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The Recent Rise in US Inflation: Policy Lessons from the Quantity Theory

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On the Mechanics of Fiscal Inflations*

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Abstract

The goal of this paper is twofold. First, we wish to better explain the relationship between Sargent and Wallace's (1981) unpleasant monetarist arithmetic, the closely connected fiscal theory of the price level (FTPL), and the monetarist view of inflation. Second, we discuss how the recent inflationary episode has contributed to redistributing real resources from holders of government debt to the public purse. In particular, financial prices before the onset of the COVID pandemic suggest that investors viewed an inflationary shock such as the one we experienced as extremely unlikely, so the magnitude of this redistribution caught them by surprise.

Friedman famously said that inflation is always and everywhere a monetary phenomenon. Lucas (1980) showed that, over long horizons, there is a tight connection between the growth rate of money and inflation. This evidence has been revisited many times, including by Gao and Nicolini (2024) in this issue, and this relationship is one of the least controversial in economics. Yet this explanation raises the question whether a common cause may lead to both money and prices growing. In an earlier issue of *Quarterly Review*, Sargent and Wallace (1981) emphasized the role of fiscal deficits in creating inflation. Sargent (1983a, 1983b) analyzed many historical episodes and turned Milton Friedman's dictum on its head by arguing that "persistent high inflation is always and everywhere a fiscal phenomenon." (Sargent 2013, p. 238).

A wide literature has since then argued that fiscal policy stance is instrumental in accounting for the behavior of inflation. Some examples include Chung, Davig, and Leeper (2007), Bianchi and Melosi (2014, 2019), and Cochrane (2022, 2023).[1] In particular, the FTPL has suggested that money is secondary and that the determination of the price level is better understood from looking at the present-value budget balance relation between the obligations of the government and its future primary surpluses. This literature, which

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traces back its roots to Leeper (1991), Sims (1994), and Woodford (1994), has often been perceived as "different" from the original unpleasant monetarist arithmetic. Our first goal is to explicitly reconcile monetarism, unpleasant monetarist arithmetic, and the FTPL, and show how the three work together in a fiscal inflation. In such an event, while money growth remains the proximate cause of inflation, the ultimate cause is the connection between nominal government bonds and money itself. Nominal bonds are claims to money, and governments all over the world have turned to the printing press in wars and other times of fiscal distress to repay them when primary surpluses are insufficient to get the money required to make good on the claims otherwise. When fiscal stress is caused by unexpected events, the FTPL provides a useful guideline of the way in which prices will be impacted (through money creation).

In the second part of our paper, we turn to the experience of the pandemic. Hall and Sargent (2022, 2023) and Barro and Bianchi (2023) argue for a fiscal view of the inflation that emerged in the aftermath of the pandemic. We do not take a stance on the ultimate cause of this inflation. Whether by design or by accident, the inflation over the last three years has engendered a large transfer of resources from the bondholders to the government (and ultimately the taxpayers), and our goal is to point out how unexpected this event was. Hilscher, Raviv, and Reis (2021) use data from inflation options to infer market expectations and estimate that, as of 2017, the probability of inflationary paths that would devalue debt by more than 4% of GDP was perceived to be about 0.3%.[2] We take conservative assumptions about the magnitude of the dilution of debt that took place between 2021 and 2023, and show that in just three years the magnitude would easily match 4%. The market for options dried up since 2017, so to get more recent estimates of inflation expectations based on interest rates, we turn to the model of Ajello, Benzoni, and Chyruk (2020) and estimate the expected distribution of inflation over the next three years as of December 2020. Results are even starker: more than three-quarters of the dilution that took place was beyond what the distribution of inflation would expect to be a 5% event (that is, an event that should take place every 60 years).

1 Money Printing in the FTPL

We start from a simple, stylized model to illustrate how fiscal constraints may lead to money growth and inflation. This model is fully described in Bassetto and Sargent (2020). This model abstracts from the short-run frictions that cause money demand to be unstable at high frequencies and that drive the cyclical component of monetary policy, and it concentrates attention on the long-run connection between fiscal and monetary policy.

The economy is populated by a continuum of identical households and a fiscal/monetary authority (the "government") interacting over an infinite horizon $t = 0, 1, 2, \ldots$.

At the beginning of a period, each household sends one buyer and one seller to distinct decentralized markets where sellers can use their labor to produce a single consumption good and buyers can purchase that consumption good. Agents are anonymous in decentralized markets so that trade requires a storable medium of exchange. We assume that this is money issued by the government. Money is also the unit of account, and we will refer to it as "dollars." After decentralized markets close, a single centralized market opens in which all household members can trade a second nonstorable good and labor for money and interest-bearing assets. All markets are competitive, as in the cash-in-advance model of Lucas and Stokey (1987). Accordingly, we refer to the consumption good exchanged in decentralized markets as the "cash good." In the centralized market, households also trade with the government and pay (lump-sum) taxes, while the government acquires resources to cover its needs for public spending G_t.

Household preferences are given by

$$E_0 \sum_{t=0}^{\infty} \beta^t [u(c_t) + v(x_t) - \ell_t], \tag{1}$$

where c_t is consumption of the "credit good," which is traded in the centralized market, x_t is consumption of the "cash good," which is traded in the decentralized market, and ℓ_t is the sum of labor supplied in both markets. We assume that u and v are strictly increasing, concave, and continuously differentiable. Lastly, E_0 denotes a mathematical expectation conditioned on time 0 information.

The spending needs of the government are a constant $\bar{G}$ in all periods, except period S. In period S, the governments needs to spend $G_S = \bar{G} + \hat{G}$, where $\hat{G}$ is the only source of uncertainty in the economy. Agents receive no advance news about $\hat{G}$, with $E_t\hat{G} = 0$ in all periods up to $S - 1$.[3] Asset markets are dynamically complete. In any period $t \neq S$, households can buy or sell a nominal one-period bond that pays B_{t+1} dollars in period $t + 1$. In period $S-1$, state-contingent securities paying $B_S(\hat{G})$ are available. All one-period assets are in zero net supply. In addition, the government issues long-term debt, whose repayment schedule decays at an exogenous rate δ.[4] We denote by D^g_{t-1} the number of government bonds outstanding at the beginning of period t, which promise a payment $D^g_t \delta^{s-t}$ in period s.

The budget constraint of the households in period t is given by

$$B_t + P_t\ell_t + D_{t-1}\left(1 + \delta Q_t\right) + M_{t-1} \geq M_t + P_t(c_t + x_t) + E_t[z_{t+1}B_{t+1}] + D_tQ_t + T_t, \tag{2}$$

where P_t is the price level of goods in terms of dollars, D_{t-1} and M_{t-1} are the household holdings of long-term debt and money at the beginning of period t, Q_t is the ex-coupon price of long-term bonds, z_{t+1} is the one-period stochastic discount factor,[5] and T_t represents nominal taxes payable to the government in money in period t. In equation (2), no uncertainty is resolved between t and $t+1$ except when $t = S-1$, so in all other periods the expectation operator is redundant. In all periods $t \neq S$, z_{t+1} is simply the inverse of the (gross) nominal interest rate R_t: $R_t = 1/z_{t+1}$. In period $S - 1$, the relationship between R_{S-1} and z_S is given by $R_S = 1/E_{S-1}(z_S)$.

The cash-in-advance constraint requires the shopper in the family to purchase the cash good using only the money that is available at the beginning of the period:

$$M_{t-1} \geq P_t x_t. \tag{3}$$

Households are subject to a no-Ponzi condition that prevents them from rolling over their debts indefinitely:

$$\lim_{s\to\infty} q_{s+1}\left(B_{s+1} + M_s + \delta(1 + Q_{s+1})D_s\right) \geq 0, \tag{4}$$

where q_s is the cumulated stochastic discount factor between period 0 and period s:

$$q_0 = 1, \tag{5}$$

$$q_s = \prod_{t=1}^{s} z_t, \quad s > 0. \tag{6}$$

The government budget evolves according to the equation

$$D^g_{t-1}(\delta + Q_t) + M^g_{t-1} = M^g_t + D^g_t Q_t + T_t, \tag{7}$$

where M^g_t is the supply of money by the government.

The first-order conditions for the household optimization imply that the following equations must hold in an equilibrium:

$$u'(c_t) = 1, \tag{8}$$

$$z_{t+1} = \beta \frac{P_t}{P_{t+1}}, \tag{9}$$

$$1 = \beta E_t \left[\frac{P_t}{P_{t+1}} v'(x_{t+1}) \right], \tag{10}$$

$$Q_t = \beta P_t \sum_{s=0}^{\infty} \frac{(\beta\delta)^s}{P_{t+s+1}}. \tag{11}$$

In addition, the budget constraint (2) and the cash-in-advance constraint (3) must hold, and the no-Ponzi condition (4) must hold as an equality. Finally, market clearing requires $B_{t+1} = 0$, $M^g_t = M_t$, $D^g_t = D_t$, and $c + t + x_t + G_t = \ell_t$.

Summing the household budget constraint forward and substituting market clearing and household optimality conditions, we obtain

$$D_{t-1}\left[\frac{\delta}{P_t} + \beta \sum_{s=0}^{\infty} \frac{(\beta\delta)^s}{P_{t+s+1}}\right] + \frac{M_{t-1}}{P_t} = E_t \sum_{s=t}^{\infty} \beta^{s-t} \left[\frac{T_s}{P_s} - G_s + \frac{M_s}{P_s}\left(1 - \frac{1}{R_s}\right)\right]. \tag{12}$$

At any time t, this equation shows that the initial real value of government liabilities (central bank money and treasury bonds) is matched by the present value of taxes minus spending, plus the present value of "seigniorage," the benefit that the government accrues when households hold money rather than bonds and forgo the interest associated with bonds.

We consider the following experiment. We assume that, if the realization of the shock $\hat{G} = 0$, then the economy is in a steady state in which $R_t = \bar{R}$, $T_t = \bar{T} P_t$, inflation $\pi_{t+1} := P_{t+1}/P_t = \bar{\pi}$, real money balances are $M_t/P_t = \bar{m}$, and real government debt is $D_t/P_t = \bar{d}$. Equation (11) implies $Q_t = \bar{Q} := \beta/(\bar{\pi} - \beta\delta)$.

In order for the government budget balance condition (12) to hold, the steady state must be such that

$$\frac{\bar{d}}{\bar{\pi}}\left[\delta + \frac{\beta}{\bar{\pi} - \beta\delta}\right] + \frac{\bar{m}}{\bar{\pi}} = \frac{1}{1-\beta}\left[\bar{T} - \bar{G} + \bar{m}\left(1 - \frac{1}{\bar{R}}\right)\right]. \tag{13}$$

Taxes and seigniorage in steady state must match spending and the cost of servicing the debt. The economy follows this steady state up to period $S-1$.

We then consider what possible equilibria are if the treasury is unable or unwilling to respond to the spending shock $\hat{G}$ by altering the path of taxes. This implies that real taxes remain constant at $\bar{T}$ even though spending in period S is not equal to $\bar{G}$. A similar conclusion applies if some adjustment of future taxes does take place but is insufficient to fully pay for the shock. We rewrite the budget balance equation for period S, with the following substitutions:

- $T_s = \bar{T} P_s$ in all future periods, and $G_s = \bar{G}$ in all future periods except $G_S = \bar{G} + \hat{G}$;
- the values of D_{S-1}/P_{S-1} and M_{S-1}/P_{S-1} are inherited from the past and are thus equal to their former steady-state values $\bar{d}$ and $\bar{m}$;
- with no further uncertainty, from equations (3), (9), and (10), we conclude that real money balances and the nominal interest rate are simple functions of future inflation; that is,
$$\frac{M_s}{P_s}\left(1-\frac{1}{R_s}\right) = v'^{-1}\left(\frac{\pi_{s+1}}{\beta}\right)\left(1-\frac{\pi_{s+1}}{\beta}\right).$$
We define the quantity above $L(\pi_{t+1})$ as in Bassetto and Sargent (2020).

We then obtain

$$\frac{\bar{d}}{P_{S-1}}\left(\frac{\delta}{P_S} + \beta \sum_{s=0}^{\infty} \frac{(\beta\delta)^s}{P_{S+s+1}}\right) + \bar{m}\frac{P_{S-1}}{P_S} = \frac{1}{1-\beta}\left[\bar{T} - \bar{G}\right] + \hat{G} + \sum_{s=S}^{\infty} \beta^{s-S} L(\pi_{s+1}). \tag{14}$$

Equation (14) shows that either the current or the future price levels must adjust to restore balance. We consider two different options that lie at opposite ends of the spectrum in some sense and the implications of those options for monetary policy. Many other possibilities arise for the timing of inflation movements, and similar conclusions would apply to those possibilities as well. Consider first the case in which an unexpectedly high $\hat{G}$ is accompanied by a one-time jump in inflation in period S, to $\psi\bar{\pi}$, with inflation returning to $\bar{\pi}$ from period $S+1$ onwards.[6] Since future inflation is unchanged, the same is true of the interest rate by equation (9), so that we have $R_t = \bar{R}$ in all periods. As a consequence, the demand for real balances M_s/P_s is unchanged at $\bar{m}$.[7] In this case, all current and future price levels are adjusted by the same factor ψ relative to the case in which $\hat{G} = 0$. When monetary policy responds this way, equation (14) becomes

$$\frac{1}{\psi\bar{\pi}}\left[\bar{d}\left(\frac{\delta}{\psi\bar{\pi}} + \frac{\beta}{\bar{\pi}-\beta\delta}\right) + \bar{m}\right] = \frac{1}{1-\beta}\left[\bar{T} - \bar{G} + \bar{m}\left(1-\frac{1}{\bar{R}}\right)\right] + \hat{G}. \tag{15}$$

This policy depreciates both long-term debt and existing money by the same amount. In order for real balances to remain at $\bar{m}$, it must be that the money supply increases by exactly the same factor as prices. The quantity theory of money is thus alive and well: inflation is a monetary phenomenon, as Friedman asserted. What is different is that the *underlying cause* for money growth is the need to restore fiscal balance, as in the unpleasant monetarist arithmetic of Sargent and Wallace (1981). Part of the additional revenues that accrue to the government are raised through seigniorage, as the government needs to print money to keep real balances at $\bar{m}$. Rather than appearing on the right-hand side of equation (14), these revenues are captured implicitly by the real devaluation of previous money balances (which are then replaced with the new issuance). Finally, the FTPL is at work in determining the *magnitude* of the required jump in prices in period S: it must be such that fiscal balance is restored in equation (14) by devaluing existing claims (both money and debt) by the appropriate amount. Far from being three separate theories, the quantity theory of money, unpleasant arithmetic, and the FTPL are all at work in this example, and simply emphasize different elements of equation (14).

As discussed in Cochrane (2001), with long-term debt, it is not necessary for the price adjustment to happen in a single period. Debt obligations that are due further into the future are eroded not only by current inflation, but by future inflation as well. In addition, not all seigniorage revenues need to be collected by devaluing initial money balances at once. Consider thus the polar opposite case, in which the monetary authorities *permanently* raise inflation to a constant value $\psi^L\bar{\pi}$. Equation (14) then becomes

$$\frac{\bar{d}}{\psi^L\bar{\pi}}\left(\delta+\frac{\beta}{\psi^L\bar{\pi}-\beta\delta}\right)+\frac{\bar{m}}{\psi^L\bar{\pi}}=\frac{1}{1-\beta}\left[\bar{T}-\bar{G}+L(\psi^L\bar{\pi})\right]+\hat{G}. \tag{16}$$

Two new forces emerge that were not present in equation (15). First, by equation (9) higher inflation in the future implies a higher nominal interest rate, by the same factor ψ^L, so that the nominal interest rate going forward becomes $\psi^L\bar{R}$. This in turn has an effect on the ex-coupon price of the long-term debt, which drops to $\frac{\beta}{\psi^L\bar{\pi}-\beta\delta}$. Because long-term bonds are exposed to future inflation as well as current inflation, their real value drops more than the one-time price increase at S. Moreover, future inflation increases seigniorage revenues $L(\pi_{s+1})$ on the right-hand side; this term captures the effect of future money printing.[8] These two forces are balanced by the fact that current prices jump less ($\psi^L<\psi$). Even with this different policy, the quantity theory of money is alive and well. With the increase in interest rates, real balances decline in period S to $v'^{-1}(\psi^L\bar{\pi}/\beta)$, so money growth is smaller than the growth of prices on impact. However, from then on both money and prices grow at $\psi^L\bar{\pi}$; if we compare average inflation and average money growth over a longer horizon, both converge to the same constant $\psi^L\bar{\pi}$. This experiment is even more similar to Sargent and Wallace (1981), as seigniorage revenues accrue over time rather than all at once. Finally, the magnitude of the required extra inflation ψ^L is still driven by the need to restore fiscal balance in equation (16), following the logic of the FTPL.

The discussion here highlights how stable inflation requires appropriate monetary-fiscal coordination: a consistent (low) growth rate of money, and a primary fiscal balance that is compatible with such monetary expansion. In the examples above, this coordination is needed only to permit a low and stable growth rate of money, but it turns out that just setting a low growth rate of money is not a guarantee of low inflation in environments in which there is no "nominal anchor," a point emphasized by Wallace (1981) and Sims (1994), among many others. We do not provide a formal treatment of this question here,[9] but we consider the simplest question: What guarantees that money has positive value, so that we can write the budget constraints using it as the numeraire, as we did? Equation (12) provides a possible answer: money can be used to pay taxes and other exchanges with the government, as emphasized by Doepke and Schneider (2017) and Malmberg and Öberg (2021). Any future primary surpluses that the government runs provide a way for the government to reabsorb the money (and the debt) that it previously issued, and represent a real backing of those liabilities. This observation may explain why the quantity theory of money that Friedman embraced holds for government-sanctioned money across the world, but it fails in the case of cryptocurrencies. Most cryptocurrencies are designed so as to keep a much tighter control on the quantity issued than any central bank has on its own monetary base; yet, their real value is subject to large swings. In the absence of asset backing, even stablecoins are subject to runs: as a prominent example, the value of TerraUSD collapsed in 2022, even though by design, its supply was set to shrink in response to inflationary pressures.[10]

2 Inflation and the Fiscal Balance in the Aftermath of the COVID Pandemic

Having discussed some theoretical underpinnings of monetary-fiscal coordination in the previous section, we now turn our attention to post-COVID inflation, and its implications for the government balance (12). We do so without taking a stance on what initiated this inflation. A fiscal-dominance interpretation would suggest that it was triggered by an anticipation by the public that future fiscal revenues would be insufficient to repay the additional obligations that the United States Treasury (as well as those of other countries) took on at the height of the pandemic. A monetarist view might emphasize the large growth of the monetary base in the new regime of "ample reserves" and the correspondingly weaker connection between this monetary base, which is directly controlled by the central bank, and broader measures of money whose long-run relationship with inflation tends to be most stable. Yet another story puts emphasis on the role of supply-chain disruptions. Rather than taking a stance on which of these factors contributed the most, we aim to point out that this inflation redistributed resources from the holders of government bonds to taxpayers. What is more, even the most conservative estimate of the magnitude of this redistribution implies that it was far larger than anything that investors anticipated on the basis of asset prices and past experience.

2.1 A Back-of-the-Envelope Calculation

As became apparent in the simple experiments of the previous section, the maturity structure of government debt held by private investors is important in establishing what fraction of it is exposed to an inflation surprise that appears at any given point in time. Given that our goal is to provide conservative bounds, we assume that the relevant maturity is that of December 2020, when core PCE inflation was at 1.6% and a resurgence of inflation was not on the horizon. We thus assume that all debt that was issued after that date factored in the inflation that would come and was fairly compensated by an appropriate interest rate as it would be if the Fisher equation (9) applied perfectly. The reason this is a conservative choice is that interest rates moved sluggishly in response to inflation, and this was not simply due to the monetary policy stance: even long-run interest rates rose only gradually with the incoming news.

We start from a preliminary rough estimate that makes minimal use of statistical tools. We take the maturity structure of private debt as of the end of December in 2020 from Table FD-5 of the March 2021 Treasury Bulletin. To this, we add data about Treasury inflation-protected securities (TIPS) and floating rate notes (we lump these two categories

Table 1
Maturity structure of U.S. government securities as of December 2020

Maturity	Private Holdings of Public Debt
Less than 1 Year	6,356,589
1-5 Years	5,716,708
5-10 Years	2,454,885
10 Years or More	1,751,078
Inflation Protected	1,721,420

together under "Inflation Protected" in Table 1); these are taken from Table FD-2, from which we subtract Fed holdings from Table H.4.1 of the Federal Reserve balance sheet.

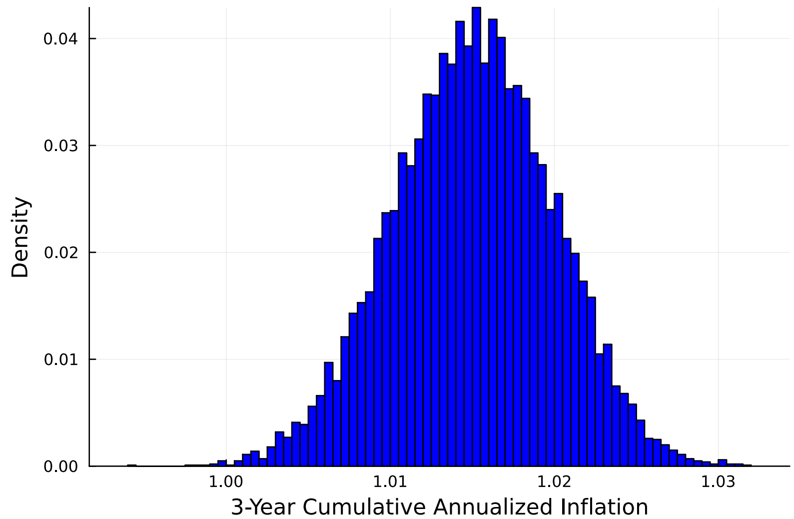
The distribution of private holdings skews toward short-term debt. This means that shorter, higher bursts of inflation (as experienced recently) do substantially more for government finances than more prolonged, but lower increases.

To calculate the size of the dilution, we need to compare actual inflation with what "markets" expected – that is, with the expectation that was reflected in asset prices at that point. Hilscher, Raviv, and Reis (2021) estimate the entire distribution of inflation expectations non-parametrically, using data up to December 2017, and observe that the median belief about cumulative annualized inflation on a three-year horizon is roughly 2.2%.[11] We take this as a baseline, since there were no drastic movements in interest rates in the intervening period, except for the brief events of March 2020, and we wish to contrast the experience of inflation in 2021-2022 with that paper's assessment of the likelihood of various dilution scenarios. We then take updated data in our next subsection. Using 2.2% as our baseline for expected inflation, we can calculate an approximation of the change in values of the bonds using the following equation:

$$\Delta V = F \times \kappa \left[\frac{1}{(\pi_E)^H} - \frac{1}{(\pi_A)^H} \right], \tag{17}$$

where F is the face-value of the bond, π_E and π^A are expected and realized cumulative annualized inflation rates respectively, H is the length of time between the end date of the episode and December 2020 (in years), and κ is the fraction of bonds that have maturity at least H. To compute the most conservative lower bound, we first set our horizon H to 3 years and disregard all bonds with a maturity of less than 3 years, assuming that they were not exposed. We also subtract *all* of the "inflation-protected" bonds from those that mature in more than 3 years. Finally, for the bonds that have a maturity within the 1 to 5 year band, we assume that just 10% of them have a maturity of at least 3 years. Cumulative annualized inflation (as measured by the Total CPI index) from December of 2020 to December of 2023 was roughly 5.6%, 3.4% higher than expected. For comparison, Hilscher, Raviv, and Reis (2021) infer a market-implied probability of observing annualized inflation above 4% in any time frame between 1 and 10 years that is less than 1.7% , so the extent of dilution for these bonds was an extreme tail event. If we consider just these bonds, the magnitude of the resulting dilution was approximately \$268 billion, or 1.3% of 2020 GDP, a transfer from this class of bond holders to the budget of the treasury (and ultimately of the taxpayers).

Figure 1
Distribution of inflation expectations



This number grows quickly if we include more of the shorter-term debt. If we assume that the remaining 90% of debt with a 1-5 maturity was exposed to inflation for 2 years, the estimated dilution grows by $411 billion to roughly 3.2% of 2020 GDP.

2.2 Inflation Expectations Implied by a Term Structure Model

Hilscher, Raviv, and Reis (2021) estimate risk-adjusted inflation probabilities using data up to December 2017. Since then, the market for inflation options that they use as the basis for their estimates has dried up, and prices are correspondingly less informative about actual market sentiment. To get a more updated estimate, we turn to the term-structure model of Ajello, Benzoni, and Chyruk (2020), which draws information from the term-structure of Treasury yields and inflation data on the three main components of the consumer-price index – that is, core, food, and energy inflation. In the model the three inflation series combine into a single total inflation measure that ties nominal and real risk-free bond prices together. Yet, as is consistent with the data, each inflation component displays different levels of persistence and volatility. The model performs well in forecasting inflation out of sample, improving upon survey forecasts of inflation and other benchmarks. Another advantage of the model is that it implies a distribution of inflation under the physical measure, in contrast to the risk-adjusted estimates of Hilscher, Raviv, and Reis (2021).

We use a simplified version of the Ajello, Benzoni and Chyruk model to recover market expectations about expected future inflation (the main difference is that we exclude real activity). The estimated distribution of three-year cumulative annualized inflation is depicted below in Figure 1. Table 2 compares the average and the 95th percentile of the forecast with realized inflation at different horizons.

These estimates of market-implied expectation are significantly lower than those of

Table 2
Annualized cumulative inflation at different horizons

Horizon	Mean Forecast	95% Forecast	Realized Inflation
6 months	1.65%	3.41%	8.8%
1 year	1.57%	2.85%	7.0%
1.5 years	1.54%	2.6%	8.97%
2 years	1.52%	2.45%	6.75%
3 years	1.50%	2.29%	5.6%

Table 3
Annualized cumulative inflation at different horizons: 2017 forecast

Horizon	Mean Forecast	95% Forecast
6 months	1.90%	3.88%
1 year	1.85%	3.32%
1.5 years	1.83%	3.04%
2 years	1.83%	2.90%
3 years	1.83%	2.72%

Hilscher, Raviv, and Reis (2021). To disentangle the discrepancy which is due to a different methodology from that which is due to the different time period, Table 3 presents inflation forecasts from the Ajello, Benzoni, and Chyruk model using data up to December 2017. Some of the lower forecast is attributable to the different methodology, but a large portion of the difference is due to differences in data between 2017 and 2020. Using these estimates rather than those of Hilscher, Raviv, and Reis, we find that realized inflation over this period exceeded what is inferred from bond prices to an even greater extent.

Table 4 depicts estimates of the revenues to the Treasury from dilution under different scenarios regarding the average maturity of the debt in the 1-5 year category. Specifically, we vary the fraction of with a 1-5 year maturity that we assume to be hit with the full 3-year dilution (κ on the rows, varying between 1 and 5 years), and time horizon over which the residual debt in the 1-5 year category is exposed to inflation (H_s on the columns, varying from 1 to 2 years).[12] We continue to disregard debt maturing in less than one year, but Table 2 shows that substantial unexpected losses in real terms were realized even on debt as short as 6 months. Table 5 computes the average corresponding loss to the exposed bondholders. Using their estimates of the distribution of expected inflation, Hilscher, Raviv, and Reis (2021) report less than a 1% probability of bondholder losses above 3.7% of GDP. Our tables show that even conservative estimates easily match these numbers, even over just 3 years rather than the 10-year horizon that they report. This result offers a fresh perspective on the extent by which this redistribution was unanticipated.

As further evidence of the extent by which bondholders were taken by surprise, we use the forecast of the 95th percentile of the inflation distribution. Tables 6 and 7 provide the magnitude of the revenues to the treasury as a fraction of GDP and losses to the exposed bondholders as a fraction of their holdings compared to the 95th percentile. Given that we

Table 4
Dilution as a percentage of 2020 GDP under different assumptions: Mean forecast

κ, H_s	1 year	1.5 years	2 years
0.1	2.7%	3.9%	3.8%
0.3	3.1%	4.0%	3.8%
0.5	3.4%	4.0%	3.9%

Table 5
Dilution as a percentage of exposed holdings under different assumptions: Mean forecast

κ, H_s	1 year	1.5 years	2 years
0.1	7.1%	10.2%	9.8%
0.3	7.9%	10.3%	10.0%
0.5	8.3%	10.4%	10.2%

are considering a 3-year episode, the 95th percentile corresponds to an event that would be expected to happen every 60 years. These tables reaffirm the view that most of the transfer that took place from the bondholders to the taxpayers was beyond even very pessimistic scenarios of the losses that investors envisaged (as revealed by information in asset prices).

3 Where Do We Go from Here?

The COVID pandemic caught the world by complete surprise, so it is not shocking that even some of its macroeconomic implications, including those for inflation, were not factored into asset prices. To find an appropriate point of comparison, Hall and Sargent (2022) turn to the two World Wars. However, the fiscal response to the COVID shock followed a pattern initiated in previous recessions. COVID caused by far the largest peacetime federal deficit as a fraction of GDP in the United States, a record that was previously held by the response to the 2008 financial crisis. At the same time, as Hall and Sargent (2023) remark, the postwar experience of returning federal outlays and revenues to an appropriate balance has not yet occurred after COVID. The logic of unpleasant monetarist arithmetic and the FTPL suggests that such an adjustment will have to happen in the future to ensure lasting price stability.

Table 6
Dilution as a percentage of 2020 GDP under different assumptions: Tail forecast

κ, H_s	1 year	1.5 years	2 years
0.1	2.1%	3.2%	3.0%
0.3	2.4%	3.2%	3.1%
0.5	2.6%	3.2%	3.1%

Table 7
Dilution as a percentage of exposed holdings under different assumptions: Tail forecast

κ, H_s	1 year	1.5 years	2 years
0.1	5.6%	8.4%	7.9%
0.3	6.2%	8.4%	8.0%
0.5	6.9%	8.4%	8.2%

Notes

1. A review of related literature appears in Bassetto and Sargent (2020).

2. To be precise, this is a *risk-adjusted* probability, and it may not be the same as the true perceived probability of an event, as it may overstate the probability of recessions and downplay that of booms. However, even if financial market participants expected high inflation to be associated with a large boom, the adjustment would not materially change the conclusion that this event was perceived as having very low odds.

3. Agents do know the ex-ante distribution of the shock, so this is not an "MIT" shock. Throughout this section, all variables with a time-t subscript are adapted to the information available in period t, so they potentially depend on $\tilde{G}$ if $t \geq S$, and they cannot depend on it otherwise.

4. Approximating the maturity structure of debt with an exponentially decaying sequence is convenient because it makes it unnecessary to keep track of the exact date at which debt was issued: all outstanding bonds share the same payment profile.

5. In the absence of arbitrage, a stochastic discount factor exists such that the price of an arbitrary, possibly state-contingent payoff A_{t+1} to be delivered in period $t+1$ is $E_t(z_{t+1}A_{t+1})$.

6. The model is symmetric, so the same discussion would apply in reverse if $\hat{G}$ were unexpectedly low.

7. We assume $\bar{R} > 1$, so that the nominal interest rate is above the zero lower bound in steady state and the cash-in-advance constraint binds.

8. We assume that the government chooses monetary policy so that $L(\pi_{s+1})$ is increasing in π_{s+1} at all times, that is, it operates on the good side of the Laffer curve: higher inflation brings more seigniorage revenues. We can prove that this must be true in the model when inflation is sufficiently low, and empirically this is true in all countries except during episodes of hyperinflations.

9. A review of the arguments appears in Bassetto and Sargent (2020).

10. We define "inflationary pressure" as a situation in which the real value of a unit of account is dropping. For the dollar this definition is familiar: inflation arises when the purchasing power of a dollar drops. The same applies to cryptocurrencies, except that their purchasing power is driven mostly by the swings in their exchange rate against the dollar and the other major world currencies.

11. See Figure 4 of that paper. Note that because their estimates of the annualized and year-on-year inflation expectations are constructed non-parametrically from options data, they estimate risk-neutral probabilities.

12. We thus compute ΔV in equation 17 separately for the two categories, and add up the results.

References

Ajello, Andrea, Luca Benzoni, and Olena Chyruk. 2020. "Core and 'Crust': Consumer Prices and the Term Structure of Interest Rates." *The Review of Financial Studies* 33 (8): 3719–3765.

Barro, Robert J, and Francesco Bianchi. 2023. "Fiscal Influences on Inflation in OECD Countries, 2020-2022." Working Paper 31838, NBER.

Bassetto, Marco, and Thomas J. Sargent. 2020. "Shotgun Wedding: Fiscal and Monetary Policy." *Annual Review of Economics* 12 (1): 659–690.

Bianchi, Francesco, and Leonardo Melosi. 2014. "Dormant Shocks and Fiscal Virtue." *NBER Macroeconomics Annual* 28 (1): 1–46.

———. 2019. "The Dire Effects of the Lack of Monetary and Fiscal Coordination." *Journal of Monetary Economics* 104:1–22.

Chung, Hess, Troy Davig, and Eric M. Leeper. 2007. "Monetary and Fiscal Policy Switching." *Journal of Money, Credit and Banking* 39 (4): 809–842.

Cochrane, John H. 2001. "Long Term Debt and Optimal Policy in the Fiscal Theory of the Price Level." *Econometrica* 69 (1): 69–116.

———. 2022. "The Fiscal Roots of Inflation." *Review of Economic Dynamics* 45:22–40.

———. 2023. *The Fiscal Theory of the Price Level.* Princeton University Press.

Doepke, Matthias, and Martin Schneider. 2017. "Money as a Unit of Account." *Econometrica* 85 (5): 1537–1574.

Gao, Han, and Juan Pablo Nicolini. 2024. "The Recent Rise in US Inflation: Policy Lessons from the Quantity Theory." *Federal Reserve Bank of Minneapolis Quarterly Review* forthcoming.

Hall, George J., and Thomas J. Sargent. 2022. "Three World Wars: Fiscal-Monetary Consequences." *Proceedings of the National Academy of Sciences* 119 (18): e2200349119.

———. 2023. *Fiscal Consequences of the US War on COVID.* http://people.brandeis.edu/~ghall/papers/Fiscal_Consequences.pdf. Mimeo, Brandeis University and NYU.

Hilscher, Jens, Alon Raviv, and Ricardo Reis. 2021. "Inflating Away the Public Debt? An Empirical Assessment." *Review of Financial Studies* 35 (3): 1553–1595.

Leeper, Eric. 1991. "Equilibria under 'Active' and 'Passive' Monetary Policies." *Journal of Monetary Economics* 27 (1): 129–147.

Lucas, Robert E., Jr. 1980. "Two Illustrations of the Quantity Theory of Money." *American Economic Review* 70 (5): 1005–14.

Lucas, Robert E., Jr., and Nancy L. Stokey. 1987. "Money and Interest in a Cash-in-Advance Economy." *Econometrica* 55 (3): 491–513.

Malmberg, Hannes, and Erik Öberg. 2021. "Price-Level Determination When Tax Payments Are Required in Money." *The Scandinavian Journal of Economics* 123 (2): 621–644.

Sargent, Thomas J. 1983a. "Stopping Moderate Inflations: The Methods of Poincaré and Thatcher." In *Inflation, Debt and Indexation,* edited by Rudiger Dornbusch and Mario Henrique Simonsen, 54–98. MIT Press.

———. 1983b. "The Ends of Four Big Inflations." In *Inflation: Causes and Effects,* edited by Robert E. Hall, 41–97. The University of Chicago Press.

———. 2013. *Rational Expectations and Inflation.* 3rd. Princeton University Press.

Sargent, Thomas J., and Neil Wallace. 1981. "Some Unpleasant Monetarist Arithmetic." *Federal Reserve Bank of Minneapolis Quarterly Review* 5 (1): 1–17.

Sims, Christopher A. 1994. "A Simple Model for Study of the Determination of the Price Level and the Interaction of Monetary and Fiscal Policy." *Economic Theory* 4 (3): 381–399.

Wallace, Neil. 1981. "A Hybrid Fiat-Commodity Monetary System." *Journal of Economic Theory* 25 (3): 421–430.

Woodford, Michael. 1994. "Monetary Policy and Price Level Determinacy in a Cash-in-Advance Economy." *Economic Theory* 4 (3): 345–380.