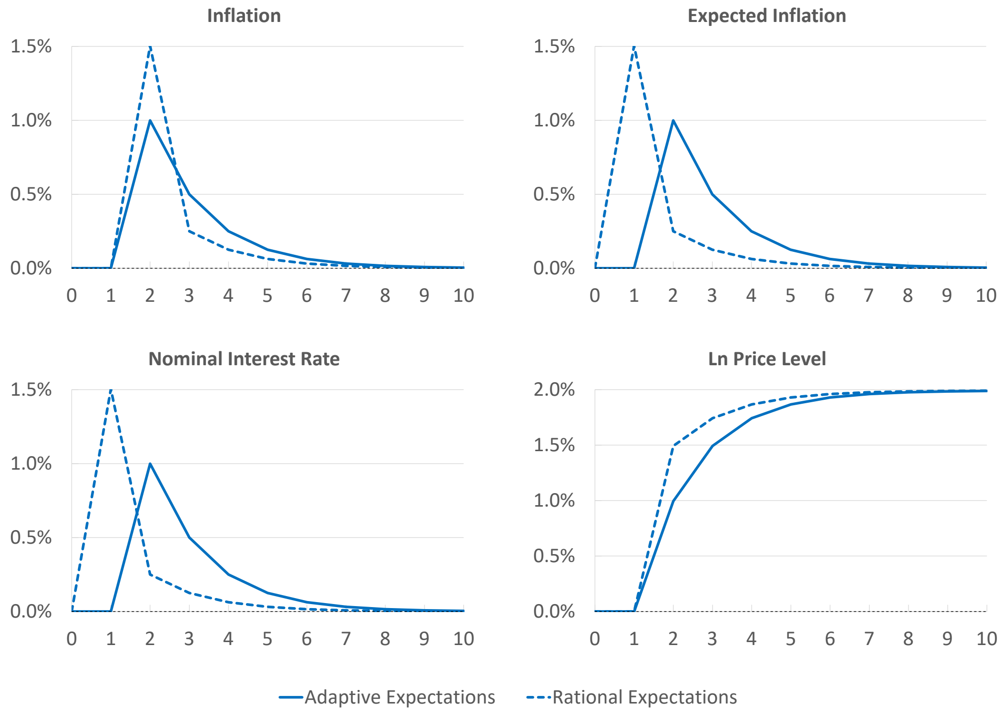
magnitude instead of the persistence of the nominal interest hike. This reaction has a deflationary effect on impact, followed by one period of high inflation. Eventually, the price converges to the same level in all cases, 1% above the pre-shock level.

Figure 13 considers the same one-time transfer shock, but for the case with partial fiscal support. In particular, we assume $\theta_t = 0.5$ and $\nu = 1$ throughout. Partial fiscal support adds persistence to the shock as now debt evolves endogenously beyond the shock period due to the higher debt-financing costs, which now get partially rolled over with new debt. Note that the price now converges to a level 2% higher than the pre-shock period, under both expectation assumptions. The initial rate hike is larger under rational expectations, while it is more muted but persistent under adaptive expectations, leading to a more gradual rise in prices under the latter assumption. Finally, note that under adaptive expectations the initial movement in variables is the same under full or partial fiscal support; the differences appear in subsequent periods due to the additional debt being issued. This is not the case with rational expectations, where the debt increase is anticipated and hence, the moentary policy reaction is front-loaded.

Combining partial fiscal support, $\theta_t < 1$, with a more responsive monetary policy, $\nu > 1$, would make the terminal impact on prices vary by expectations assumptions. For adaptive expectations the combination would compound and increase the persistence of the monetary policy response. Under rational expectations, the combination would increase the initial interest rate hike. In both cases, the final impact of prices is larger than when only having partial fiscal support or a more responsive monetary policy.

Next, we shall look at the impact of shocks to the real rate, r_t, and aggregate parameters α_t and $w_t(i)$. Since inflation dynamics are the same when $\theta_t = 1$ we focus on the case with partial fiscal support. In addition, we maintain the benchmark assumption on monetary policy responsiveness, $\nu = 1$. In all cases, shocks are calibrated so that the

Figure 13: Impact of a one-time transfer with partial fiscal support



initial response on inflation under adaptive expectations and full fiscal support is 1%.

C.2 The impact of a one-time real rate hike

Figure 14 shows the impact of a one-time change in the monetary policy parameter or real rate, r_t. The real rate is hiked for one period and then lowered back to its pre-shock value. Again, with full fiscal support inflation dynamics would be the same under rational and adaptive expectations. Hence, we show the case with partial fiscal support, $\theta_t < 1$. In contrast to the one-time transfer, a one-time increase in the real rate has a different impact on the total increase of the price level, depending on our assumption on expectations. As in previous cases, the response under rational expectations is front-loaded, while it is more muted but persistent under adaptive expectations. The overall effect in this example is that prices ultimately rise more under rational expectations.

C.3 The impact of aggregate shocks

We conclude with the case of a one-time aggregate shock. Since we calibrate the shock to have the same impact on inflation (under adaptive expectations and with full fiscal support), the dynamics are the same whether we are considering a shock to patience, α_t, or earnings, $w_t(i)$. Figure 15 shows the case with a one-time patience shock, a on-period increase in α_t that then returns to its steady state level in the following period. Qualitatively, the dynamics of the main variables are similar to the case of an real interest rate hike. Quantitatively, the impact is smaller. Under adaptive expectations, the temporary increase in patience has no permanent effect on the price level (the same occurs for a one-time shock to earnings). In contrast, the front-loading of the monetary policy response under rational expectations results in additional debt accumulation and hence, a permanent increase in the price level.

Figure 14: Impact of a one-time real rate hike with partial fiscal support

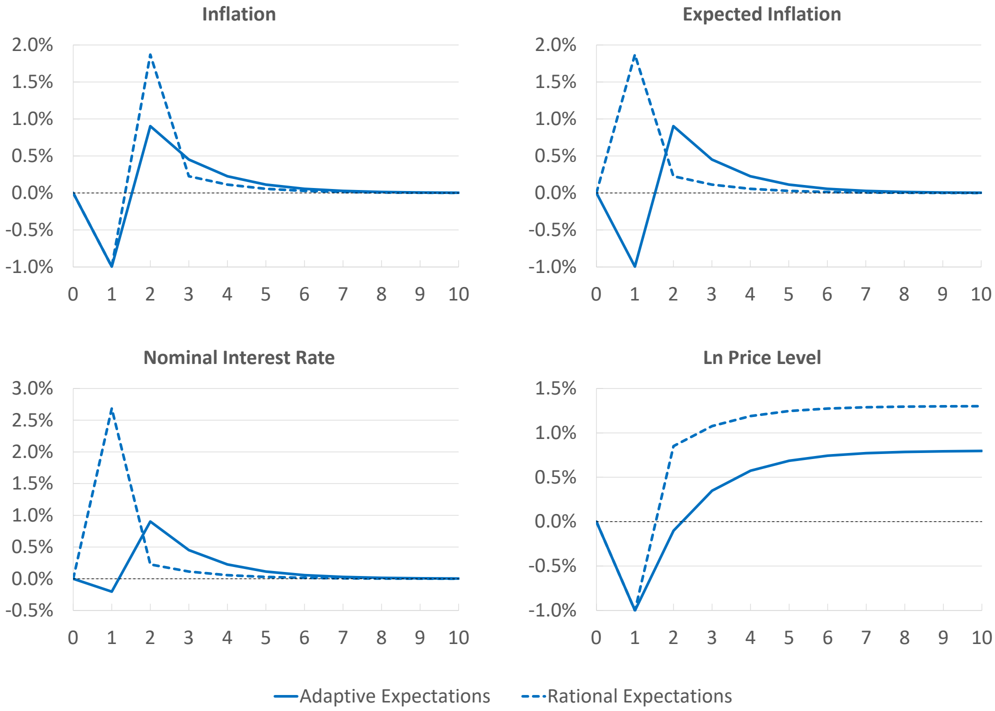


Figure 15: Impact of a one-time increase in patience with partial fiscal support