DISSERTATION

Monetary-Fiscal Independence, Institutional Strength, and Trade-Offs in Government Financing

by

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CONTENTS

ABSTRACT

This collection of papers investigates how independently optimizing fiscal and monetary policy institutions jointly determine macroeconomic variables. The first paper develops a theoretical framework modeling strategic interactions between fiscal and monetary authorities, introducing "fiscal strength" as a tool to explain historical U.S. economic outcomes. The second paper introduces the "dilution rate of government debt" and applies it to uncover effects of dynamic debt maturity management on inflation using a structural vector autoregression (SVAR) approach. The third paper provides a fiscal accounting of COVID-era inflation, showing how large deficit-financed government spending during the pandemic, with minimal discussion of repayment, contributed to subsequent inflation.

Fiscal Strength within a Framework of Institutional Independence

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Abstract

This paper develops a theoretical framework in which fiscal and monetary authorities interact strategically to determine tax, inflation, and debt policy. A tax-minimizing debt-manager and an inflation-minimizing central bank operate non-cooperatively, constrained by government solvency, household optimization, and each other's choices. Greater fiscal strength, measured as debt-manager bargaining power, leads to higher inflation and lower taxes. I impute American post-war fiscal strength and compare it with data on presidential pressure on the Fed, finding the two generally move in tandem. When compared with first-best, U.S. fiscal policy was too strong in the 1970s and has been too weak since 2008, largely because surprise inflation is more effective at financing highly indebted governments.

Keywords: Fiscal policy, Monetary policy, Central bank independence, Nash bargaining, U.S. macroeconomic policy.

JEL Classification: E52, E63, H62, H63, C72.

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1 Introduction

America's monetary and fiscal architecture has remained remarkably consistent since the 1951 Treasury-Fed Accord, yet the individuals directing these institutions are ever-changing. Presidents and high-ranking Federal Reserve (Fed) officials alike bring ideologies concerning how Congressional and Fed policies should jointly shape the country's economic backdrop. As part of his 2024 presidential campaign, Donald Trump released his vision for the future of this relationship, endorsing that "Congress should limit [the Fed's] mandate to the sole objective of stable money" and stating, "I feel that the president should have at least [a] say in [making interest rate decisions]."[1]

Many theoretical models exist separating fiscal and monetary policy within a competitive, general equilibrium setting, beginning with work by Sargent and Wallace (1981). The Fiscal Theory of the Price Level (FTPL) initially developed by Leeper (1991), Sims (1994) and Woodford (1995) characterizes distinct regimes where fiscal and monetary policy commit to follow rules in an economy with nominal government debt. Models by Dixit and Lambertini (2003), Gnocchi (2013) and Gnocchi and Lambertini (2016) iterate on FTPL by assuming monetary and fiscal policies engage in non-cooperatively optimal policy unrestricted by a rules framework, pinning down unique subgame perfect equilibria through discrepancies in institutions' abilities to commit. Work by Chen, Leeper, and Leith (2021) combines non-cooperation with FTPL by including Markov switching and policy non-cooperation within a policy rules framework. Yet, a common and persistent challenge exists throughout the literature: reconciling high U.S. inflation during periods of low and stable government indebtedness, as in the 1970s, and low U.S. inflation during periods of high and rising government indebtedness, as in the 2010s.

This paper develops a theory of fiscal and monetary non-cooperation, where a unique equilibrium is determined by fiscal policy's strength relative to monetary policy. An inflation-targeting central bank and tax-minimizing debt-manager operate within an economy similar to that in Lucas and Stokey's (1983) model but with nominal debt. Policy authorities simultaneously commit to state contingent plans that maximize their own institution-specific payoffs, resulting in a one-shot game. Equilibrium satisfies requirements for a competitive equilibrium outlined by Barro (1979) and Lucas and Stokey (1983) and a Nash equilibrium introduced by Nash (1951). I select a unique equilibrium

[1] See Chapter 24 of *Project 2025* by Winfree (2024) and the *Wall Street Journal*'s 4/26/2024 article by Restuccia, Timmons, and Leary (2024).

from the resulting continuum using Harsanyi and Selten's (1972) asymmetric Nash bargaining concept and interpret the bargaining parameter as a measure of fiscal strength.

Given inherited debt and a stochastic stream of current and future government spending, the debt-manager chooses a plan for labor-distorting taxes and fiscally-issued debt, while the central bank chooses a plan for costly inflation and monetarily-demanded debt. Households hold the difference of fiscal and monetary debt portfolios once markets clear. Given one institution's plan and optimal household consumption, labor supply, and savings behavior, the other institution must satisfy government solvency along an individually-optimal policy path.

The government must be financed somehow, introducing a fundamental trade-off. Surprise inflation devalues debt to keep taxes low, while distortionary taxes raise real revenues to keep inflation low. The central bank selects the zero-inflation equilibrium when it has unilateral control of government policy. The debt-manager selects a tax-minimizing equilibrium with arbitrarily high inflation when it has unilateral control of government policy. If only one of these government branches exists in the economy, households improve welfare by institutionalizing the other.

A Ramsey planner selects the tax/inflation financing mix that maximizes household welfare. The planner calls for an interior solution: one with non-zero inflation and non-minimized tax rates. The Ramsey plan is achievable under a non-cooperative government when fiscal strength is low, echoing a chorus of work supporting strong, independent monetary policy like that by Alesina (1988), Grilli, Masciandaro, and Tabellini (1992), and Alesina and Summers (1993).

Recent work by Drechsel (2024) uncovers historical data on meetings between U.S. presidents and Fed officials and compares them to U.S. inflation outcomes, positing that presidents meet with Fed officials to pressure them into reducing rates. Drechsel supports this claim by finding a causal link between the meetings President Richard Nixon (1969–1974) held with Fed officials in 1971 during Fed Chair Arthur Burns's (1970–1978) tenure and a decrease in the Fed Funds rate, calling such an event a 'political pressure shock.'

It is not entirely clear what a political pressure shock looks like in a DSGE model as compared with a monetary or fiscal policy shock, for instance. If political pressure exists in the meeting rooms of high-ranking policymakers and affects macroeconomic variables like the Fed's policy rate, a theory that specifies this pressure may be useful. Additionally, such a theory may be the *only* way to identify political pressure going forward, as presidential meeting agendas are no longer available to the public. I consider this paper's notion of fiscal strength the theoretical counterpart to Drechsel's empirical political pressure concept.

To show the relationship between the two, I solve this paper's model in every year from 1943–2023 given American data on privately held debt and spending, and I impute the implicit amount of fiscal strength required for the model to match realized U.S. inflation rates each year. I compare the imputed fiscal strength time series with that of hours presidents spent with Fed officials in meetings each year from 1943–2008 (hours data end in 2008). The time series line up especially well from 1952, the year after the Treasury-Fed Accord, until 1975 and again from 1983 until 2008.[2] Both datasets exhibit two major upward spikes between 1971–1981. Imputed fiscal strength remains low until post-COVID inflation arrives in 2021.

For further comparison, I calculate average imputed fiscal strength and average annual meeting hours by presidential and Fed chair term over the same time frame, finding a positive relationship between the number of hours presidents and Fed chairs spent in meetings and the amount of imputed fiscal strength they experienced during their time in office.

Another question the paper answers is normative: when was American fiscal policy 'too strong' and when was it 'too weak?'[3] Given U.S. debt and spending data each year from 1943–2023, I calculate the amount of fiscal strength that implements the model's Ramsey plan each year and compare it with imputed fiscal strength. Imputed and first-best fiscal strengths line up well from the beginning of the sample until the late 1960s, and again from the mid-1980s until the Great Financial Crisis (GFC) in 2008. I find that fiscal policy was too strong throughout the 1970s and has been too weak since the GFC. The key piece of intuition is that surprise inflation is a more powerful financing tool in high-debt economies than low-debt ones, while imposing similar welfare costs on households in both. Debt-to-GDP remained between 20%-30% in the 1970s, while inflation soared: high inflation financed a large portion of a small debt stock. Government debt spiked in 2008 and rose to more than 80% by 2015 while inflation remained below the Fed's 2% target: low surprise inflation financed a small amount of a large debt stock. The COVID spike in fiscal strength and corresponding inflation better approximated the model planner's solution because such an inflation greatly reduced tax distortions the government would otherwise need to levy.

[2]Hours fall in the late 70s while fiscal strength remains high until 1982.

[3]Too strong and too weak compared to what the planner would choose if at America's helm that year.

Greenwood et al. (2015) argue the Treasury partially neutralized Fed QE after the GFC through longer newly-issued debt. Miran and Roubini (2024) claim the Treasury offset the Fed's post-COVID quantitative tightening efforts by issuing large amounts of short-term debt. The final set of exercises in the paper examines how a maturity structure of government debt interacts with fiscal and monetary non-cooperation.

I find that replacing one-period inherited debt with one- and two-period inherited debt matching the average privately held U.S. debt structure from 1942–2022 results in debt savings analogous to $247B (in 2024 dollars) along the Ramsey plan. When the market value of inherited debt can be devalued through commitments about future policy, the government can better smooth tax and inflation policy over time, increasing welfare as in models by Lustig, Sleet, and Yeltekin (2008), Debortoli, Nunes, and Yared (2017), Faraglia et al. (2019) and Leeper and Zhou (2021), among others.

Finally, long-term government debt provides better insurance against monetary-fiscal non-cooperation. Given two welfare-equivalent economies along their respective Ramsey plans, one with a maturity structure and one without, deviations from the Ramsey plan (in both directions) are more welfare-reducing in the economy without a maturity structure. A debt structure allows for even a weak fiscal or monetary policymaker to better smooth its own financing tool.

This paper offers four main contributions. First, it develops a theory by which intra-governmental bargaining power determines a unique equilibrium under individually optimizing fiscal and monetary policy, providing a measure of fiscal strength relative to monetary policy. Second, it reconciles theoretical underpinnings of new and exciting empirical data and offers a way to extend that data to present day. Third, it gives a glimpse into the history of fiscal and monetary interaction in post-war America and compares those interactions to a normative standard. Fourth, it explores how the maturity structure of government debt can be used as insurance against non-cooperative policy away from first-best, when either fiscal or monetary policy is too strong.

2 Model

2.1 Environment

I consider an infinitely-lived flexible-price economy with periods indexed by $t \in \{0, 1, 2, \cdots\}$. Three types of agents inhabit the model: households, a debt-manager and a central bank.

A measure-1 continuum of identical price-taking households consume c_t and produce an aggregated, non-storable good in every period equal to their labor supply n_t. Households own the economy's production technology, and their labor income is taxed at rate $\tau_t \in [0, 1)$.

Exogenous government purchases of the consumption good g_t evolve according to an S-state Markov process with transition matrix $\mathcal{P}$. The $S \times 1$ vector of spending states is $g \equiv \{g(s)\}_s$ where $s \in \{1, \cdots, S\}$, and the time t history of government spending realizations is $g^t \equiv \{g_0, g_1, \cdots, g_t\}$. The set of potential time t histories is given by G^t. Finally, let F^t denote the marginal distribution of histories implied by $\mathcal{P}$ and g_0, and let f^t denote the density for F^t. There is no other source of uncertainty in the model.

Total production is consumed by households and the government, so the economy's aggregate resource constraint (ARC) is

$$n_t = c_t + g_t \;\; \forall \, t \tag{1}$$

Define $P_t > 0$ as the aggregate price level, which represents the exchange rate between nominal objects (hereafter referred to as 'dollars') and the numeraire. Households lend (borrow) in dollars using a portfolio of nominal, one-period, state-contingent government debt $B_t = \left\{B_t^{(s)}\right\}_{s=1}^{S}$, where they receive $B_t^{(s')}$ dollars upon realizing state $s' \in \{1, \cdots, S\}$ when entering period $t+1$. This is a nominal version of the portfolio originally studied in Arrow (1964). Finally, call $\pi_t = \frac{P_t}{P_{t-1}}$ the economy's time t gross inflation rate.

Household welfare is defined as the sum of discounted expected utility over its lifetime according to the function

$$W_0 = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{u(c_t) - v(n_t) - w(\pi_t)\right\} = \sum_{t=0}^{\infty} \beta^t \sum_{g_t \in G^t} \left\{u(c_t) - v(n_t) - w(\pi_t)\right\} f^t\left(g^t\right) \tag{2}$$

where $\beta \in (0, 1)$, where u, v and w are twice-differentiable, where $u' > 0$, $u'' < 0$, $v' > 0$, $v'' > 0$, and where w is minimized at 1.

The government is split into two branches: the debt-manager and central bank. Institutions have commitment power, and each institution aims to maximize the sum of discounted expected household utility under a reweighing of utility components.

The debt-manager chooses the issued supply of government debt across types $\boldsymbol{B}_t^{dm} = \left\{\boldsymbol{B}_t^{(s),dm}\right\}_{s=1}^S$ and the labor income tax rate τ_t each period to maximize its lifetime payout given by

$$\begin{aligned} W_0^{dm} &= \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{\left(1-\rho^{dm}\right)\left[u\left(c_t\right)-v\left(n_t\right)\right]-\rho^{dm} w\left(\pi_t\right)\right\} \\ &= \sum_{t=0}^{\infty} \beta^t \sum_{g_t \in G^t} \left\{\left(1-\rho^{dm}\right)\left[u\left(c_t\right)-v\left(n_t\right)\right]-\rho^{dm} w\left(\pi_t\right)\right\} f^t\left(g^t\right) \end{aligned} \quad (3)$$

where $\rho^{dm} \in [0,1]$, and where $\boldsymbol{B}_t^{dm} \in \mathbb{R}^S$ is otherwise unrestricted.

The central bank simultaneously chooses its debt demand $\boldsymbol{B}_t^{cb} = \left\{\boldsymbol{B}_t^{(s),cb}\right\}_{s=1}^S$ and the inflation rate π_t each period to maximize its lifetime payout given by

$$\begin{aligned} W_0^{cb} &= \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{\left(1-\rho^{cb}\right)\left[u\left(c_t\right)-v\left(n_t\right)\right]-\rho^{cb} w\left(\pi_t\right)\right\} \\ &= \sum_{t=0}^{\infty} \beta^t \sum_{g_t \in G^t} \left\{\left(1-\rho^{cb}\right)\left[u\left(c_t\right)-v\left(n_t\right)\right]-\rho^{cb} w\left(\pi_t\right)\right\} f^t\left(g^t\right) \end{aligned} \quad (4)$$

where $\rho^{cb} \in [0,1]$, and where $\boldsymbol{B}_t^{cb} \in \mathbb{R}^S$ is otherwise unrestricted.

The structure of outstanding government debt at time t is $\boldsymbol{B}_t = \boldsymbol{B}_t^{dm} - \boldsymbol{B}_t^{cb}$. Debt markets clear when household lending equals consolidated government borrowing so that

$$\boldsymbol{B}_t = B_t \quad \forall\ t \quad (5)$$

where $B_t = \left\{B_t^{(s)}\right\}_{s=1}^S$.

2.2 Market Structure

S asset markets exist in every period: one for each circulating debt instrument. Debt is exchanged at nominal prices $Q_t \equiv \left\{Q_t^{(s)}\right\}_{s=1}^S$ where $Q_t^{(s)}$ is the time t price of a bond that matures in state s at time $t+1$.

Upon entering state $s' \in \{1, \cdots, S\}$, each household chooses $\{c_t, n_t, B_t\}_{t=0}^{\infty}$ to maximize (2) subject to its household budget constraint (HHBC), given as

$$P_t c_t + \sum_{s=1}^{S} Q_t^{(s)} B_t^{(s)} \leq P_t \left(1 - \tau_t\right) n_t + B_{t-1}^{(s')} \tag{6}$$

Household debt holdings are subject to limits that eliminate Ponzi schemes:

$$B_t^{(s)} \in \left[\underline{B}, \overline{B}\right] \quad \forall\ t, s \tag{7}$$

where debt limits $\underline{B}$ and $\overline{B}$ are set to be sufficiently large so that (7) does not bind in equilibrium.

The debt-manager chooses fiscal policy $\left\{\tau_t, \boldsymbol{B}_t^{dm}\right\}_{t=0}^{\infty}$ to maximize (3). The central bank chooses monetary policy $\left\{\pi_t, \boldsymbol{B}_t^{cb}\right\}_{t=0}^{\infty}$ to maximize (4). Institutions are constrained by the ARC (1), HHBC (6), household optimization, and the other institution's simultaneous policy choice, which is taken as given at time t. The ARC (1) and HHBC (6), combine to produce the consolidated government's budget constraint (GBC), written as

$$B_{t-1}^{(s')} + P_t g_t \geq \sum_{s=1}^{S} Q_t^{(s)} B_t^{(s)} + P_t \tau_t n_t \tag{8}$$

upon entering state $s' \in \{1, \cdots, S\}$ at time t.

3 Competitive Nash Equilibrium

3.1 Equilibrium Definition

Equilibrium is similar to that in the anonymous commitment game found in Chari and Kehoe (1990) except for the addition of a second committing policymaker. Time 0 institutions select infinite sequences of policies, contingent on future realizations of uncertainty. Due to initial institutions' commitment technologies, future institutions are constrained to follow such time 0 plans. Households move after institutions at time 0.

I define the economy's time t state as $x_t \equiv \left\{g^t, B_{t-1}\right\}$. The debt-manager's time t action is a selection of fiscal policy $\eta_t^{dm} = \eta^{dm}\left(x_t\right) = \left\{\tau_t, \boldsymbol{B}_t^{dm}\right\}$, the central bank's time t action is a selection of monetary policy $\eta_t^{cb} = \eta^{cb}\left(x_t\right) = \left\{\pi_t, \boldsymbol{B}_t^{cb}\right\}$ and households' time t action is a selection of consumption, labor supply and debt holdings $\eta_t^{hh} = \eta^{hh}(x_t) = \{c_t, n_t, B_t\}$.

I index government institutions by $i \in \{dm, cb\}$ and denote i's opponent by $-i$. A time 0 strategy for institution i is a set of current and future committed action profiles $\gamma_0^i(x_0, \gamma^i(\cdot), \gamma^{-i}(\cdot)) \equiv \left\{\{\eta(x_t, \gamma^i(\cdot), \gamma^{-i}(\cdot))\}_{g^t \in G^t}\right\}_{t=0}^{\infty}$ and its time $t > 0$ strategy is simply its previously-committed, state-contingent action $\gamma_t^i(x_t, \gamma^i(\cdot), \gamma^{-i}(\cdot)) \equiv \eta^i(x_t, \gamma^i(\cdot), \gamma^{-i}(\cdot))$.[4] Combine these strategies into i's unified strategy profile $\gamma^i(\cdot) \equiv \{\gamma_0^i(\cdot), \gamma_t^i(\cdot)\}$.

A pure strategy competitive Nash equilibrium (CNE) consists of a debt-manager strategy $\gamma^{dm}(\cdot)$, a central bank strategy $\gamma^{cb}(\cdot)$, a household strategy $\gamma^{hh}\left(x_t, \gamma^{dm}(\cdot), \gamma^{cb}(\cdot)\right) = \eta^{hh}\left(x_t, \gamma^{dm}(\cdot), \gamma^{cb}(\cdot)\right)$, a pricing function for the aggregate price level $P_t = \gamma^P\left(x_t, \gamma^{dm}(\cdot), \gamma^{cb}(\cdot)\right)$ and a pricing function for the vector of bond prices $Q_t = \gamma^Q\left(x_t, \gamma^{dm}(\cdot), \gamma^{cb}(\cdot)\right)$ such that in every period:

1. The household strategy $\gamma^{hh}(\cdot)$ maximizes (2) given $\gamma^{dm}(\cdot)$, $\gamma^{cb}(\cdot)$, $\gamma^P(\cdot)$ and $\gamma^Q(\cdot)$ while satisfying (6) and (7),

2. The debt-manager's strategy $\gamma^{dm}(\cdot)$ maximizes (3) given $\gamma^{hh}(\cdot)$, $\gamma^{cb}(\cdot)$, $\gamma^P(\cdot)$ and $\gamma^Q(\cdot)$ while satisfying (8),

3. The central bank's strategy $\gamma^{cb}(\cdot)$ maximizes (4) given $\gamma^{hh}(\cdot)$, $\gamma^{dm}(\cdot)$, $\gamma^P(\cdot)$ and $\gamma^Q(\cdot)$ while satisfying (8),

4. The set of pricing equations $\gamma^P(\cdot)$ and $\gamma^Q(\cdot)$ clear all markets, satisfying (1) and (5).

Households, the debt-manger and the central bank are fully rational, have complete information about each others' problems and understand the underlying government spending process $\{g, \mathcal{P}\}$.

3.2 Household Optimization

Household optimization ensures the HHBC (6) and GBC (8) hold as strict equalities and that

$$1 - \tau_t = \frac{v'(n_t)}{u'(c_t)} \quad \text{and} \quad Q_t^{(s')} = \beta \mathbb{E}_t \left[\frac{u'(c_{t+1}) P_t}{u'(c_t) P_{t+1}}\right] \mathcal{P}_{s,s'} \quad \forall\ s, s' \in \{1, \cdots, S\} \tag{9}$$

when all debt is traded, where $\mathcal{P}_{s,s'}$ is the $s \times s'$ element of $\mathcal{P}$: the probability of entering state s' at time $t+1$, conditional on being in state s at time t.

[4]Where action profiles are now more appropriately written as functions of the economy's state and government strategy.

Well-known properties of such a Markovian process allow for a reduction in the economy's state space, as, at time t, the time $t-1$ history of spending states g^{t-1} is not informative to households or government branches, given B_{t-1}. The economy's relevant state space can therefore be rewritten as $\tilde{x}_t = \{g_t, B_{t-1}\}$.

Equation (9) and properties of $u(\cdot)$, $v(\cdot)$ and β imply a transversality condition (TVC) on the real value of maturing government debt so that

$$\lim_{i\to\infty}\left(\frac{\beta^i B_{t-1+i}^{(s)}}{P_{t+i}}\right) = 0 \quad , \quad \forall\, s \in \{1,\cdots,S\} \tag{10}$$

3.3 Price Level Determination

I combine the ARC (1), HHBC (6) and household optimization (9), forward-iterate on the probability-weighted sum of maturing government debt and apply the TVC (10) to write

$$\underbrace{\frac{B_{t-1}^{(s)}}{P_t}}_{(\text{Maturing debt})/P_t} = \underbrace{\frac{1}{u'(c_t)}\mathbb{E}_t\sum_{i=0}^{\infty}\beta^i\left[u'(c_{t+i})\,c_{t+i} - v'(n_{t+i})\,n_{t+i}\right]}_{\mathbb{E}_t[\text{PV(primary surpluses)}]} \tag{11}$$

which I call the economy's pricing equation.

As is the case in the New Keynesian, FTPL, and other conventional, macroeconomic DSGE models, the price level P_t adjusts in every period to ensure that the real value of outstanding nominal debt equals the expected present value of government primary surpluses.[5]

3.4 A Quasi-Primal Approach

Households and government branches derive utility in part from inflation. The analysis thus far has focused on the relationships between nominal debt, fiscal financing and the price level. To better align the model with agents' preferences, it is useful to convert the pricing equation (11) from being in terms of nominal debt and the price level to instead being in terms of real debt and inflation.

Define a household's real (indexed) debt holdings as $b_t^{(s)} \equiv \frac{B_t^{(s)}}{P_t}$ and the government's real debt supplied as $\boldsymbol{b}_t^{(s)} \equiv \frac{\boldsymbol{B}_t^{(s)}}{P_t}$, and define the vector of real debt allocations held by households as $b_t \equiv \left\{b_t^{(s)}\right\}_{s=1}^{S}$ and jointly-supplied by the government as $\boldsymbol{b}_t \equiv \left\{\boldsymbol{b}_t^{(s)}\right\}_{s=1}^{S}$. The economy's pricing

[5] Notice that $u'(c_{t+i})\,c_{t+i} - v'(n_{t+i})\,n_{t+i} = u'(c_{t+i})\,(\tau_{t+i}n_{t+i} - g_{t+i})$ from the ARC (1) and the HH FOC on τ_t (9).

equation (11) can now be expressed as

$$\underbrace{\frac{b_{t-1}^{(s)}}{\pi_t}}_{\text{(Maturing debt)}/P_t} = \underbrace{\frac{1}{u'(c_t)}\mathbb{E}_t \sum_{i=0}^{\infty} \beta^i \left[u'(c_{t+i})\, c_{t+i} - v'(n_{t+i})\, n_{t+i}\right]}_{\mathbb{E}_t[\text{PV(primary surpluses)}]} \tag{12}$$

where I call (12) the economy's implementability constraint (IC).

Any CNE must be a competitive equilibrium. Lucas and Stokey (1983) employ the primal approach to characterize a competitive equilibrium, which consists of substituting out all prices from the economy and writing the system in terms only of allocations. I employ a quasi-primal approach that follows Lucas and Stokey (1983), except I allow π_t to remain in the system. Equations (1) and (12) are necessary and sufficient conditions for a competitive equilibrium.

Proposition 1 ***(competitive equilibrium)*** *A stochastic sequence* $\left\{\left\{c_t(x_t), n_t(x_t), g_t, \pi_t(x_t)\right\}_{g^t \in G^t}\right\}_{t=0}^{\infty}$ *is a competitive equilibrium if and only if it satisfies* (1) $\forall g^t \in G^t, \forall t$ *and* $\exists \left\{\left\{\left\{\boldsymbol{b}_t^{(s)}(x_t)\right\}_{s=1}^{S}\right\}_{g^t \in G^t}\right\}_{t=0}^{\infty}$ *which satisfies* (12) $\forall g^t \in G^t, \forall t.$

Proof: The proof can be found in appendix A.

The requirements for a competitive equilibrium are met so long as there exists allocations that satisfy the ARC and the IC every period for every possible draw of exogenous government spending. Nominal Arrow securities complete financial markets, so they can be issued to implement any feasible, pre-committed joint tax/inflation path.[6] Solving government institutions' problems subject only to (1) and (12) dramatically simplifies the analysis.

The IC (12) is the key to the game played between institutions. Because inflation doesn't enter the ARC (1), $\{c_t, n_t\}$ depends entirely on fiscal policy while $\{\pi_t\}$ depends entirely on monetary policy.[7] The IC (12) connects the two: institutions' state-contingent plans must be jointly consistent with (12). A debt-manager that chooses current and future tax policy constrains the central bank through (12). Symmetrically, a central bank that chooses current and future inflation policy constrains the debt-manager through (12). The IC becomes the frontier along which the institutional

[6]Implementing these plans requires that $b_{t-1}^{(s)} = \frac{B_{t-1}^{(s)}}{P_{t-1}}$ satisfies the IC (12) for every potential time t realized state.

[7]Notice that the ARC (1) and the HH FOC on τ_t (9) form a system of two equations with two unknowns in c_t and n_t, given τ_t and g_t.

game is played.

4 Equilibrium Analysis

4.1 Ramsey Plan: An Efficient Benchmark

I begin by considering welfare-maximizing joint fiscal-monetary policy conducted by a Ramsey planner with commitment power. Such a Ramsey plan serves as an efficient benchmark by which to compare outcomes from equilibrium government policy.

The Ramsey planner commits to state-contingent plans for $\{\tau_t\}$, $\{\pi_t\}$, and $\{\boldsymbol{b}_t\}$ to maximize true household welfare (2), given its constraint set (1), (5)–(7), (9)–(10). Applying the quasi-primal approach described in Section 3.4 transforms the problem so the Ramsey planner equivalently commits to state-contingent plans for $\{c_t\}$, $\{n_t\}$, $\{\pi_t\}$, and $\{\boldsymbol{b}_t\}$ subject to the ARC (1) and IC (12).

The Ramsey planner's FOCs on $\{c_t\}$ and $\{n_t\}$ combine to yield

$$u'(c_0)[1+\lambda_0] + \lambda_0 \left[u''(c_0)\left(c_0 - \frac{b_{-1}^{(s)}}{\pi_0}\right)\right] = v'(n_0)[1+\lambda_0] + \lambda_0 v''(n_0)\,n_0 \qquad \text{and} \tag{13}$$

$$u'(c_t)[1+\lambda_0] + \lambda_0 u''(c_t)\,c_t = v'(n_t)[1+\lambda_0] + \lambda_0 v''(n_t)\,n_t \qquad \forall\, t>0 \tag{14}$$

where λ_0 is the planner's Lagrange multiplier on the time 0 IC (12).[8]

The Ramsey planner's FOCs on $\{\pi_t\}$ are

$$w'(\pi_0)\,\pi_0^2 = \lambda_0 u'(c_0)\,b_{-1}^{(s)} \qquad \text{and} \tag{15}$$

$$\pi_t = 1 \qquad \forall\, t>0 \tag{16}$$

The Ramsey planner sets $\{\tau_t\}$ and $\{\pi_t\}$ to simultaneously achieve three directives. The first is an intratemporal goal to align marginal welfare losses between using τ_t and π_t each period. The second is a goal to smooth welfare losses from its costly tools intertemporally. Both goals take the amount of financing needed to satisfy the IC (12) as given. The third goal is embedded in the planner's FOC on τ_0's (13) and π_0's (15) terms which include inherited, maturing debt $b_{-1}^{(s)}$: the

[8] Specifying linearly-separable CRRA utility in c_t and n_t would imply a perfectly-smooth stationary tax rate. When $u''(c_t)\,c_t = \bar{u}u'(c_t)$ and $v''(n_t)\,n_t = \bar{v}v'(n_t)$, where $\bar{u}$ and $\bar{v}$ are constants, the Ramsey FOC on τ_t (14) becomes $\frac{v'(n_t)}{u'(c_t)} = \frac{1+\lambda_0(1+\bar{u})}{1+\lambda_0(1+\bar{v})}$. The tax rate is then $\tau_t = \tau = 1 - \frac{1+\lambda_0(1+\bar{u})}{1+\lambda_0(1+\bar{v})}$ by the household's FOC on τ_t (9).

planner sets τ_t and π_t to lessen its own financing burden by devaluing (appreciating) inherited debt (assets).

The planner chooses $\boldsymbol{b}_t$ so that, given its own Ramsey plan defined by FOCs on τ_t (14) and π_t (16), the state of the economy $\{g_t, b_{t-1}\}$, and the government's exogenous spending process embedded in $\{g, \mathcal{P}\}$, $b_t^{(s')}$ satisfies the time $t+1$ IC (12) in every potential time $t+1$ state $s' \in \{1, \cdots, S\}$.

4.2 Non-Cooperative Equilibrium

Sargent (1986) credits Neil Wallace for characterizing monetary-fiscal coordination during the Reagan (1981–1989) and Volcker (1979–1987) years as a precarious 'game of chicken,' where fiscal policymakers promised tax reductions and expenditure plans while Fed officials pledged unwavering commitment to tight money. They pursued conflicting plans with the expectation that the other would 'chicken out' as the U.S.'s GBC tightened. These incompatible strategies created an unsustainable impasse: either the Fed would capitulate by monetizing government debt, or Congress would yield by reducing expenditures to balance budgets.

Wallace's metaphor illuminates how institutional commitments transform policy coordination into strategic gamesmanship, with macroeconomic consequences hanging in the balance.

The debt-manager commits to state-contingent plans for $\{\tau_t\}$ and $\left\{\boldsymbol{b}_t^{dm}\right\}$ to maximize its payout (3), and the central bank commits to state-contingent plans for $\{\pi_t\}$ and $\left\{\boldsymbol{b}_t^{cb}\right\}$ to maximize its payout (4), given each branch's opponent's plan and given the consolidated government's constraint set (1), (5)–(7), (9)–(10). Applying the quasi-primal approach described in Section 3.4 transforms the problem so that the debt-manager equivalently commits to state-contingent plans for $\{c_t\}$, $\{n_t\}$ and $\left\{\boldsymbol{b}_t^{dm}\right\}$ to maximize its payout (3), and the central bank commits to state-contingent plans for $\{\pi_t\}$ and $\left\{\boldsymbol{b}_t^{cb}\right\}$ to maximize its payout (4), given each branch's opponent's plan and given the ARC (1) and IC (12). For the rest of the analysis, assume inherited, maturing debt $b_{-1}^{(s)}$ is such that the debt-manager could feasibly, individually satisfy the ARC (1) and IC (12) under $\pi_t = 1$ every period.

I specify the model by setting $\rho^{dm} = 0$ and $\rho^{cb} = 1$ so that the debt-manager minimizes welfare loss from tax distortions while the central bank minimizes welfare loss from inflation.

The debt-manger's FOCs on $\{c_t\}$ and $\{n_t\}$ imply

$$u'(c_0)\left[1+\lambda_0^{dm}\right]+\lambda_0^{dm}\left[u''(c_0)\left(c_0-\frac{b_{-1}^{(s)}}{\pi_0}\right)\right]=v'(n_0)\left[1+\lambda_0^{dm}\right]+\lambda_0^{dm}v''(n_0)\,n_0 \quad \text{and} \tag{17}$$

$$u'(c_t)\left[1+\lambda_0^{dm}\right]+\lambda_0^{dm}u''(c_t)\,c_t=v'(n_t)\left[1+\lambda_0^{dm}\right]+\lambda_0^{dm}v''(n_t)\,n_t \quad \forall\ t>0 \tag{18}$$

where λ_0^{dm} is the debt-manager's Lagrange multiplier on the time 0 IC (12).

The central bank's FOCs on $\{\pi_t\}$ are

$$w'(\pi_0)\,\pi_0^2=\lambda_0^{cb}u'(c_0)\,b_{-1}^{(s)} \qquad \text{and} \tag{19}$$

$$\pi_t=1 \qquad \forall\ t>0 \tag{20}$$

where λ_0^{dm} is the central bank's Lagrange multiplier on the time 0 IC (12).

FOCs (17)–(20) are identical to the planner's FOCs (13)–(16), except for the replacement of λ_0 with λ_0^{dm} in (17)–(18) and with λ_0^{cb} in (19)–(20).

The non-cooperative government shares only two of the Ramsey planner's three policy directives. While institutions individually smooth welfare losses intertemporally and devalue inherited debt, no longer does government policy ensure that *intratemporal* marginal welfare losses from τ_t and π_t equate.

Splitting the government into two non-cooperative institutions results in a second Lagrange multiplier and, with no additional restrictions on the model, multiple state-contingent policy paths consistent with the definition of CNE.

4.2.1 A Continuum of Equilibria

For the remainder of the analysis, assume the time 0 government inherits a strictly positive amount of maturing debt $b_{-1}^{(s)}>0$.[9] So long as the debt-manager's and central bank's plans follow (17)–(20) while satisfying the ARC (1) and IC (12), no institution finds it desirable to deviate from its own plan. Any deviation from such a plan along the ARC (1) violates either the IC (12) or optimal smoothing of individual payout losses.

For instance, in the case where the debt-manager sets taxes lower than what is required to

[9] This assumption is not required for future results, but it aids in clarifying exposition.

finance inherited debt and current and expected future spending along a zero (net) inflation plan ($\pi_t = \pi = 1 \ \forall t$), the central bank optimally inflates away a portion of the inherited debt stock's real value to ensure the ARC (1) and IC (12) hold while it follows its payout-maximizing plan according to (19)–(20).

Conversely, in the case where the central bank sets inflation lower than what is required to entirely erode away inherited debt's value ($\pi_0 < \infty$), for instance, the debt-manager optimally taxes households to pay off un-eroded inherited debt and current and expected future spending to ensure the ARC (1) and IC (12) hold while it follows its payout-maximizing plan given by (17)–(18).

Either institution can act in an unconstrained manner, but only so long as the other institution picks up the slack to satisfy the consolidated government's constraints. An unconstrained debt-manager sets taxes only to finance new government spending without financing any inherited debt, relying on the central bank to hyperinflate all debt away at time 0 $\left(\lambda_0^{cb} \to \infty\right)$. An unconstrained central bank sets inflation to $\pi_t = \pi = 1$ every period, leaving the debt-manager to finance the entire stock of inherited debt as well as current and future spending with explicit taxes $\left(\lambda_0^{cb} = 0\right)$. The continuum between these extremes all satisfy CNE and can be indexed by the central bank's Lagrange multiplier $\lambda_0^{cb} \in [0, \infty)$.

There exists another continuum of CNE – one associated with time 0 deflation $\left(\lambda_0^{cb} < 0\right)$. I define a boundary set of inherited debt structures $\hat{b}_{-1}$ as

$$\hat{b}_{-1} \equiv \left\{ b_{-1} \in \mathbb{R}^S_{++} : \forall b'_{-1} > b_{-1}, \pi_0 > 1 \text{ is required for CNE} \right\}$$

to characterize this continuum in Lemma 1.

Lemma 1 ***(payoff dominated CNE)*** *$\forall b_{-1} \in \left(\mathbf{0}, \hat{b}_{-1}\right)$, $\exists \lambda_0^{dm} > 0$, $\lambda_0^{cb} < 0$ which satisfies a CNE.*

Proof: The proof can be found in appendix A.

As long as solvency is feasible under time 0 deflation ($\pi_0 < 1$), there exists CNE beyond the continuum observed between unconstrained institutions $\lambda_0^{cb} \in [0, \infty)$. Given maturing inherited debt, this continuum of 'payoff dominated' CNE can be indexed by $\lambda_0^{cb} \in [-N, 0)$ where $N \geq 0$ is a constant. Deflated inherited debt needs to be financed by higher taxes than those required for a zero inflation economy. Conversely, any path of sufficiently elevated tax rates needs to be accommodated by deflation so that the ARC (1) and IC (12) hold.

I call this set of equilibria 'payoff dominated' due to the fact that institutions could individually be made better off moving the economy toward a zero inflation ($\lambda_0^{cb} = 0$) equilibrium. Tax distortions fall and costly deflation wanes as a negative λ_0^{cb} approaches 0.

4.2.2 Payoff Dominance: A Refinement

Payoff dominance, as proposed by Harsanyi and Selten (1988), is a refinement criterion for selecting among multiple Nash equilibria. It asserts that, when faced with multiple equilibria, rational, non-cooperative players will coordinate to eliminate equilibria where players can be individually made better off.

I apply Harsanyi and Selten (1988)'s payoff dominance refinement to Section 3.1's CNE definition, eliminating all CNE indexed from $\lambda_0^{cb} \in [-N, 0)$ and leaving the set of payoff dominant CNE as those indexed from $\lambda_0^{cb} \in [0, \infty)$.

4.2.3 Fiscal Strength and a Unique Equilibrium

Beginning with the Fed's inception in 1913, and continuing through the Treasury-Fed Accord in 1951 until today, U.S. fiscal policymakers have placed varying degrees of (implicit and explicit) pressure on Fed officials. Arguments in support of reduced Fed operational independence resurfaced during the U.S.'s 2024 presidential election. Common rhetoric included calls for a fiscal seat on the FOMC, for the president to be personally consulted on rate decisions, and for stronger Fed oversight by the Treasury.

The model's multiplicity serves as an opportunity to determine a unique equilibrium while simultaneously introducing a measure of institutional strength. One that can be used to measure the degree to which fiscal policy pressures monetary policy using macroeconomic data alone.

To close the model, I introduce the asymmetric Nash bargaining solution proposed by Harsanyi and Selten (1972). Institutions agree to maximize a product of individual surpluses, weighted by the amount of bargaining power the debt-manager possesses relative to the central bank. The weighted product is

$$\left(W_0^{dm} - d_0^{dm}\right)^{\alpha} \left(W_0^{cb} - d_0^{cb}\right)^{1-\alpha} \tag{21}$$

where d_0^i is institution i's payout under its worst-case feasible CNE and where $\alpha \in [0,1)$ is a measure of fiscal strength. Maximize (21) taking α as given to arrive at the model's unique solution.

Conventional bargaining models include non-cooperative games where a set of feasible equilibria lie inside the Pareto frontier. With some justification, one such equilibrium from that set is designated the game's 'disagreement equilibrium,' which players realize should negotiations break down. Players' 'disagreement payouts' are typically used for $\{d_0^i\}$.

This paper's model differs from a standard bargaining set-up due to the full set of feasible CNE lying on the Pareto frontier – the IC (12). Imagine a single, feasible equilibrium is labeled the model's disagreement point. In such a scenario, equilibrium collapses to that disagreement point for all $\alpha \in [0,1)$ as the bargaining solution (21) maximizes a weighted product of utility gains relative to the disagreement point, and, by definition, any movement along the IC (12) results in a negative weighted product (21).

I use the endpoints of the Pareto frontier as player-specific reference points for $\{d_0^i\}$, rather than those from a single disagreement outcome. The approach shares conceptual similarities with economic analyses of claims problems in O'Neill's (1982) work and spatial voting models by Downs (1957) and Black (1958), while maintaining a structure consistent with asymmetric bargaining.

The debt-manager enjoys its best-case scenario when fiscal strength approaches $\alpha \to 1$ so that inherited nominal debt is fully financed by time 0 hyperinflation and taxes only need to finance current and expected future spending. Symmetrically, the central bank achieves its best-case scenario when fiscal strength is set to $\alpha = 0$ so that debt and spending are entirely tax-financed. The continuum indexed by $\lambda_0^{cb} \in [0,\infty)$ is also indexed by $\alpha \in [0,1)$.

Finally, denote the welfare-maximizing level of fiscal strength α^* as the amount of fiscal bargaining power for which equilibrium allocations are consistent with those defined by the Ramsey plan in Section 4.1. Institutions are equally constrained when $\alpha = \alpha^*$ so that $\lambda_0^{dm} = \lambda_0^{cb} = \lambda_0$.

5 Model Calibration

I consider a two-sate (low and high government spending) economy where households derive per-period payoffs in the form

$$u(c_t) - v(n_t) - w(\pi_t) = \frac{c_t^{1-\sigma}}{1-\sigma} - \frac{n_t^{1+\varphi}}{1+\varphi} - \frac{1}{2}\theta\left(\frac{1}{\pi_t} - 1\right) \tag{22}$$

for the remainder of the paper, where $\sigma = \varphi = 2$. Time periods are years, so I set $\beta = 0.9875^4$ to match the annualized time discount factor from Chari, Christiano, and Kehoe (1995) and Buera and Nicolini (2004). I set government spending $\{g_\ell, g_h\} = \{0.1764, 0.3568\}$ and transition matrix probabilities $\{p_{\ell\ell}, p_{hh}\} = \left\{\frac{75}{76}, \frac{2}{3}\right\}$ to match U.S. (spending+transfer) moments from 1942–2024.[10]

Inherited debt $b_{-1} = 0.5210$ matches the U.S.'s average debt-to-GDP ratio from 1942–2022. The functional form for $w(\pi_t)$ comes from Sims's (2013) work. I set $\theta = 1.22$ so that the planner chooses $\pi_0 = 1.0340$, the U.S.'s average inflation rate from 1943–2023, given the rest of the calibration.

5.1 Fiscal Strength and Tax, Inflation Determination

An optimizing debt-manager perfectly smooths time $t > 0$ tax rates $\tau_t = \bar{\tau}$ according to its FOC (18).[11] An optimizing central bank perfectly smooths time $t > 0$ inflation $\pi_t = 1$ according to its FOC (20). The IC (12) relates surprise inflation π_0 and the path of taxes $\{\tau_0, \bar{\tau}\}$.

Figure 1 shows the relationship between the stationary tax rate $\bar{\tau}$ and time 0 inflation π_0, visualizing the economy's Pareto frontier discussed in Section 4.2.3 along which institutions determine economic outcomes. Government policy to the left of the frontier violates the household budget constraint, while policy to the right is inconsistent with household, debt-manager and/or central bank optimization.

The government can jointly set taxes lower than 20.2% should it inflate away inherited debt. Hyperinflation of such debt allows for a 3.5% tax reduction to 16.7%. Setting fiscal strength $\alpha \in [0, 1)$ determines where on Figure 1's frontier the economy falls.

Figure 2 displays the relationship between tax and inflation rates along a portion of the fiscal-monetary regime continuum, marking the amount of fiscal strength required to implement the

[10]Data sources are listed in Appendix D.
[11]The debt-manger's FOC (18) and isoelastic household utility in c_t and n_t imply this result.

Ramsey plan. I compare the CNE consistent with first-best to corner CNE in Table 1.

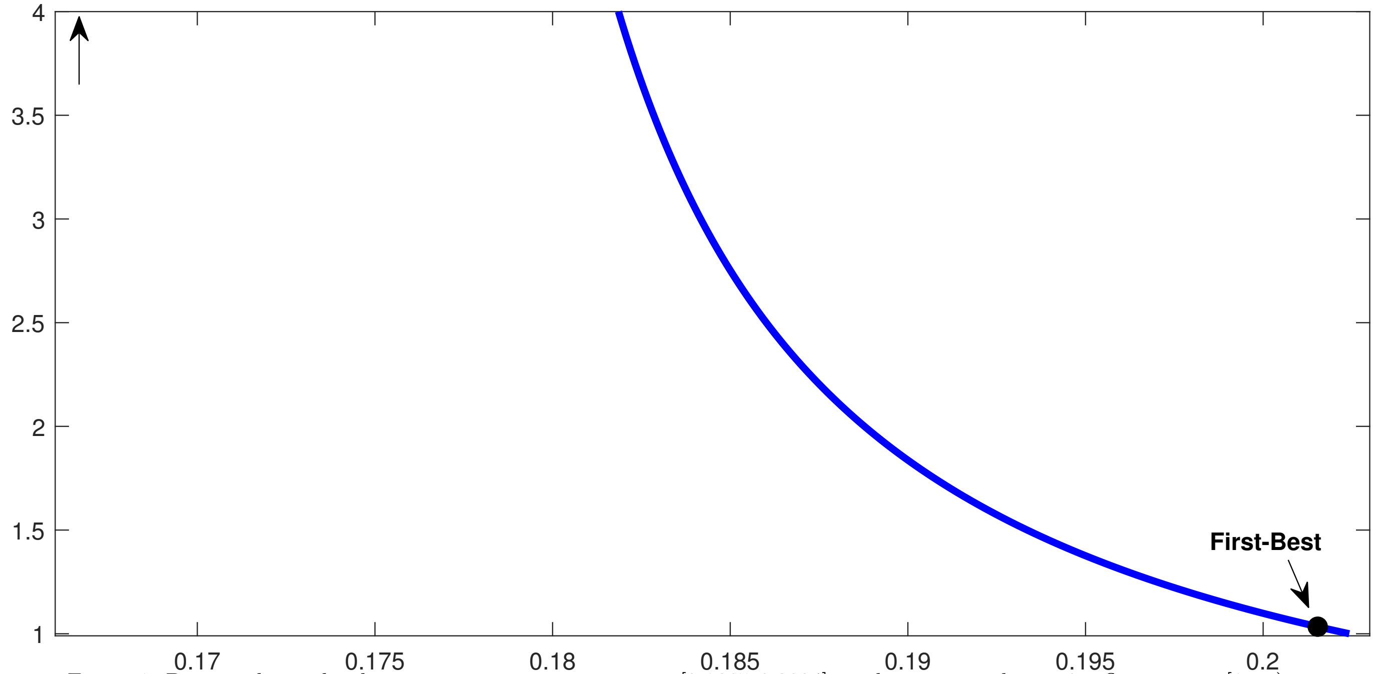

Figure 1: Pareto relationship between stationary tax rate $\bar{\tau} \in [0.1665, 0.2024]$ on the x-axis and time 0 inflation $\pi_0 \in [1, \infty)$ on the y-axis. All feasible equilibria lie along the frontier: points to the left violate the household budget constraint (6) and points to the right violate household, government optimization (9), (17)–(20).

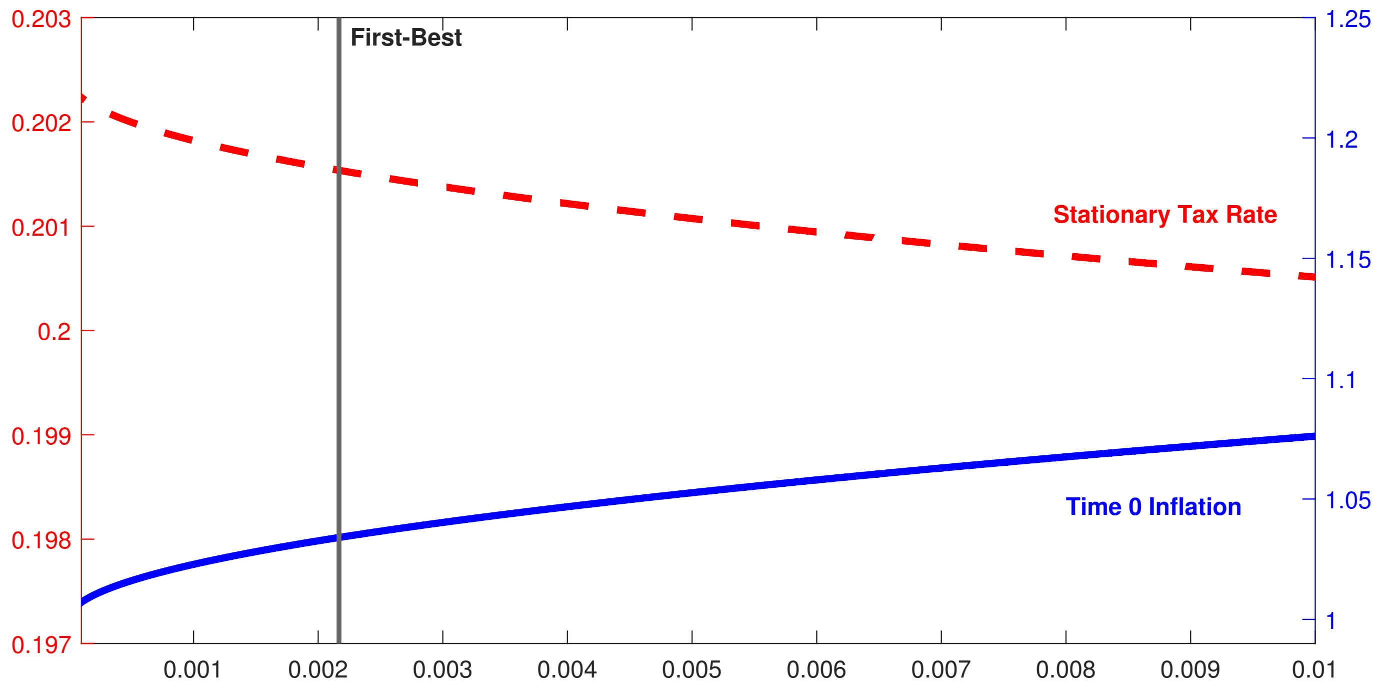

Figure 2: Stationary tax rate $\bar{\tau}$ (left y-axis) and time 0 inflation π_0 (right y-axis) across fiscal strengths, $\alpha \in [0, 0.01]$ (x-axis).

The economy matches the Ramsey Planner's solution only under an extremely powerful central bank, one with more than 99% of the government's relative bargaining power. This result arises

CNE	α	$\bar{\tau}$	π_0
All-powerful central bank	0	0.2024	1
Ramsey plan	0.0022	0.2015	1.0340
All-powerful debt-manager	1	0.1665	∞

Table 1: Fiscal strengths, stationary tax rates and time 0 inflation rates across corner and first-best CNE

because, while the debt-manager feasibly sets taxes somewhere between 16.65%-20.24%, a relatively narrow range, feasible central bank outcomes span from zero (net) inflation to hyperinflation. This large fiscal-monetary asymmetry in payout possibilities, paired with the fact that welfare is maximized when $\pi_0 = 1.0340$, results in a government that requires a strong central bank to match the planner's solution.

Figure 3 displays welfare outcomes across the same fiscal strength range. Consumption-equivalent welfare loss moving left from the Ramsey plan $\alpha = \alpha^*$ to an all-powerful central bank $\alpha = 0$ is about half of that moving right from the Ramsey plan $\alpha = \alpha^*$ to a government where fiscal policy has just one percent of relative bargaining power $\alpha = 0.01$. Welfare maximization is approximated by an all-powerful central bank – a theoretical result joining a well-established chorus of support for strong, independent monetary policy.

An omnipotent central bank comes closer to maximizing welfare with higher welfare costs from inflation $\theta \to \infty$ and with lower levels of inherited debt $b_{-1}^{(s)} \to 0$, relative to baseline. When households greatly dislike inflation, a more powerful inflation-minimizing central bank is required to match the Ramsey plan. When the government is saddled with high levels of maturing debt, though, a less powerful central bank is required to match the Ramsey plan, as surprise inflation devalues more debt while imposing identical welfare losses. Appendix B explains these relationships in more detail.

5.2 A Time Series of American Fiscal Strength

I use this paper's framework to rationalize American inflation outcomes. Figure 4 displays imputed U.S. government fiscal strength relative to the Fed from 1943–2023.

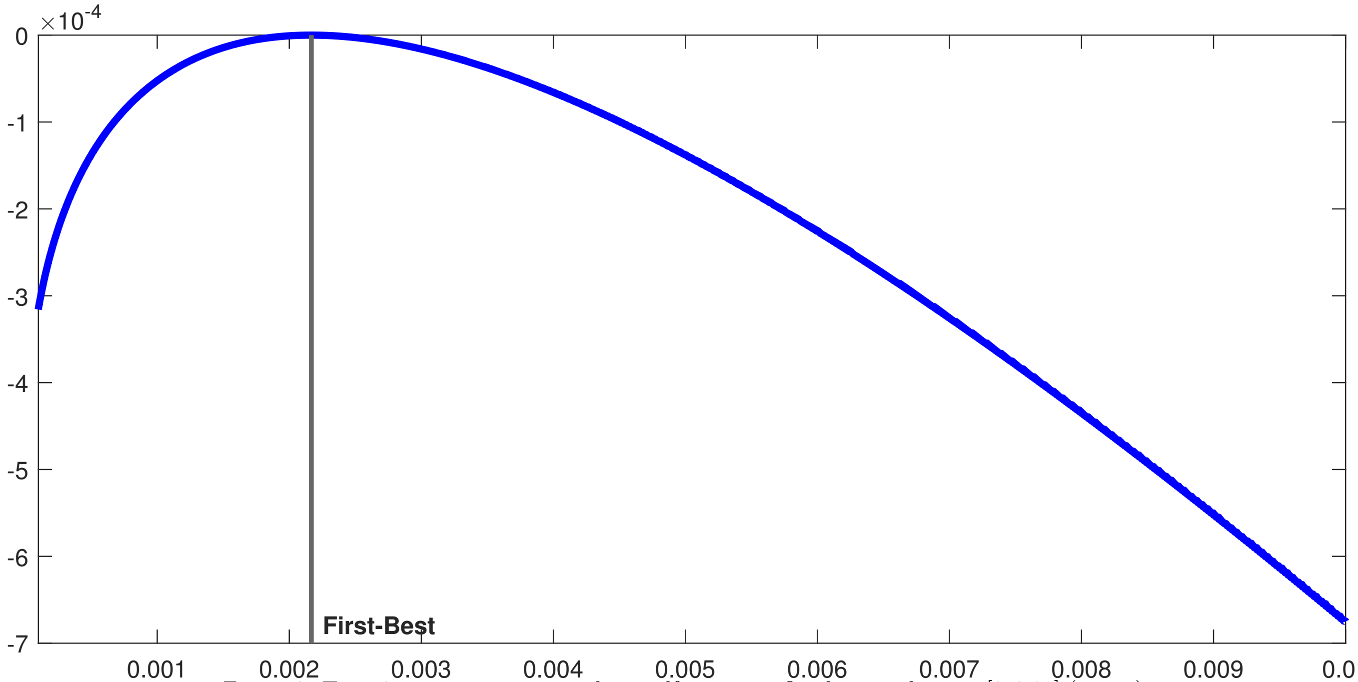

Figure 3: Time 0 consumption-equivalent welfare across fiscal strengths, $\alpha \in [0, 0.01]$ (x-axis).

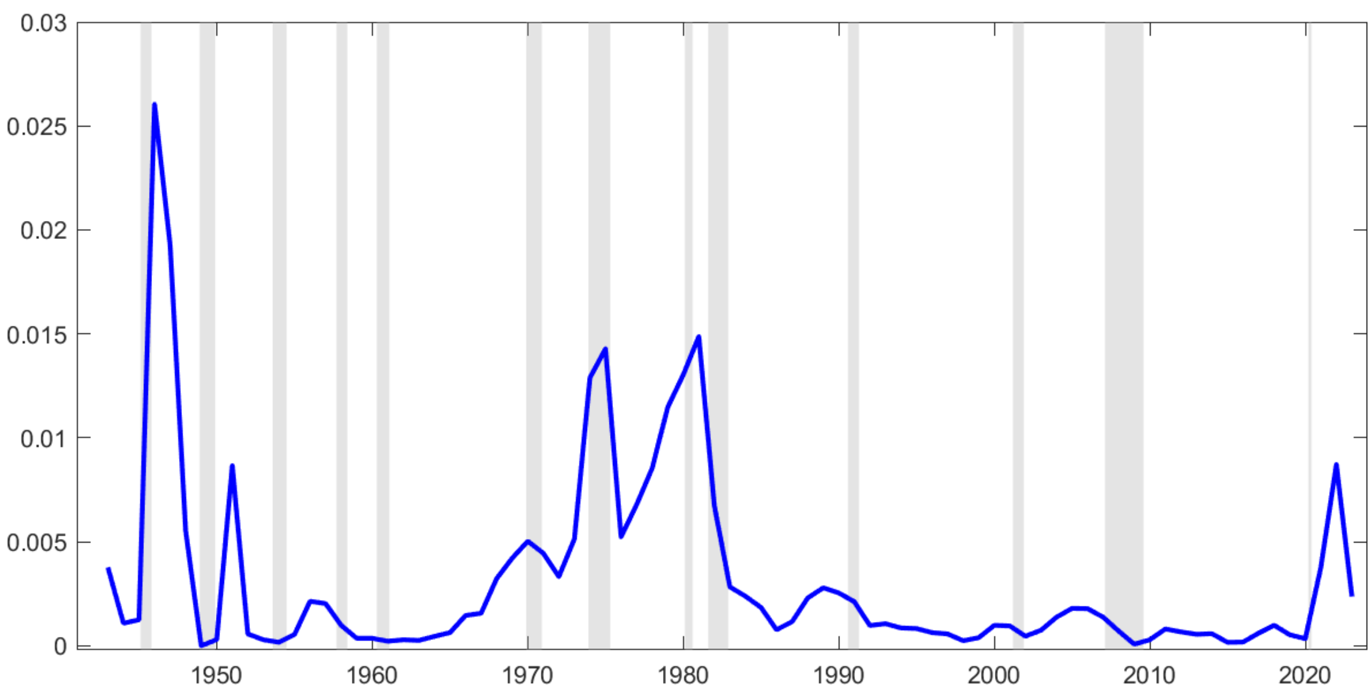

Figure 4: U.S. fiscal strength from 1943-2023. I re-solve the model every year, given that year's observed inherited debt and spending $\{b_{-1,t}, g_{0,t}\}_{t=1943}^{2023}$, and selecting fiscal strength $\{\alpha_t\}_{t=1943}^{2023}$ (y-axis) which sets time 0 inflation π_0 equal to observed inflation $\pi_{0,t}$ every year. Debt and spending data are measured as percentages of GDP.

The series exhibits three periods of elevated fiscal strength: from 1947–1951, throughout the 1970s, and from 2021–2023.

The U.S. Treasury explicitly pressured the Fed from WWII until the 1951 Treasury-Fed Accord. Prior to the Accord, the Fed had an obligation to repress interest rates to support new debt issuance, which constrained its ability to independently manage monetary policy to fight inflation. Pre-1951, monetary policy was thus torn between fighting inflation and propping up bond prices. This, coupled with Congress's repeated reluctance to raise post-war surpluses until the second half of 1948, resulted in increased levels of fiscal strength until the 1949 recession.[12] Fiscal strength again spiked upward in 1951 but immediately fell and remained low until the late 1960s.

In 1964, President Lyndon B. Johnson pushed Fed Chair William McChesney Martin against a wall and exclaimed, "Martin, my boys are dying in Vietnam and you won't print the money I need." In 1971, Fed Chair Arthur Burns wrote, "I am convinced that the President [Nixon] will do anything to be reelected." Indeed, Figure 4 shows fiscal strength beginning to rise during the U.S.'s mid-1960s deployments to Vietnam. American inflation followed suit, continuing to rise and peaking at above 13% in 1979 before falling to less than 4% in 1982, midway through Paul Volcker's (1979-1987) term: a Fed Chair who stood up to Congress in 1980, declaring, "Monetary policy cannot – without peril – be relied on alone to halt inflation. The other major tools of public policy must also be brought to bear on the problem, with fiscal policy playing a central role."

America endured a global health crisis from 2020-2022, committing to six trillion dollars in additional spending and transfer programs over that time.[13] Despite the U.S.'s large fiscal response and resulting ballooning debt position, there was little discussion from policymakers about how COVID policies would ultimately be financed. Eventually, in 2022, White House Press Secretary Jen Psaki said "It's important to note that we believe [federal transfers] should be provided on an emergency basis, not something where it would require offsets." Congress heavily borrowed and chose to keep taxes low despite potential inflationary consequences, which were then realized from 2022–2023. These events perfectly illustrate growing fiscal strength's economic impacts.

[12] Caplan (1956) documents federal policy shifts leading up to the 1949 recession.
[13] Anderson and Leeper (2023) break down the U.S.'s fiscal response to COVID.

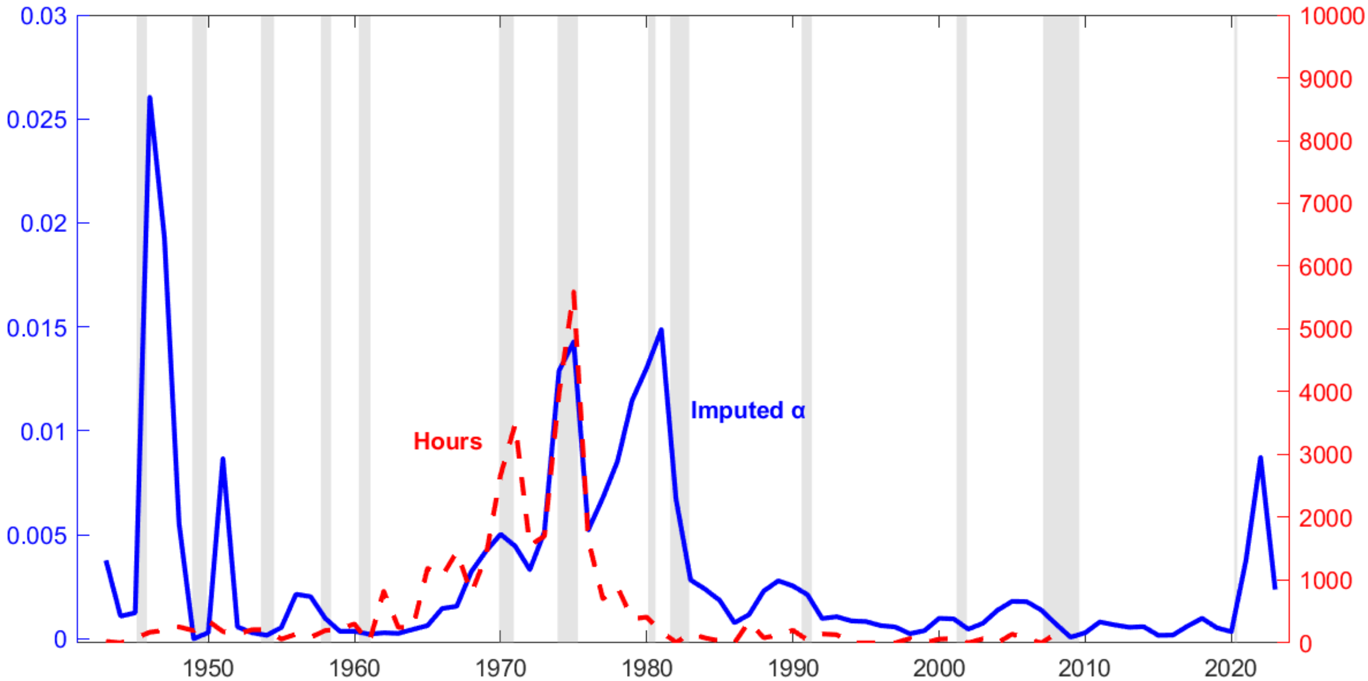

Figure 5: Imputed U.S. fiscal strength (left y-axis) and Drechsel (2024)'s president-Fed official hours in meetings (right y-axis) from 1943-2023.

5.2.1 Comparing to President-Fed Meeting Data

Drechsel (2024) extracts presidential meeting data from archival records and measures inflationary effects of presidential pressure on the Fed. One of the paper's major contributions is a novel dataset including the number of meetings between American presidents and Fed officials from 1933-2016 and the hours presidents spent with Fed officials from 1933-2008.

I see fiscal strength as the theoretical counterpart to Drechsel (2024)'s political pressure, so I plot imputed fiscal strength against the number of hours the president met with Fed officials per year in Figure 5.

Prior to the Treasury-Fed Accord of 1951, the Fed lacked meaningful monetary policy independence despite limited direct presidential engagement, operating primarily in support of Treasury issuance. The 1951 Accord formally established the Fed's policy autonomy, and post-Accord fiscal strength declined as president-Fed hours remained low. Fiscal strength started to pick up in the mid-1960s when meeting hours began to increase, marking a new era of political influence on monetary policy through direct presidential pressure.[14]

From 1960–1970, the steady increase in imputed fiscal strength matches that in president-Fed

[14]Drechsel (2024) explores strains on early-1970s fiscal and monetary relationships in more detail.

hours. Imputed fiscal strength and president-Fed hours each spike upwards twice between 1971–1981, with hours declining in the late 70s before fiscal strength declines in the early 80s. The two remain low from the mid-80s until the end of hours data in 2008.

A major advantage of imputing fiscal strength through a model like the one described above is the availability of data. Records of presidential meeting duration ended in 2008 during W. Bush's final term. Those of presidential meetings ceased altogether in 2016 during Obama's final term. Fortunately, interpreting fiscal strength as political pressure allows one to implicitly derive political pressure for any year when aggregate economic data are available.

I follow Drechsel (2024) by classifying presidents and Fed chairs according to the average annual imputed fiscal strength during their terms from 1943–2023. I compare this to the average annual number of hours the president spent meeting with Fed officials over the same date range. Table 2 lists presidents in the left panel and Fed chairs in the right panel.

President	**Fiscal Strength**	**Hours**
Carter (D)	1.19	455.43
Ford (R)	0.75	1897.4
Nixon (R)	0.71	3021.1
Truman (D)	0.69	213.83
Biden (D)	0.55	
Roosevelt (D)	0.44	47
Reagan (D)	0.26	102.03
Johnson (D)	0.22	1169.3
Bush HW (R)	0.17	127.35
Trump (R)	0.16	
Bush W (R)	0.10	
Eisenhower (R)	0.08	158.77
Clinton (D)	0.07	24.742
Obama (D)	0.05	
Kennedy (D)	0.03	443.51

Fed Chair	**Fiscal Strength**	**Hours**
Miller	1.22	395.56
Eccles	0.92	122.84
Burns	0.77	2368.5
Volcker	0.46	124.76
Powell	0.32	
McCabe	0.28	232.44
Martin	0.13	632.95
Greenspan	0.12	61.731
Bernanke	0.06	
Yellen	0.05	

Table 2: President and Fed chair average annual imputed fiscal strength (in hundredths) and annual president-Fed official meeting hours from 1943–2023. Hours data are from Drechsel (2024). Blank entries represent periods for which data are unavailable.

Jimmy Carter's (1977–1981) average annual imputed fiscal strength is substantially higher than any other eligible president at 1.19 despite spending relatively few hours with Fed officials. Carter's presidency succeeded Gerald Ford's (1974–1977) and Richard Nixon's (1969–1974) terms – the presidents with the next highest fiscal strengths and who spent the most hours meeting with the Fed. G. William Miller (1978–1979) tops eligible Fed chairs with 1.22 average annual fiscal strength, and, while his tenure at the Fed was brief, monetary policy had a reputation for being loose under his watch. Marriner S. Eccles (1934–1948) and Arthur Burns (1970–1978) are next on the list.

The two presidential terms featuring the least amount of fiscal strength are those of Barack Obama (2009–2017) and John F. Kennedy (1961–1963). Inflation remained historically low during Obama's presidency after he announced "... I'm pledging to cut the deficit we inherited in half by the end of my first term in office" in 2009 during the Great Recession. Ben Bernanke's (2006–2014) and Janet Yellen's (2014–2018) terms feature the lowest amount of fiscal strength among in-sample Fed chairs, as their time heading the Fed featured low inflation in spite of high government debt.

Figure 6 plots the relationship between imputed fiscal strength and hours data from Table 2. The relationship between the two among presidential and Fed chair terms are positive, with R^2s of 0.15 and 0.04, respectively.

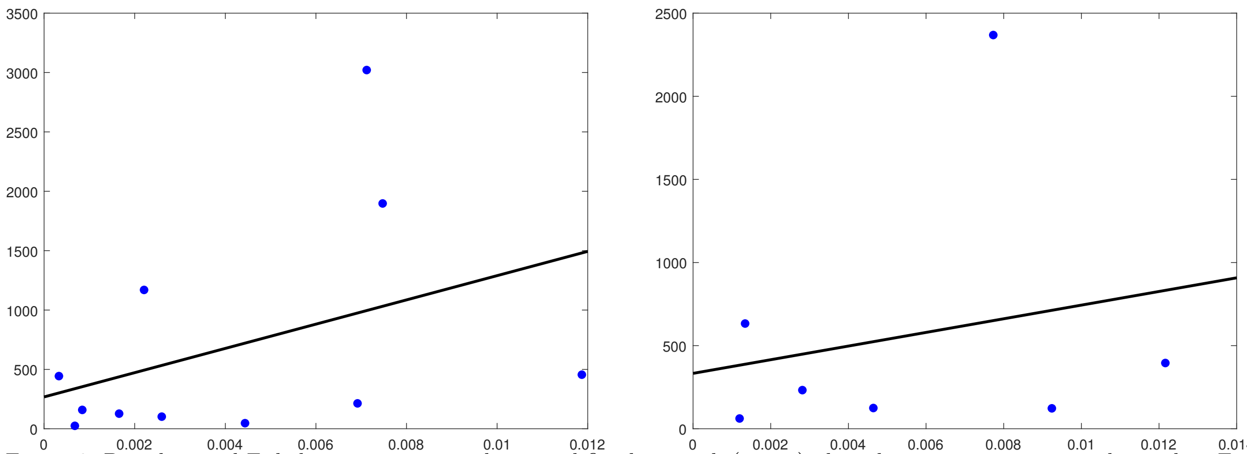

Figure 6: President and Fed chair average annual imputed fiscal strength (x-axis) plotted against average annual president-Fed official meeting hours (y-axis) from 1943–2023. Presidents plotted in the left panel and Fed chairs plotted in the right panel. Each term in office is one entry. Hours data are from Drechsel (2024).

5.2.2 Comparing to First-Best

This section's final exercise is a normative one. For each year from 1943–2023, how does imputed fiscal strength compare to that which would maximize welfare? Figure 7 plots imputed fiscal strength against first-best fiscal strength.

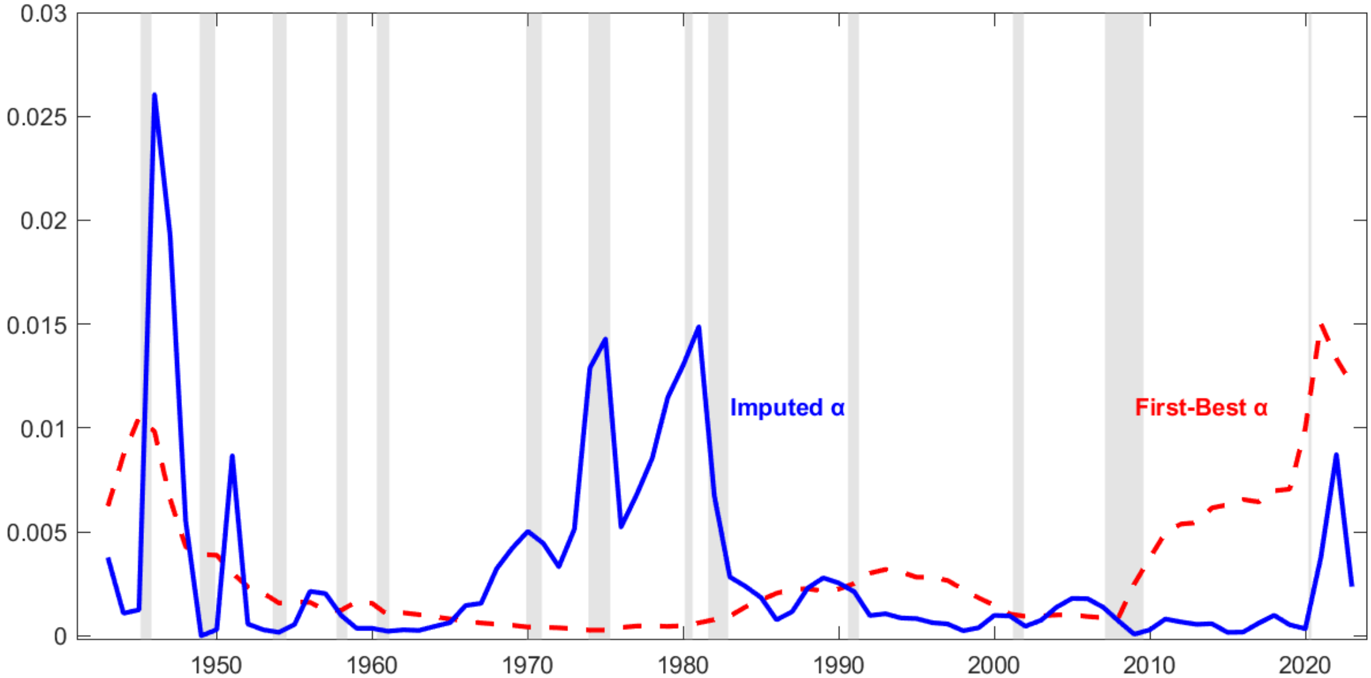

Figure 7: Comparing U.S. fiscal strength to that which implements the Ramsey plan from 1943–2023. I re-solve the model every year, given that year's observed inherited debt and spending $\{b_{-1,t}, g_{0,t}\}_{t=1943}^{2023}$, and select fiscal strengths $\{\alpha_t\}_{t=1943}^{2023}$ (y-axis) which result in allocations matching the model's Ramsey plan. Debt and spending data are measured as percentages of GDP.

Wartime and post-war imputed strength, albeit with high variability, decline with first-best strength. Imputed strength in the 1970s is an order of magnitude larger than that which matches the Ramsey plan. Starting with the Great Recession in 2008 and moving forward until 2023, first-best fiscal strength is *larger* than imputed fiscal strength.

If taxes are too high (fiscal strength is too low) relative to the Ramsey plan, welfare losses from labor distortions dominate those from inflation. If inflation is too high (fiscal strength is too high) relative to the Ramsey plan, inflation-derived welfare losses dominate those from labor market distortions. Financing the government requires facing a trade-off between using the two tools, and the Ramsey planner equates their marginal welfare losses.

The discrepancies in Figure 7 largely relate to the link between inherited debt and welfare maximizing inflation. Surprise inflation is more powerful at financing high-debt governments than low-debt ones, but 1% of inflation reduces household welfare identically across the two. First-best fiscal strength rises in years where the U.S. inherits large levels of debt. Figure 8 visualizes this relationship.

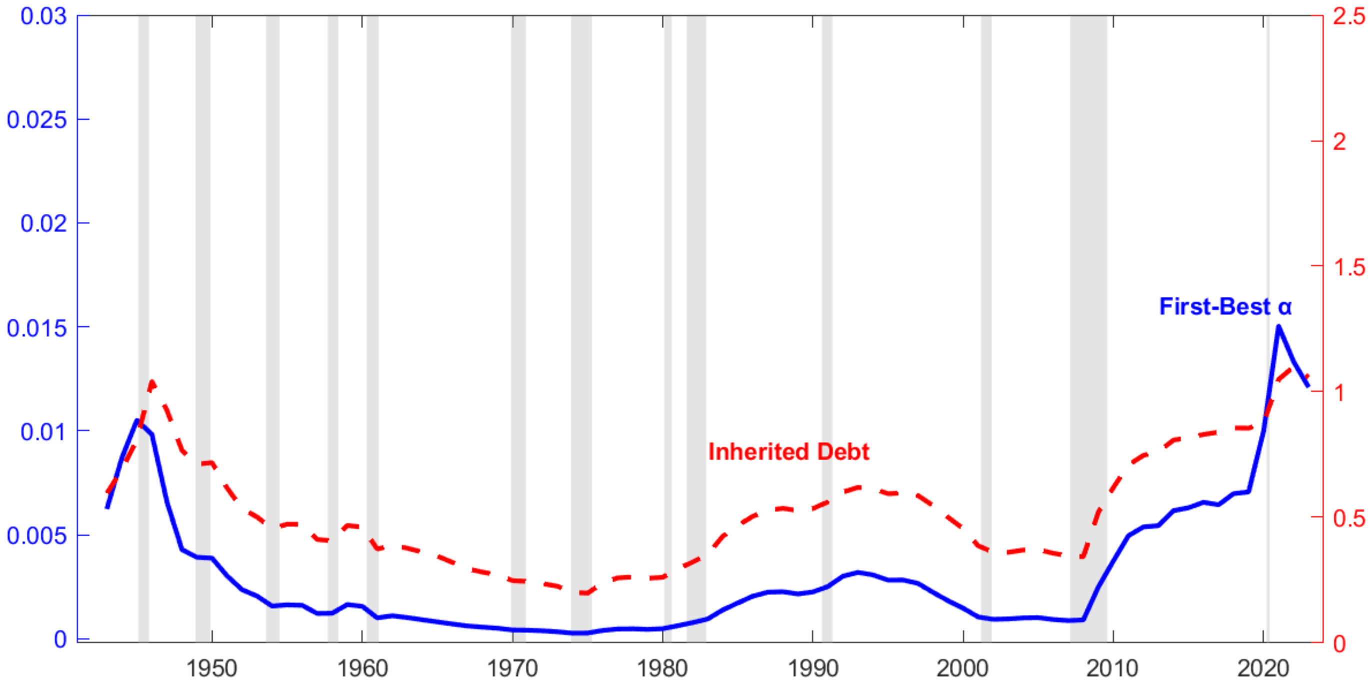

Figure 8: Comparing U.S. fiscal strength which implements the Ramsey plan (left y-axis) to the U.S.'s inherited debt/GDP ratio (right y-axis) from 1943–2023.

The 1970s featured less than 27% outstanding debt/GDP, yet U.S. annual inflation topped out at around 10% over the period – high inflation financed a large portion of a small debt stock. From 2008–2018, inflation peaked at around 2% while government debt spiked in 2008 and gradually increased through 2018, where it reached around 86% of GDP – low inflation did little to finance a large debt stock. According to the model, if the rise in COVID fiscal strength (and resulting inflation) was surprising, such a surprise *improved* welfare relative to an alternative at the Fed's 2% target because it relieved the economy from tax-financing the increase in indebtedness.

6 Under a Maturity Structure of Non-Contingent Debt

This section answers two main questions. First, "What is the value of borrowing in long-term debt along the Ramsey plan?" Second, "How well does the maturity structure of government debt mitigate welfare loss when the government settles on policy away from first-best?"

I answer these questions in three steps. First, I re-specify the baseline model's debt portfolio so that the government issues an effectively-complete markets maturity structure of debt, re-calibrating inherited debt to target the average U.S. maturity structure from 1943–2023.[15] Second, I specify two analogous Arrow security economies by varying the baseline model's inherited debt stock: a welfare-equivalent economy and a debt-equivalent economy. In the welfare-equivalent Arrow security economy, I set inherited debt such that households are indifferent between living in the maturity structure economy and the welfare-equivalent economy when both economies operate along their own Ramsey plans. In the debt-equivalent Arrow security economy, I set inherited debt such that the real (deflated) market value of inherited debt is identical to that of the inherited maturity structure, holding policy constant across the two. Third, I compare the three economies' welfare outcomes, both at first-best and along the fiscal strength continuum $\alpha \in [0,1)$.

To be concrete, assume an identical model to that described in Section 2 and specified in Section 4.2, except that households now lend (borrow) in dollars using a portfolio of nominal, non-contingent government debt $B_t = \left\{B_t^{(t+j)}\right\}_{j=1}^{J}$, where j represents a bond's term to maturity. Additionally, the number of debt maturities J is equal to the number of Markov states $S = 2$ so that, according to arguments similar to those made in Angeletos (2002) and Buera and Nicolini (2004), the government may implement almost any complete market allocation by replicating state-contingent debt using unique linear combinations of debt maturities.[16] As a result, Proposition 1 continues to hold: the ARC, IC and opponent's choices remain each institution's relevant constraints.

The debt-manager now chooses (issues) a maturity structure $\boldsymbol{B}_t^{dm} = \left\{\boldsymbol{B}^{(t+j),dm}\right\}_{j=1}^{2}$ and the central bank simultaneously chooses (demands) debt holdings $\boldsymbol{B}_t^{cb} = \left\{\boldsymbol{B}^{(t+j),cb}\right\}_{j=1}^{2}$ to maximize their respective objectives (3)–(4). Debt markets continue to clear according to (5). The full model is described in appendix C.

The economy's IC now reads

$$\underbrace{\frac{1}{\pi_t}\left\{b_{t-1}^{(t)} + \beta \mathbb{E}_t\left[\frac{1}{\pi_{t+1}}\frac{u'(c_{t+1})}{u'(c_t)}\right] b_{t-1}^{(t+1)}\right\}}_{\text{MV(debt)}/P_t} = \underbrace{\frac{1}{u'(c_t)}\mathbb{E}_t\sum_{i=0}^{\infty}\beta^i\left[u'(c_{t+i})\,c_{t+i} - v'(n_{t+i})\,n_{t+i}\right]}_{\mathbb{E}_t[\text{PV(primary surpluses)}]} \tag{23}$$

[15] Lucas and Stokey (1983), Angeletos (2002), Buera and Nicolini (2004) and Faraglia, Marcet, and Scott (2010), among others, explore how a Ramsey planner completes markets using a maturity structure of public debt. Such an assumption is tractable yet counter-factual (see Faraglia, Marcet, and Scott (2010) for a critique). I assume effectively complete markets here in an effort to fairly compare such an economy to baseline.

[16] There is a question of whether state-contingent inflation may be chosen such that the government cannot insure itself with ex-post prices of unmatured, deflated debt. This is not an issue in the following numerical exercises.

where a household's real (indexed) debt holdings are $b_t^{(t+j)} \equiv \frac{B_t^{(t+j)}}{P_t}$, the government's real debt supply is $\boldsymbol{b}_t^{(t+j)} \equiv \frac{\boldsymbol{B}_t^{(t+j)}}{P_t}$.

The left-hand side of the economy's IC (23) includes the market value of unmatured debt, which depends on future policy. Because τ_{t+1} and π_{t+1} now affect the level of initial government indebtedness, institutions may choose to smooth welfare losses from surprise debt devaluation over time by using time t and time $t+1$ policy.[17]

6.1 Two Welfare Comparisons

I continue to use Section 5's utility specification and numerical calibration except for the model's initial maturity structure, which is now $\left\{b_{-1}^{(0)}, b_{-1}^{(1)}\right\} = \{0.2261, 0.2949\}$, matching U.S. average debt-to-GDP ratios from 1943–2023 of debt maturing within 1 year and in greater than 1 year, respectively.

To responsibly measure welfare improvements when introducing a maturity structure to an economy, I compare three economies: the recently-described 'maturity structure economy,' a 'welfare-equivalent economy,' and a 'debt-equivalent economy.' The latter two are Arrow security economies with structures like the baseline economy discussed in sections 2–5.

The welfare-equivalent economy is defined by simply setting this paper's baseline economy's inherited debt stock $b_{-1}^{(s)}$ so that welfare along the maturity structure economy's Ramsey plan is equivalent to that along the welfare-equivalent economy's Ramsey plan.

The debt-equivalent economy is defined by setting this paper's baseline economy's inherited debt stock $b_{-1}^{(s)}$ so that its market value of inherited debt is equivalent to that of the maturity structure economy's inherited debt, holding policy constant at the debt-equivalent economy's Ramsey plan, so that

$$\underbrace{b_{-1}^{(s)}}_{\text{Debt-Equivalent}} = \underbrace{b_{-1}^{(0)} + \beta \mathbb{E}_0 \left[\frac{1}{\pi_1} \frac{u'(c_1)}{u'(c_0)} \right] b_{-1}^{(1)}}_{\text{Maturity Structure}} \tag{24}$$

I define the debt-equivalent economy this way to ensure that any additional debt devaluation by the maturity structure's planner is not bestowed upon the debt-equivalent economy in par value terms in its definition.

[17] More generally, smoothing occurs from period 0 to period $J - 1$.

6.1.1 Value of Long-Term Debt

What is the value of borrowing in long-term debt along the Ramsey plan? Table 3 compares welfare improvements from moving from the debt-equivalent economy to the welfare-equivalent economy.

Economy (Ramsey Plan)	b_{-1}	W_0 (CE)
Welfare-Equivalent	$\{0.5093, 0\}$	0
Debt-Equivalent	$\{0.5182, 0\}$	-0.0005

Table 3: Inherited debt and consumption-equivalent welfare in the welfare-equivalent and debt-equivalent economies.

Households in the first-best debt-equivalent economy are indifferent between consuming 0.0005, or 0.054%, more in period 0 and moving to the first-best welfare-equivalent economy. A more salient measure of improvement across economies may be that households in the debt-equivalent economy are indifferent between their Ramsey planner inheriting 0.89% less debt and moving to the first-best welfare-equivalent economy. This 0.89% times 2023 U.S. GDP ($27.72T) is about $247B.

Adding a maturity structure allows the Ramsey planner to improve welfare by smoothing surprise debt devaluation across time. Such a result is not unique to effectively complete markets. Work by Lustig, Sleet, and Yeltekin (2008), Debortoli, Nunes, and Yared (2017), Faraglia et al. (2019) and Leeper and Zhou (2021) in incomplete market settings discuss unmatured long-term debt's role in absorbing unforeseen monetary and fiscal shocks through movements in its ex-post market price. The added flexibility of debt revaluation without the exclusive use of contemporaneous taxes and inflation results in a planner that can push financing costs further into the future.

6.1.2 Maturity Structure and Non-Cooperation

How well does the maturity structure of government debt mitigate welfare loss when the government chooses policy away from first-best? Figure 10 compares time 0 consumption-equivalent welfare from the maturity structure economy and welfare-equivalent economy along $\alpha \in [0, 0.01]$.

While the two economies are welfare-equivalent at each of their Ramsey plans, the Ramsey plan with a maturity structure includes more fiscal strength than that with only maturing one period debt. Households prefer the welfare-equivalent economy when FP is weak and prefer the maturity structure economy when FP is strong. To better compare the two welfare relations to *deviations* in

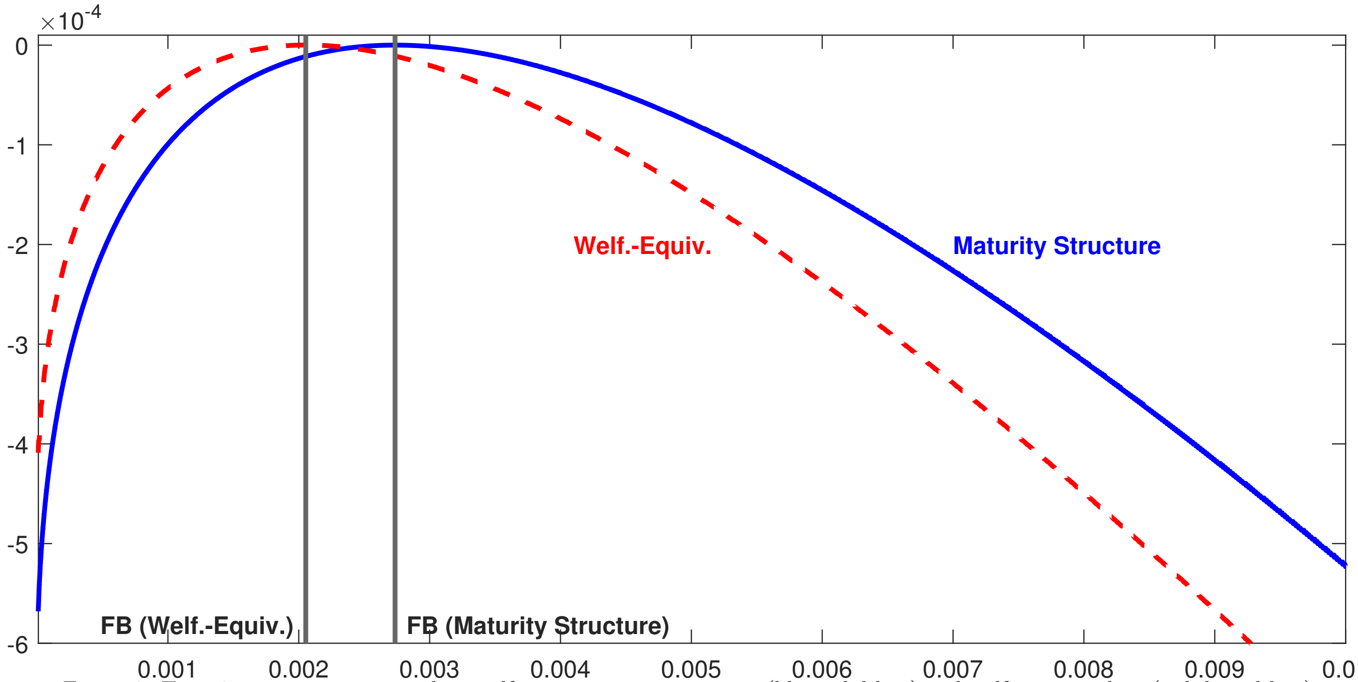

Figure 9: Time 0 consumption-equivalent welfare in maturity structure (blue solid line) and welfare-equivalent (red dotted line) economies across fiscal strengths $\alpha \in [0, 0.01]$ (x-axis).

fiscal strength from first-best, Figure 10 overlays these curves so that the x-axis is now the difference in realized and first-best fiscal strength in each economy.

Households living in the maturity structure economy enjoy better welfare insurance against jointly implemented government policy away from the Ramsey plan than those living in the economy without a maturity structure. Even at relative deviations of only $\alpha - \alpha^* = -0.002$, the maturity structure economy has lost less than half of the welfare compared with the welfare-equivalent economy. Similar to an envelope theorem result, when monetary and fiscal policies have additional ways to smooth their costly policy over time, deviations from welfare maximization hurt them less than they would otherwise.

Even when federal institutions act non-cooperatively with respect to how they manage the maturity structure of government, as suggested by Greenwood et al. (2015) and Miran and Roubini (2024), the existence of a maturity structure softens the blow better than a comparable, alternative economy without a maturity structure.

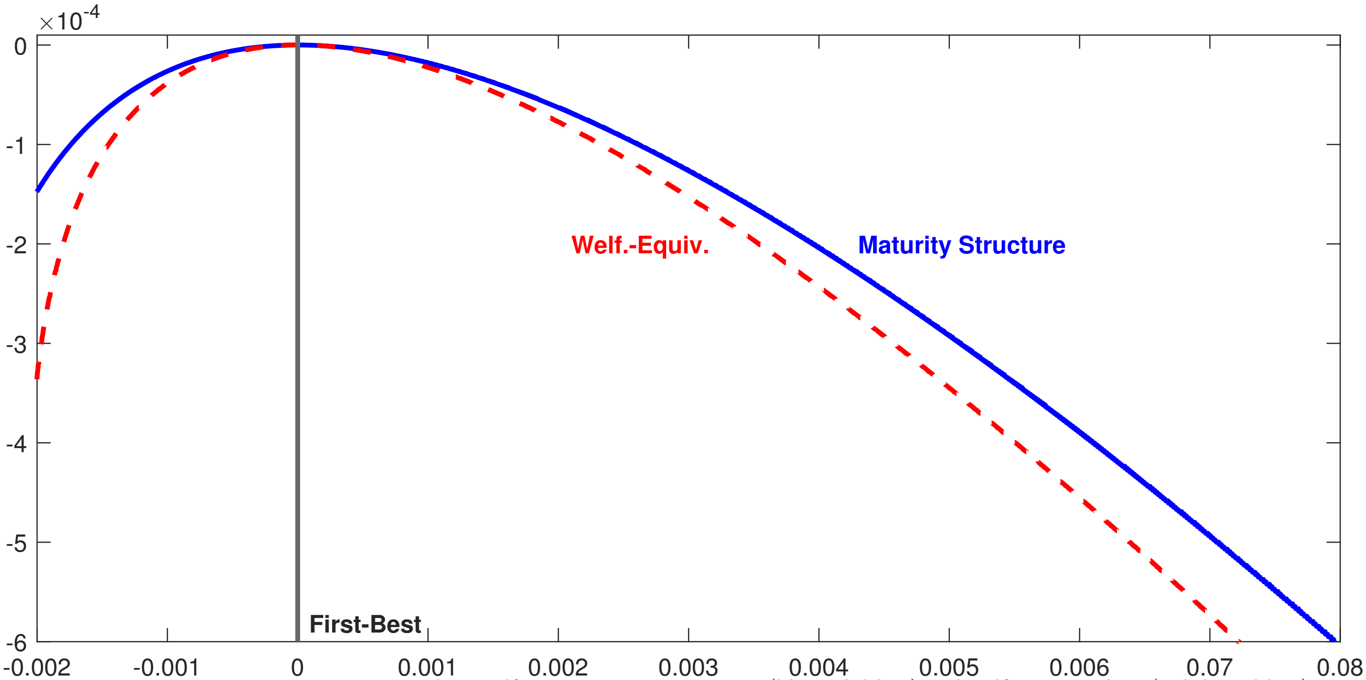

Figure 10: Time 0 consumption-equivalent welfare in maturity structure (blue solid line) and welfare-equivalent (red dotted line) economies by deviations in fiscal strength from first-best (x-axis).

7 Conclusion

This paper develops a framework for understanding fiscal and monetary policy non-cooperation through the lens of relative institutional strength. By modeling the strategic interaction between an inflation-targeting central bank and a tax-minimizing debt-manager as a non-cooperative game with asymmetric Nash bargaining, the model connects tax/inflation trade-offs in government financing to intra-governmental relations.

The paper makes four main contributions to the literature. First, it develops a theory by which intra-governmental bargaining power both determines a unique equilibrium under individually optimizing fiscal and monetary policy and provides a measure of fiscal strength relative to monetary policy. Second, it provides theoretical underpinnings for the president-Fed meeting data in Drechsel (2024) and offers a way to extend them to the present. Third, it documents the history of fiscal and monetary interactions in post-war America and compares those interactions to a first-best measure of fiscal strength. Fourth, it investigates a maturity structure's role in monetary-fiscal non-cooperation, finding that such a structure is useful in insuring households against policy with too much or too little fiscal strength.

As the U.S. government continues to accumulate debt at an impressive rate, it is useful to consider how Americans' tax rates need to adjust in order to finance this debt without the need for inflation. If those distortions are too much to stomach, it may be worthwhile to re-frame how we think about surprise inflation: a costly tax on bondholders that provides more financing the more bonds are held. These discussions may be able to guide Fed and Treasury leadership to arrive at amicable agreements in policy despite their obvious differences in objectives.

As policymakers debate potential reforms to the U.S.'s fiscal-monetary architecture, including proposals to alter the Fed's mandate, increase presidential influence or otherwise erode the Fed's independence, it is important to emphasize that *institutional cooperation is not necessarily a good thing.* A fiscal authority and a central bank with no independence work cooperatively. A central bank that can use interest rates and remittance/recapitalization policy to unilaterally adjust taxes and keep inflation at zero is cooperative with fiscal policy. Both miss welfare gains from using available tools to finance the consolidated government. Non-cooperative policy can work just as well, if not better, than cooperative policy. Especially when factoring in real-world financial frictions, incomplete markets, political motives and asymmetric information, dividing government objectives among operationally independent institutions creates and enforces checks and balances needed to maintain credible policy, high employment, stable prices and financial stability.

Future research can extend this work in many directions. First may be to incorporate a bargaining equation with time-varying fiscal strength in a linearized model that includes a full suite of economic shocks, estimating the effect movements in fiscal strength have on model variables. It would be interesting to see what a fiscal strength IRF looks like in such a model. A second direction would be to think of fiscal strength as an endogenous variable, asking what economic and societal factors play into its movements throughout history.

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A Appendix: Proofs

Proof for Proposition 1

Let $\left\{\{c_t(x_t), n_t(x_t), g_t, \pi_t(x_t)\}_{g^t \in G^t}\right\}_{t=0}^{\infty}$ represent a stochastic sequence. Substituting (1), (9), and the definitions $b_t^{(s)} = \frac{B_t^{(s)}}{P_t}$ and $\pi_t = \frac{P_t}{P_{t-1}} > 0$ into (6), while considering (7), forward-iterating, and applying (10), results in (12). If a stochastic sequence $\left\{\{c_t(x_t), n_t(x_t), g_t\}_{g^t \in G^t}\right\}_{t=0}^{\infty}$ is generated by a competitive equilibrium, then it necessarily satisfies (1) and (12).

Let government institutions jointly choose the associated level of debt $\left\{\left\{\left\{\boldsymbol{b}_t^{(s)}(x_t)\right\}_{s=1}^{S}\right\}_{g^t \in G^t}\right\}_{t=0}^{\infty}$, let the debt-manager choose a tax sequence $\left\{\{\tau_t(x_t)\}_{g^t \in G^t}\right\}_{t=0}^{\infty}$ and the central bank choose a sequence of inflation rates $\left\{\{\pi_t(x_t)\}_{g^t \in G^t}\right\}_{t=0}^{\infty}$ such that (9) is satisfied. (12) and (1) imply (6) and (8) as well as (5) are satisfied, given definitions $\boldsymbol{b}_t^{(s)} = \frac{\boldsymbol{B}_t^{(s)}}{P_t}$ and $\pi_t = \frac{P_t}{P_{t-1}} > 0$. All optimality conditions, dynamic budget constraints, and market clearing criteria are satisfied, so the equilibrium is competitive.

Proof for Lemma 1

By definition, if $\pi_0 > 1$ is not required for a CNE, then the debt-manager can feasibly individually satisfy (1) and (12) under $\pi_t = 1\ \forall t$.

$0 < b_{t-1} < \hat{b}_{t-1} \implies \exists \varepsilon \in \mathbb{R}_{++}^S$ for which $b'_{t-1} = b_{t-1} + \varepsilon < \hat{b}_{t-1}$. Due to the properties of u, v and w and the definition of $\hat{b}_{t-1}$, $\exists \left\{\{\tau_t(x_t)\}_{g^t \in G^t}\right\}_{t=0}^{\infty}$ for which an economy inheriting b'_{t-1} requires $\pi_0 < 1$ for (1) and (12) to hold. Finally, by (19)–(20), $\pi_0 < 1 \implies \lambda_0^{cb} < 0$.

B Appendix: CNE Sensitivity

B.1 Inherited Debt

This section finds to what degree an increased inherited debt position affects the baseline model's CNE. I begin by calibrating the model's inherited debt position to match the average par value/GDP ratio of privately held U.S. debt during the post-COVID era from 2020 to 2022, so that $b_{-1}^{(s)'} = 1.07$, keeping the rest of the model calibration fixed. Figure 11 plots the two economies' Pareto frontiers.

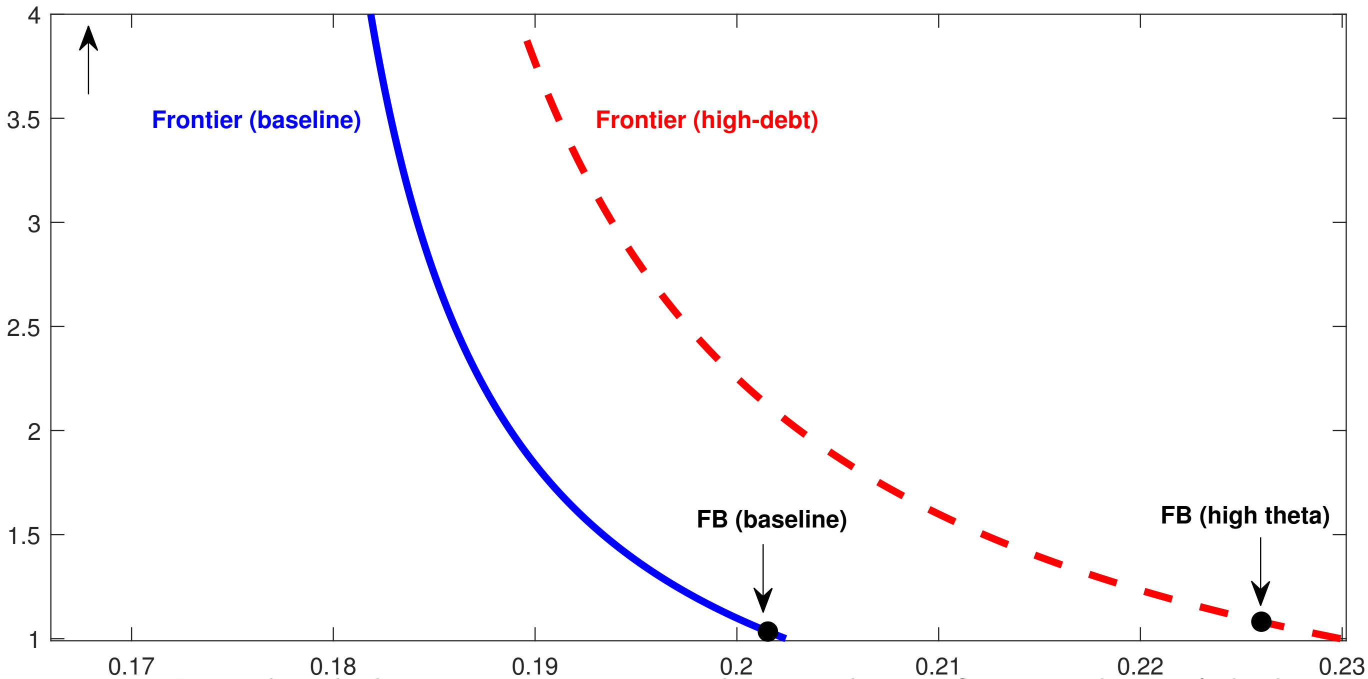

Figure 11: Pareto relationship between stationary tax rate $\bar{\tau}$ on the x-axis and time 0 inflation π_0 on the y-axis for baseline (blue solid line) and high-debt (red dotted line) economies. Feasible equilibria lie along the frontier: points to the left violate the household budget constraint (6) and points to the right violate household, government optimization (9), (17)–(20).

Increasing $b_{-1}^{(s)}$ tightens the government budget constraint, shifting its Pareto frontier to the right. The Ramsey plan in the high-debt economy thus includes higher taxes and greater inflation. Also apparent from the curvature of the two frontiers is that surprise inflation, as opposed to explicit taxation, does a better job of financing high-debt economies.

How does institutional non-cooperation factor into equilibrium determination? Figure 15 visualizes the two frontiers as functions of fiscal strength, and Table 4 displays tax and inflation at the economies' corners and Ramsey plans where $\alpha \in [0, .02]$.

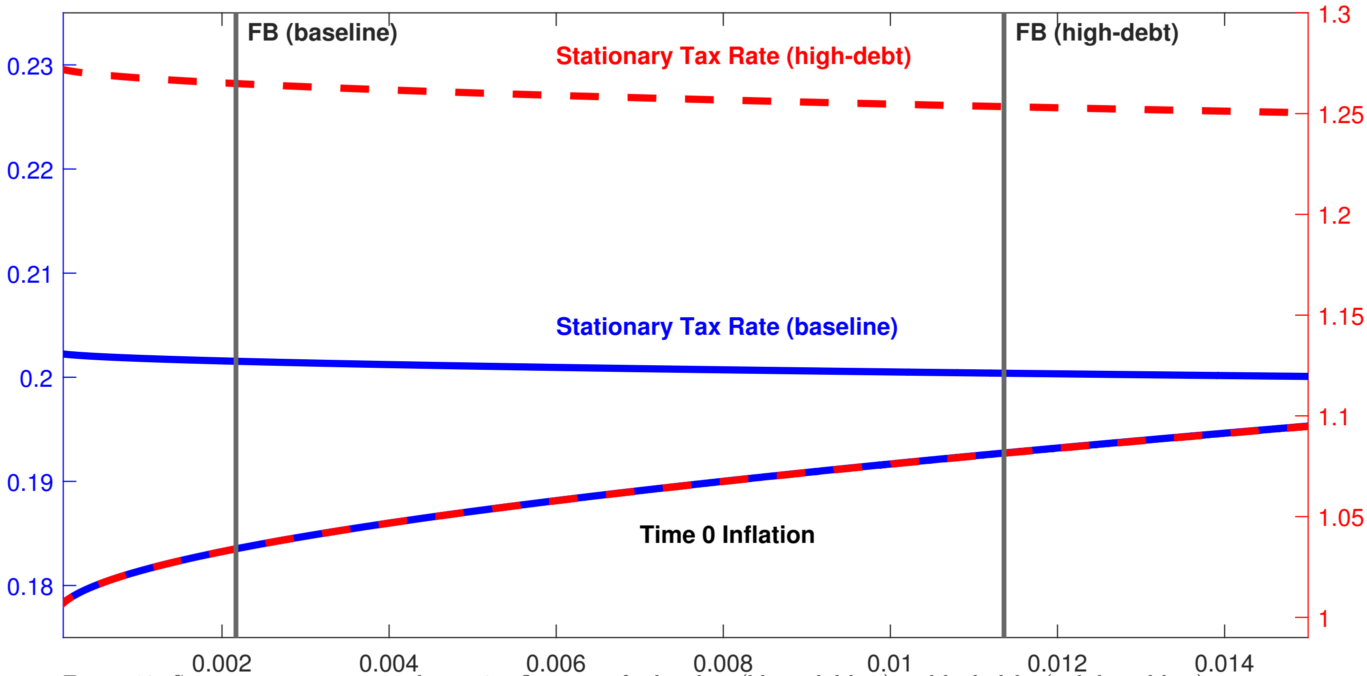

Figure 12: Stationary tax rate $\bar{\tau}$ and time 0 inflation π_0 for baseline (blue solid line) and high-debt (red dotted line) economies across fiscal strengths, $\alpha \in [0, 0.015]$.

CNE	α	$\bar{\tau}$	π_0
All-powerful central bank (baseline)	0	0.2024	1
Ramsey plan (baseline)	0.0022	0.2015	1.0340
All-powerful debt-manager (baseline)	1	0.1665	∞
All-powerful central bank (high-debt)	0	0.2299	1
Ramsey plan (high-debt)	0.0114	0.2260	1.0814
All-powerful debt-manager (high-debt)	1	0.1665	∞

Table 4: Fiscal strengths, stationary tax rates and time 0 inflation rates in corner and first-best CNE for baseline and high-debt economies.

Feasible stationary tax rates $\bar{\tau}$ are more than 2.5% higher between the baseline and high-debt economies, yet inflation is identical. This is because the figure is displaying policy close to $\alpha = 0$, where time 0 inflation π_0 equals 1 regardless of the government's outstanding debt position.

Households with more indebted governments prefer stronger fiscal policy. The intuition is an extension of that discussed above: surprise inflation is more effective at financing high-debt economies *and* imposes no more welfare costs than inflation in a low-debt economy.

Figure 13 compares the baseline and high-debt economies' relative time 0 consumption-equivalent welfares as functions of fiscal strength. Households in the high-debt economy not only prefer more fiscal strength, deviations from first-best are less impactful than those in the low-debt economy.

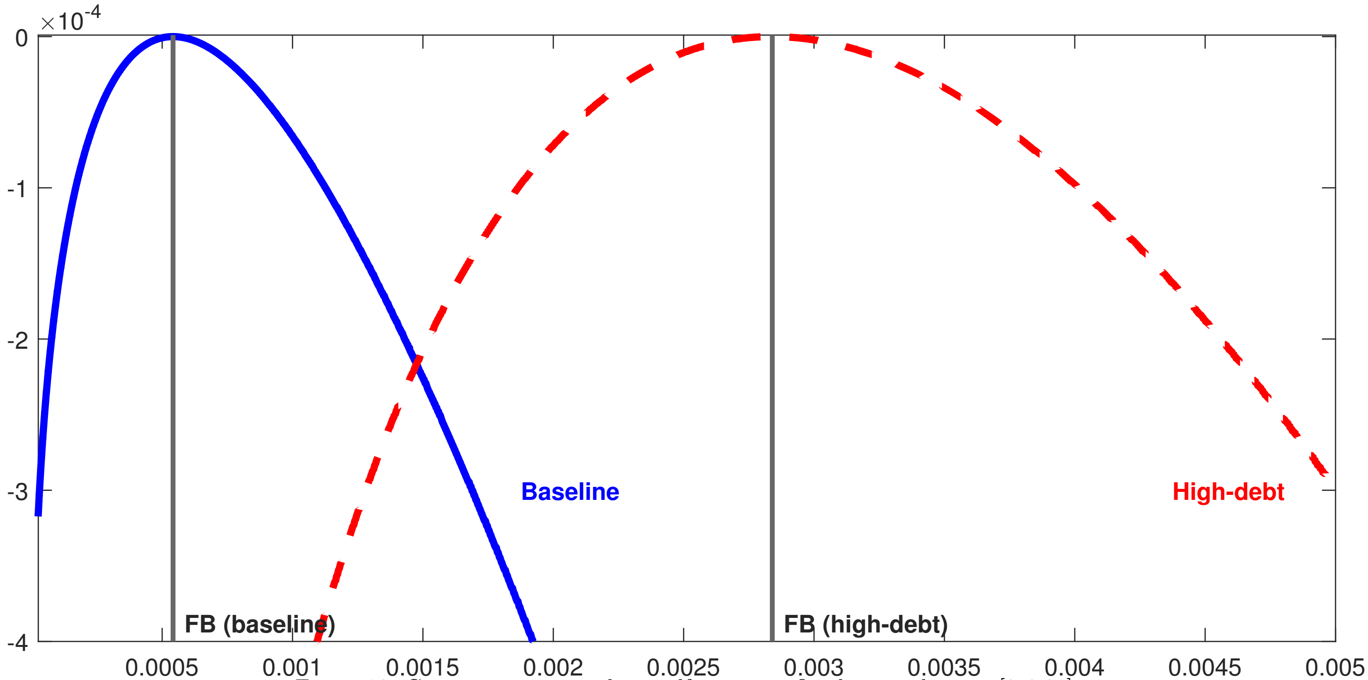

Figure 13: Consumption-equivalent welfare across fiscal strengths, $\alpha \in [0, 0.01]$.

This is largely due to the fact that, in absolute terms, welfare is higher in the low-debt economy along its Ramsey plan than the high-debt economy along its Ramsey plan, which is apparent from the frontiers in Figure 11.

The main takeaway from this section is that, while surprise inflation is costly, its benefits positively co-move with the government's outstanding debt stock.

B.2 Welfare's Sensitivity to Inflation

This section investigates how the baseline model's equilibrium changes after increasing θ, the parameter governing relative welfare costs to inflation. I compare the baseline model to one where θ is twice as large $\theta' = 2.344$ so that households are more sensitive to inflation. Figure 14 plots the relationship of the two economies' Pareto frontiers.

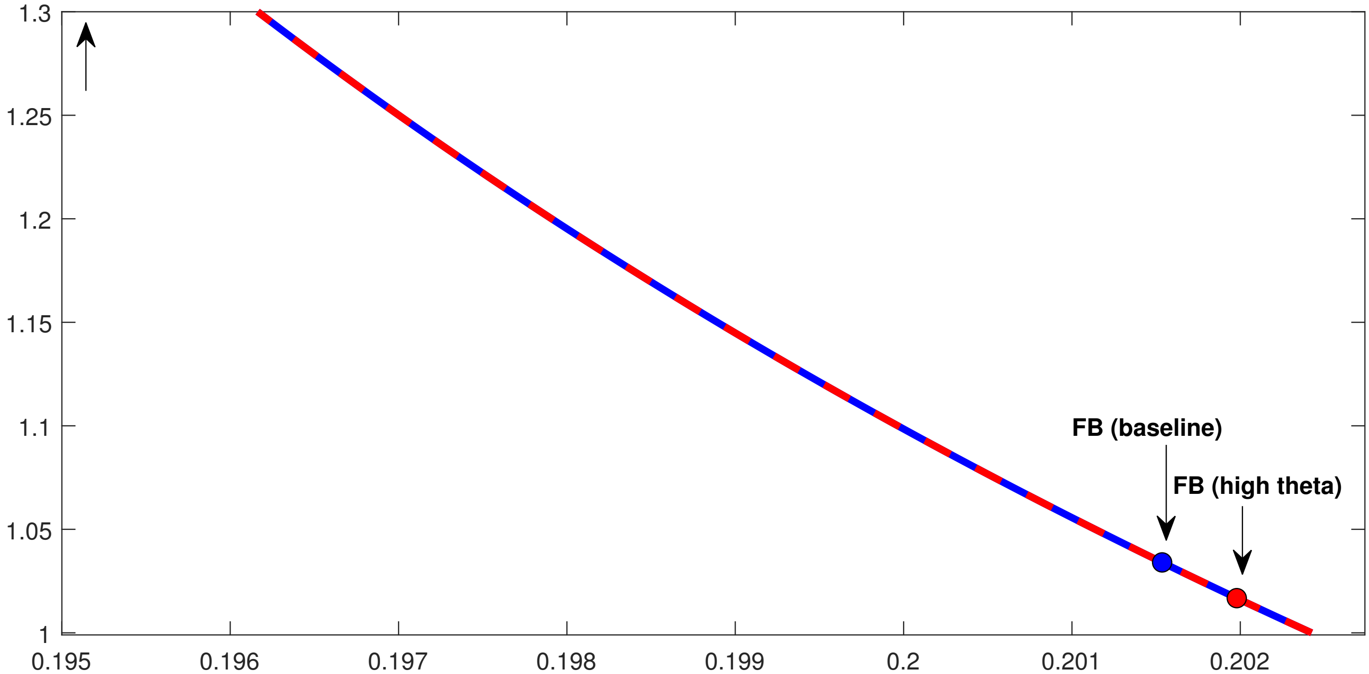

Figure 14: Pareto relationship between stationary tax rate $\bar{\tau}$ on the x-axis and time 0 inflation π_0 on the y-axis for baseline (blue solid line) and high-θ (red dotted line) economies. Feasible equilibria lie along the frontier: points to the left violate the household budget constraint (6) and points to the right violate household, government optimization (9), (17)–(20).

Adjusting θ does nothing to adjust either the ARC (1) or IC (12). The continuum of feasible equilibria (and supporting policy choices) is thus unchanged. Unsurprisingly, the welfare-maximizing policy mix adjusts to include more tax financing and less financing from surprise inflation. While using inflation is no more and no less advantageous for government financing in the high-θ economy, inflation is more welfare-reducing and thus used less by the Ramsey planner. Figure 15 visualizes the same frontier plotted as a function of fiscal strength.

The feasible set of tax/inflation combinations that satisfy the joint government's relevant constraints overlap everywhere, as in Figure 15. Welfare-maximizing monetary policy is all-powerful $\alpha \to 0$ when households are infinitely sensitive to inflation $\theta \to \infty$. The symmetric case also holds: optimal fiscal policy is all-powerful $\alpha \to 1$ when households do not care about inflation $\theta \to 0$.

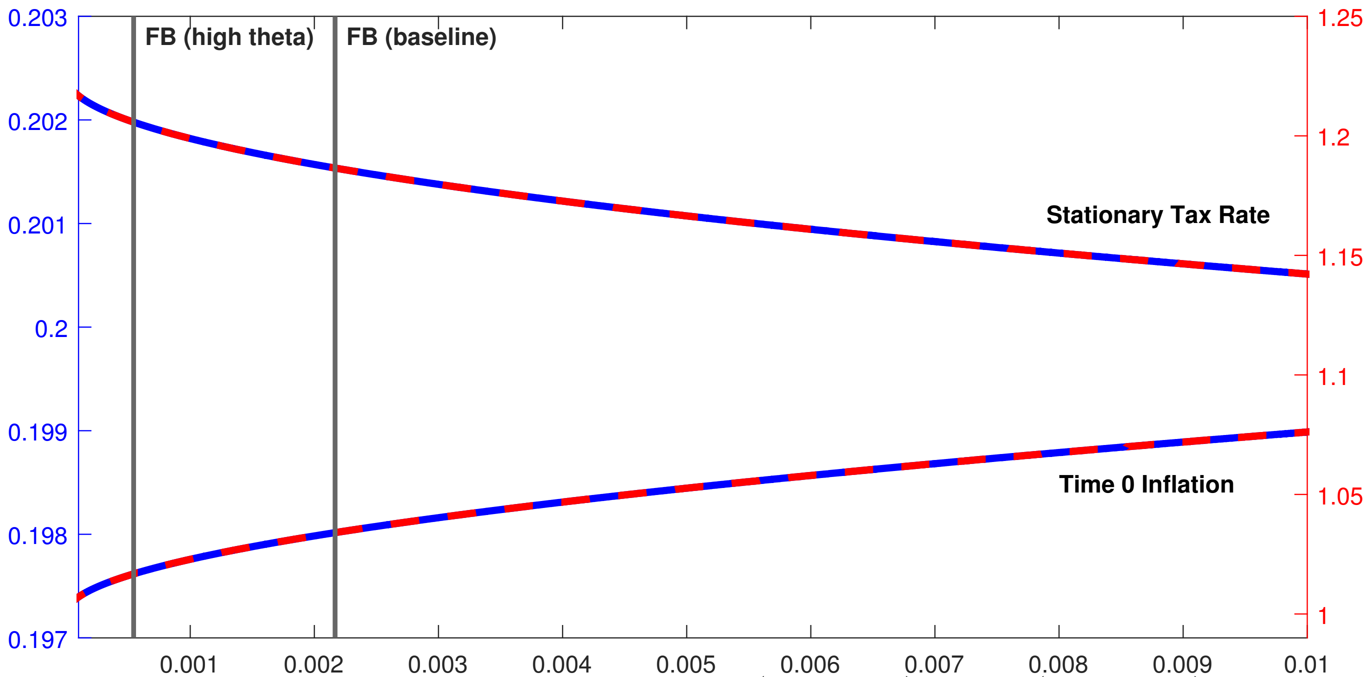

Figure 15: Stationary tax rate $\bar{\tau}$ and time 0 inflation π_0 for baseline (blue solid line) and high-θ (red dotted line) economies across fiscal strengths, $\alpha \in [0, 0.01]$.

CNE	α	$\bar{\tau}$	π_0
All-powerful central bank	0	0.2024	1
Ramsey plan (high-θ)	0.0005	0.2020	1.0168
Ramsey plan (baseline)	0.0022	0.2015	1.0340
All-powerful debt-manager	1	0.1665	∞

Table 5: Fiscal strengths, stationary tax rates and time 0 inflation rates in corner and first-best CNE for baseline and high-θ economies.

Figure 16 plots economy-specific consumption-equivalent welfare along the fiscal strength continuum. While more inflation-sensitive households imply a stronger welfare-maximizing central bank, deviations from first-best joint-policy become more costly in such economies. For low values of θ, policy away from first-best is less welfare-reducing.

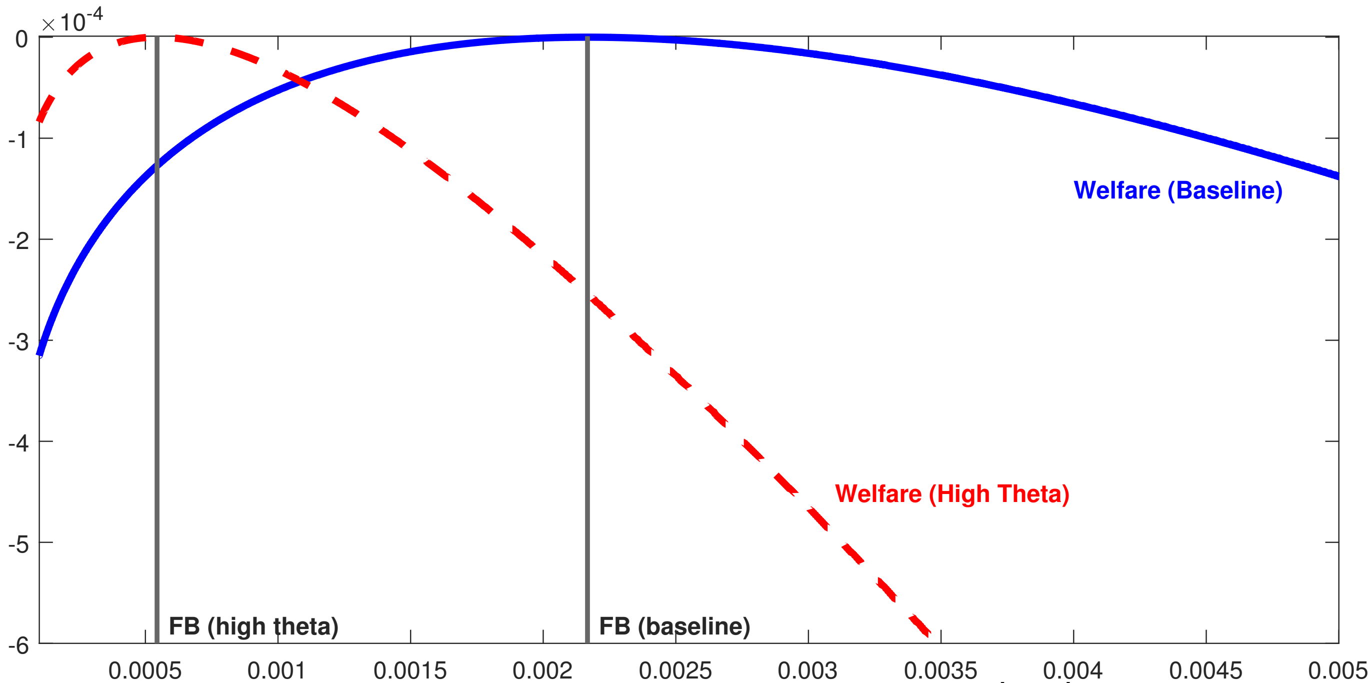

Figure 16: Consumption-equivalent welfare across fiscal strengths, $\alpha \in [0, 0.01]$.

C Appendix: Model with a Maturity Structure

The debt-manager chooses (issues) a maturity structure $\boldsymbol{B}_t^{dm} = \left\{\boldsymbol{B}^{(t+j),dm}\right\}_{j=1}^{2}$ and the central bank simultaneously chooses debt holdings $\boldsymbol{B}_t^{cb} = \left\{\boldsymbol{B}^{(t+j),cb}\right\}_{j=1}^{2}$ to maximize their respective objectives (3)–(4). Debt markets continue to clear according to (5).

The household budget constraint now reads

$$P_t c_t + \sum_{j=1}^{2} Q_t^{(t+j)} \left(B_t^{(t+j)} - B_{t-1}^{(t+j)}\right) \leq P_t \left(1 - \tau_t\right) n_t + B_{t-1}^{(t)}$$

and the no-Ponzi condition now reads

$$B_t^{(t+j)} \in \left[\underline{B}, \overline{B}\right] \quad \forall\, t, j \in \{1, 2\}$$

where the sum on the left side of the household budget constraint represents new household borrowing across maturities.

Household optimization is now governed by

$$1 - \tau_t = \frac{v'\left(n_t\right)}{u'\left(c_t\right)} \quad \text{and} \quad Q_t^{(t+j)} = \beta^j \mathbb{E}_t \left[\frac{u'\left(c_{t+j}\right) P_t}{u'\left(c_t\right) P_{t+j}}\right] \quad \forall\, j \in \{1, 2\}$$

which implies a new TVC, reading

$$\lim_{i \to \infty} \left(\frac{\sum_{j=0}^{1} \beta^{j+i} \mathbb{E}_t \left[\frac{u'\left(c_{t+j+i}\right) P_t}{u'\left(c_t\right) P_{t+j+i}}\right] B_{t-1+i}^{(t+j+i)}}{P_t} \right) = 0$$

and where the household FOC on taxes τ_t is unchanged from (9).

Define a household's real (indexed) debt holdings as $b_t^{(t+j)} \equiv \frac{B_t^{(t+j)}}{P_t}$ and the government's real debt supplied as $\boldsymbol{b}_t^{(t+j)} \equiv \frac{\boldsymbol{B}_t^{(t+j)}}{P_t}$, and define the vector of real debt allocations held by households as $b_t \equiv \left\{b_t^{(t+j}\right\}_{j=1}^{2}$ and supplied by the government as $\boldsymbol{b}_t \equiv \left\{\boldsymbol{b}_t^{(t+j)}\right\}_{j=1}^{2}$. Again combine the ARC (1), household budget constraint and FOCs, forward-iterate on the probability-weighted sum of maturing government debt and apply the TVC to express the new economy's IC as

$$\underbrace{\frac{1}{\pi_t}\left\{b_{t-1}^{(t)}+\beta\mathbb{E}_t\left[\frac{1}{\pi_{t+1}}\frac{u'(c_{t+1})}{u'(c_t)}\right]b_{t-1}^{(t+1)}\right\}}_{\text{MV(debt)}/P_t}=\underbrace{\frac{1}{u'(c_t)}\mathbb{E}_t\sum_{i=0}^{\infty}\beta^i\left[u'(c_{t+i})\,c_{t+i}-v'(n_{t+i})\,n_{t+i}\right]}_{\mathbb{E}_t[\text{PV(primary surpluses)}]}$$

The Ramsey planner's FOCs on $\{c_t\}$ and $\{n_t\}$ now combine to yield

$$u'(c_0)\left[1+\lambda_0\right]+\lambda_0\left[u''(c_0)\left(c_0-\frac{b_{-1}^{(0)}}{\pi_0}\right)\right]=v'(n_0)\left[1+\lambda_0\right]+\lambda_0 v''(n_0)\,n_0 \qquad \text{and}$$

$$u'(c_1)\left[1+\lambda_0\right]+\lambda_0\left[u''(c_1)\left(c_1-\frac{b_{-1}^{(1)}}{\pi_0\pi_1}\right)\right]=v'(n_1)\left[1+\lambda_0\right]+\lambda_0 v''(n_1)\,n_1 \qquad \text{and}$$

$$u'(c_t)\left[1+\lambda_0\right]+\lambda_0 u''(c_t)\,c_t=v'(n_t)\left[1+\lambda_0\right]+\lambda_0 v''(n_t)\,n_t \qquad \forall\ t>1$$

The Ramsey planner's FOCs on $\{\pi_t\}$ are now

$$w'(\pi_0)\,\pi_0^2=\lambda_0\left\{u'(c_0)\,b_{-1}^{(0)}+\beta\mathbb{E}_0\left[\frac{u'(c_1)}{\pi_1}\right]b_{-1}^{(1)}\right\} \qquad \text{and}$$

$$w'(\pi_1)\,\pi_1^2=\lambda_0\mathbb{E}_0\left[\frac{u'(c_1)}{\pi_0}\right]b_{-1}^{(1)} \qquad \text{and}$$

$$\pi_t=1 \qquad \forall\ t>1$$

As in the economy with state contingent debt, institutional FOCs are identical to Ramsey FOCs with the exception of the Lagrange multipliers.

The debt-manger's FOCs on $\{c_t\}$ and $\{n_t\}$ now imply

$$u'(c_0)\left[1+\lambda_0^{dm}\right]+\lambda_0^{dm}\left[u''(c_0)\left(c_0-\frac{b_{-1}^{(0)}}{\pi_0}\right)\right]=v'(n_0)\left[1+\lambda_0^{dm}\right]+\lambda_0^{dm}v''(n_0)\,n_0 \qquad \text{and}$$

$$u'(c_1)\left[1+\lambda_0^{dm}\right]+\lambda_0^{dm}\left[u''(c_1)\left(c_1-\frac{b_{-1}^{(1)}}{\pi_0\pi_1}\right)\right]=v'(n_1)\left[1+\lambda_0^{dm}\right]+\lambda_0^{dm}v''(n_1)\,n_1 \qquad \text{and}$$

$$u'(c_t)\left[1+\lambda_0^{dm}\right]+\lambda_0^{dm}u''(c_t)\,c_t=v'(n_t)\left[1+\lambda_0^{dm}\right]+\lambda_0^{dm}v''(n_t)\,n_t \qquad \forall\ t>1$$

The central bank's FOCs on $\{\pi_t\}$ are now

$$w'(\pi_0)\,\pi_0^2 = \lambda_0^{cb}\left\{u'(c_0)\,b_{-1}^{(0)} + \beta\mathbb{E}_0\left[\frac{u'(c_1)}{\pi_1}\right]b_{-1}^{(1)}\right\} \qquad \text{and}$$

$$w'(\pi_1)\,\pi_1^2 = \lambda_0^{cb}\mathbb{E}_0\left[\frac{u'(c_1)}{\pi_0}\right]b_{-1}^{(1)} \qquad \text{and}$$

$$\pi_t = 1 \qquad \forall\ t > 1$$

A government may use linear combinations of debt maturities to implement complete markets allocation paths when $J \geq S$, understanding how ex-post, unmatured debt prices move in each potential future state.[18] Buera and Nicolini (2004) prove that the $S \times J$ (payoff) matrix of ex-post debt prices being invertable along such a path is necessary and sufficient for this result to hold under a Markovian stochastic process.

Given that the matrix

$$\begin{bmatrix} \left(\frac{1}{\pi_t}|s=1\right) & \beta\mathbb{E}_t\left(\frac{u'(c_{t+1})}{u'(c_t)\,\pi_t\pi_{t+1}}|s=1\right) \\ \left(\frac{1}{\pi_t}|s=2\right) & \beta\mathbb{E}_t\left(\frac{u'(c_{t+1})}{u'(c_t)\,\pi_t\pi_{t+1}}|s=2\right) \end{bmatrix}$$

is invertable for every period and possible state along a complete-markets path of allocations; such an equilibrium is implementable using linear combinations of nominal debt.[19] This matrix is always invertable in the calibrated version of this economy.

[18] Angeletos (2002) and Buera and Nicolini (2004) are the first to point this equivalence out. When $J = S$ the implementing debt maturity combination is unique.

[19] This requirement is satisfied when inflation is always 1 as $u'(c_t)$ differs across potential time t spending states when taxes are smooth.

D Appendix: Data Sources

Apart from Drechsel's (2024) data on president-Fed official meetings, which is available on his website, this paper uses three main time series: U.S. inflation (1943–2023), U.S. spending-to-GDP (1943–2023) and U.S. par value debt-to-GDP (1942–2022).

- U.S. Inflation (1943–2023)
  - Growth rate in annual GDP deflator. Section 1, table T10109-A, line 1 in the NIPA from the BEA. Found at `https://apps.bea.gov/iTable/?isuri=1&reqid=19&step=4&categories=flatfiles&nipa_table_list=1`
- U.S. Spending-to-GDP (1943–2023)
  - GDP: Annual nominal GDP. Section 1, table T10105-A, line 1 in the NIPA from the BEA. Found at `https://apps.bea.gov/iTable/?isuri=1&reqid=19&step=4&categories=flatfiles&nipa_table_list=1`
  - Spending: Annual nominal spending. Calculated as (Total expenditures) - (Interest payments) + (Interest receipts) - (federal employee pension interest accrual), as in Hall and Sargent (2022).
    * Total expenditures. Section 3, table T30200-A, Line 43 in the National Income and Product Accounts (NIPA) from the BEA and found at `https://apps.bea.gov/iTable/?isuri=1&reqid=19&step=4&categories=flatfiles&nipa_table_list=1`.
    * Interest payments: Section 3, table T30200-A, line 33 in the National Income and Product Accounts (NIPA) from the BEA and found at `https://apps.bea.gov/iTable/?isuri=1&reqid=19&step=4&categories=flatfiles&nipa_table_list=1`.
    * Interest receipts: Section 3, table T30200-A, line 14 in the National Income and Product Accounts (NIPA) from the BEA and found at `https://apps.bea.gov/iTable/?isuri=1&reqid=19&step=4&categories=flatfiles&nipa_table_list=1`.
    * Federal employee pension interest accrual: Section 3, table T31800(A,B)-A, line 22 in the National Income and Product Accounts (NIPA) from the BEA and found at

https://apps.bea.gov/iTable/?isuri=1&reqid=19&step=4&categories=flatfiles&nipa_table_list=1.

- U.S. Par Value Debt-to-GDP (1942–2022)
  - Calculated as (Reserves Outstanding) + (Privately-Held Treasurys). All reserves outstanding is considered <1 year duration.
    - GDP: Annual nominal GDP. Section 1, table T10105-A, line 1 in the NIPA from the BEA. Found at https://apps.bea.gov/iTable/?isuri=1&reqid=19&step=4&categories=flatfiles&nipa_table_list=1
    - Reserves Outstanding (2002–2022). calculated as (Federal Reserve Notes, Net of F.R. Bank Holdings) + (Deposits with F.R. Banks, Other Than Reserve Balances) + (Other Deposits at the Fed) + (Term Deposits Held by Depository Institutions) - (U.S. Treasury, Supplementary Financing Account) - (Treasury balance in TGA) + (Reverse Repurchase Agreements).
      - Federal Reserve Notes, Net of F.R. Bank Holdings. Table H.4.1.T5 on the Fed's weekly balance sheet and found at https://fred.stlouisfed.org/series/WLFN.
      - Deposits with F.R. Banks, Other Than Reserve Balances. Table H.4.1.T5 on the Fed's weekly balance sheet and found at https://fred.stlouisfed.org/series/WDFOL.
      - Other Deposits at the Fed. Table H.4.1.T5 on the Fed's weekly balance sheet and found at https://fred.stlouisfed.org/series/WLODL.
      - Term Deposits Held by Depository Institutions. Table H.4.1.T5 on the Fed's weekly balance sheet and found at https://fred.stlouisfed.org/series/TERMT.
      - U.S. Treasury, Supplementary Financing Account. Table H.4.1.T5 on the Fed's weekly balance sheet and found at https://fred.stlouisfed.org/series/WLSFAL.

- Treasury balance in TGA. Daily Treasury Statements, found at `https://fsapps.fiscal.treasury.gov/dts/issues`.
- Reverse Repurchase Agreements. Table H.4.1.T5 on the Fed's weekly balance sheet and found at `https://fred.stlouisfed.org/series/WLRRAL`.

* Reserves Outstanding (1942–2001). Calculated as the average reserves outstanding/GDP from 2002–2022 multiplied by GDP from 1942–2001.
* Privately-Held Debt (1942–2022). Center for Research in Security Prices (CRSP) U.S. Treasury Database

The Dilution Rate of Government Debt

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Abstract

This paper introduces the dilution rate of government debt which measures newly-issued short-term to previously-issued long-term government debt. The concept allows for dynamic maturity management analysis in linearized frameworks. I construct one such model and use it to motivate a structural vector autoregression (SVAR) which I estimate with U.S. post-war data. Debt dilution increases with negative shocks to the Fed's policy rate and U.S. tax rate. Positive shocks to debt dilution reduce inflation contemporaneously and increase long-run inflation. The results raise questions about deflationary effects from open market purchases and inflationary impacts of open market sales.

Keywords: Federal Reserve, U.S. Treasury, Debt maturity management, SVARs, U.S. inflation.

JEL Classification: E52, E58, E63, H63, C32.

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1 Introduction

The U.S. Federal Reserve (Fed) often deploys quantitative easing (QE) and interest rate cuts simultaneously during severe economic downturns, unleashing a powerful two-pronged approach to monetary stimulus. Slashing the federal funds rate reduces short-term borrowing costs for households, firms and the government, while purchasing long-term assets like U.S. Treasurys injects liquidity into financial markets.

Despite this policy marriage, a tractable theory describing the direct impact of short-term–for–long-term asset swaps on inflation remains absent, so it is difficult to answer questions like 'does QE contribute to low inflation during recessions?' and 'does quantitative tightening (QT) counteract contractionary monetary policy?' The main issue arises largely due to the interaction between DSGE linearization and the household's no-arbitrage condition on debt objects of differing maturities.[1] Without additional assumptions on this no-arbitrage condition (e.g., risk premia), these debt objects are approximately perfect substitutes.[2] I overcome the need for additional assumptions and bypass the perfect substitution issue in this paper, developing and outlining simple theoretical predictions relating maturity management to inflation outcomes that survive linearization.

Cochrane (2001) and Leeper and Leith (2017) develop a general theory of debt management in a constant endowment setting, allowing for an arbitrarily large number of debt maturities to be freely issued by the government. They characterize the equilibrium price level as a weighted sum of current and expected future discounted primary surpluses but with a weight structure difficult to penetrate intuitively. Cochrane (2023) writes, "These formulas likely hide additional interesting insights and special cases."

This paper investigates one such case, requiring only a resource constraint, household budget constraint, and household optimization over long- and short-term government debt. Limiting government issuance to two periods dramatically simplifies the general formulas in Cochrane's (2001) and Leeper and Leith's (2017) papers and allows for new, exciting perspectives on maturity

[1] Debt of various maturities can be used to complete markets in non-linear models like those in work by Angeletos (2002), Buera and Nicolini (2004) and Faraglia, Marcet, and Scott (2010). They are also useful insurance tools in non-linear, incomplete-markets models such as those in papers by Lustig, Sleet, and Yeltekin (2008), Debortoli, Nunes, and Yared (2017), and Faraglia et al. (2019)

[2] Woodford (2001) develops a second-best approach by examining a maturity structure consisting of perpetuities with exponentially-decaying coupons where the decay rate is held constant. Leeper and Zhou (2021) vary such a portfolio's rate of decay to compare welfare outcomes from policy across economies with different debt durations.

management as a policy tool.

The main object of interest in this paper is the dilution rate of government debt (hereby referred to as the dilution rate), which measures the amount of outstanding short-term government debt relative to the amount of outstanding previously-issued, unmatured long-term debt. The name, inspired by concepts discussed in Cochrane's (2023) book, describes how the government dilutes the real value of its unmatured debt when it issues new debt maturing on the same date. The concept is similar to that of a publically-traded company diluting its current market capitalization by issuing additional stock, reducing price per share.

Keeping expectations about future primary surpluses fixed, a theoretical government raises expected future inflation when it dilutes outstanding unmatured debt with short-term issuance. The increase in expected inflation reduces the market value of existing unmatured debt, lowering outstanding debt's market value. This reduction in government indebtedness relieves the aggregate price level from adjusting upward to revalue debt to equate the government's present value condition. Theoretical debt dilution reduces current prices at the expense of higher expected future prices.

The U.S.'s outstanding maturity structure is jointly determined by the U.S. Treasury and the Fed. The Treasury finances government deficits through new issuance while the Fed engages in open-market operations like QE and QT, exchanging ultra-short-term debt (reserves) with longer-term debt (Treasurys) at market prices. The residual, privately held structure represents consolidated government indebtedness. U.S. dilution is a function of fiscal and monetary debt management.

I divide the paper into three sections. First, I introduce the dilution rate. Second, I embed the dilution rate in a DSGE model with household optimization and government policy. Finally, I log-linearize the model to motivate a recursively-identified structural vector autoregression (SVAR) analysis of U.S. policy comprised of inflation and fiscal (tax rate), monetary (interest rate) and debt management (dilution rate) policy variables.

I find four main results from the SVAR analysis. First, a surprise decrease in tax rates causes a contemporaneous, transitory increase in debt dilution. Second, a surprise decrease in interest rates causes a contemporaneous and highly persistent increase in dilution. Third, in line with the model's theoretical predictions, an unexpected increase in dilution causes a contemporaneous, somewhat persistent decrease in inflation at the cost of a gradual, highly persistent long-run rise in inflation. Fourth, dilutive effects do not fully resolve the "price puzzle" originally described in Sims (1992) as an unexpected monetary tightening causes a contemporaneous, transitory increase in inflation.

In summary, I not only introduce a theoretical, linearizeable object that allows for intuitive analysis of dynamic maturity management policy, but I also support theoretical predictions of this object's relation to inflation with analogous causal findings in U.S. post-war data.

2 The Dilution Rate of Government Debt

Consider the government's equilibrium flow government budget constraint (GBC) from papers by Cochrane (2001) and Leeper and Leith (2017) implied by the household budget constraint (HHBC), goods market clearing $C_t = Y_t$, and household optimization. Assume the special case where the government can freely borrow in $K = 2$ debt instruments and that its maximum available maturity is $J = 2$ periods to write the flow GBC as

$$\frac{B_{t-1}^{(t)}}{P_t} + \frac{Q_t^{(t+1)} B_{t-1}^{(t+1)}}{P_t} = \frac{Q_t^{(t+1)} B_t^{(t+1)}}{P_t} + \frac{Q_t^{(t+2)} B_t^{(t+2)}}{P_t} + s_t \tag{1}$$

where $B_t^{(t+j)}$ is outstanding j-period nominal debt with corresponding price $Q_t^{(t+j)}$, where P_t is the economy's aggregate price level, and where $s_t = \tau_t Y_t$ is government primary surplus.

Household optimization over $B_t^{(t+j)}$ determines the price of one-period debt and reveals the no-arbitrage condition $Q_t^{(t+2)} = Q_t^{(t+1)} \mathbb{E}_t Q_{t+1}^{(t+2)}$. Forward-iterate on the market value of debt to write the government's present value condition as

$$\underbrace{\frac{B_{t-1}^{(t)}}{P_t} + \mathbb{E}_t \frac{B_{t-1}^{(t+1)}}{r_{t,t+1} P_{t+1}}}_{MV(\text{Debt})/P_t} = \underbrace{\mathbb{E}_t \sum_{i=0}^{\infty} \frac{s_{t+i}}{r_{t,t+i}}}_{\mathbb{E}[PV(\text{Prim. Spls.})]} \tag{2}$$

where the j-period real interest rate is defined to be $r_{t,t+j} = \beta^{-j} c_t^{-\sigma} / c_{t+j}^{-\sigma}$. The flow condition (2) says that the real market value of maturing and unmatured government debt must equal the expected discounted sum of current and future government primary surpluses.

The forward iteration outlined thus far is standard in models that examine fiscal policy's role in breaking Ricardian equivalence. Such forward-iteration is sufficient to express P_t alone as a function of current and expected future allocations when the debt takes the form of perpetuities with geometrically declining coupons, introduced in work by Woodford (2001).[3]

The government's present value condition (2) features an expectation including P_{t+1} within the price of unmatured long-term debt. Current and future debt variables $\left\{\left\{B_t^{(t+j)}, B_{t+1}^{(t+1+j)}, \cdots\right\}_j\right\}$ load into expectations about future price levels recursively; P_{t+1}'s determination includes expectations about P_{t+2} and so on. I express the government's present value condition so that P_t is exclusively a function of current and expected future allocations. When expectations about future debt policy are uncorrelated with those about primary surpluses, the present value condition (2) becomes

$$\underbrace{\frac{B_{t-1}^{(t)}}{P_t}}_{(\text{Mat. Debt})/P_t} = \underbrace{s_t + \mathbb{E}_t \sum_{i=1}^{\infty} \frac{s_{t+i}}{r_{t,t+i}} \left(1 + \sum_{h=1}^{i} -\Psi_{t,t+h-1}^{-1}\right)}_{\mathbb{E}[PV(\text{Diluted Primary Surpluses})]} \tag{3}$$

where $\Psi_{t,t} = B_t^{(t+1)}/B_{t-1}^{(t+1)}$ is the economy's nominal dilution rate of government debt and where $\Psi_{t,t+i} = \left(B_t^{(t+1)} \cdots B_{t+i}^{(t+i+1)}\right) / \left(B_{t-1}^{(t+1)} \cdots B_{t+i-1}^{(t+i+1)}\right)$ is the i-period ahead product of dilution rates.[4]

The dilution rate relates the time t stock of outstanding short-term debt to the time $t-1$ stock of outstanding long-term debt. For some, it may be easier to think of the dilution rate as relating short-term to long-term debt outstanding, holding the date of maturity constant.

The rewritten present value condition (3) includes P_t as a function exclusively of current and expected future allocations. Writing the condition this way also transforms the government's time t debt supply decision from $\left(B_t^{(t+1)}, B_t^{(t+2)}\right)$ to $\Psi_{t,t}$. Though the algebraically relevant term in this rewritten condition is not the dilution rate, but the inverse dilution rate $\Psi_{t,t}^{-1}$. One can immediately see that the rewritten present value condition (3) collapses to the standard case when a government has no outstanding long-term debt $B_{t-1}^{(t+1)} = 0$. Additionally, it must be the case that the government is expected to issue a non-zero amount of short-term debt each period, or else $\Psi_{t,t+i}^{-1}$ becomes undefined for some i. Interpreting the inverse dilution rate directly is challenging, so I recommend thinking in terms of the (non-inverted) dilution rate and flipping the ratio when examining the algebra.

I name $\Psi_{t,t}$ the dilution rate because the government dilutes the real value of its unmatured long-term debt when it issues new short-term debt maturing at the same date, similar to a publicly

[3] This set of structures includes the 1-period-only case.

[4] Covariance terms make the rewritten present value condition (3) less straightforward while adding little expositional value. I relegate the general formula to its derivation in Appendix A.

traded company diluting its current market capitalization by issuing additional stock, reducing price per share.

To give a demonstration, a government enters time t with previously-issued long-term debt outstanding $B_{t-1}^{(t+1)} > 0$. The outstanding debt's market value is $Q_t^{(t+1)} B_{t-1}^{(t+1)}$, which includes expectations over P_{t+1}. Absent other changes to current or expected policy, a budget-neutral increase in $B_t^{(t+1)}$ and decrease in $B_t^{(t+2)}$ increases period $t+1$'s maturing debt and P_{t+1} as a result according to the present value condition (2). Household demand for debt maturing at $t+1$ falls with its real (deflated) payout, so that $Q_t^{(t+1)}$ falls. According to the present value condition (2), equilibrium prices are low when the market value of inherited debt is low. Short-term issuance dilutes long-term debt through $Q_t^{(t+1)}$, that dilution partially relieves government indebtedness at time t, and P_t is depressed. The mechanism here reflects a trade-off in the timing of inflation: surprise dilution reduces current prices at the cost of higher future prices.[5]

This exercise's effects are visible in the new present value condition (3): a surprise increase in $B_t^{(t+1)}$ and decrease in $B_t^{(t+2)}$ decreases $\Psi_{t,t}^{-1}$ and increases $\Psi_{t,t+1}^{-1}$ by less, increasing the effective discounted value of s_{t+1} and decreasing that of s_{t+2} also by less. The right-hand side increases and P_t falls.

In a steady state with $c_t = c$, $B_t^{(t+j)} = B^{(j)}$ and $s_t = s$, the rewritten present value condition (3) becomes

$$\frac{B^{(1)}}{P} = \left(\frac{1}{1-\beta}\right)\left(\frac{1}{1+\beta\Psi^{-1}}\right) s \tag{4}$$

The steady state present value condition (4) reveals a long-run restriction on the dilution rate that must hold to ensure equilibrium: $|B^{(1)}| > \beta |B^{(2)}|$. There must exist a sufficiently large amount of short-term debt (assets) to ensure equilibrium determinacy. Such a condition is easily met in U.S. data where most outstanding debt (Treasurys + reserves) matures within two years.

The Fed engages in open market operations when it implements rate policy, exchanging ultra-short-term debt (reserves) for long-term debt (U.S. Treasurys), among other assets. Additionally, the U.S. Treasury finances deficits by regularly auctioning off newly-issued debt to primary dealers, and it redeems debt from open markets periodically. The Treasury releases its auction schedule six months in advance, while the Fed frequently revises its open market operations strategies. Given

[5] A similar exercise is outlined in Cochrane (2023) in a three-period economy.

the nature of joint debt determination in the U.S., I hypothesize that dilutive policy effects largely derive from surprises to realized dilution rates rather than surprises to expected future dilution rates. As such, I determine whether innovations to the U.S.'s realized dilution rate affects macroeconomic outcomes and whether those effects match this section's theoretical predictions.

3 A Guiding Model

In this section, I describe a flexible-price economy augmented with rules governing monetary (interest rate) policy, fiscal (tax) policy and policy joint-implementation through the maturity structure of government debt. The model is meant to be a guide for the paper's empirical strategy.

Households choose consumption C_t and provide a fixed supply of labor to firms $N = 1$. Firms choose labor demand and face a tax rate τ_t on output, given a linear production function $Y_t = AN_t$. The resource constraint is $C_t = Y_t$, so consumption is constant at $C_t = A$ and the real interest is constant at β^{-1}. Monetary and fiscal rules are similar to those studied in the Fiscal Theory of the Price Level (FTPL) pioneered by Leeper (1991), Sims (1994) and Woodford (1995).

The government can borrow in short-term (1-period) and long-term (2-period) debt. To put the flow GBC (1) in terms of inflation rates rather than price levels, I define real (deflated) debt allocations $b_t^{(t+j)} = B_t^{(t+j)}/P_t$ and gross inflation $\pi_t = P_t/P_{t-1}$. Also, I define the one-period nominal interest rate i_t as the inverse of outstanding unmatured debt's price $Q_t^{(t+1)}$. The log-linearized present value condition (3) takes the form

$$0 = \hat{\pi}_t + (1-\beta)\,\hat{\tau}_t - \left(\frac{\beta}{1-\beta\psi^{-1}}\right)\left(\hat{\psi_t^{-1}} - \hat{i}_t\right) + \boldsymbol{E}_t + u_t^{GBC} \tag{5}$$

where $\hat{\pi}_t$, $\hat{\tau}_t$, and $\hat{i}_t$ are log-linearized inflation, nominal interest rate and tax rate, respectively, where $\psi_t = b_t^{(t+1)}/b_{t-1}^{(t+1)}$ is the economy's real dilution rate of government debt and $\hat{\psi_t^{-1}}$ is the log-linearized inverse dilution rate, and where $\boldsymbol{E}_t$ contains all expectations of variables dated time $t+1$ and beyond.[6] The shock u_t^{GBC} is mean-zero Gaussian. Inverse dilution rates without a t subscript ψ^{-1} relate to steady state values.

A tax rule determines the distortionary levy on household income as a linear function of model

[6] I derive this equilibrium condition in Appendix B.

variables, written as

$$\hat{\tau}_t = f_\tau\left(\hat{\pi}_t, \widehat{\psi_t^{-1}}, \hat{i}_t\right) + u_t^{FP} \tag{6}$$

and a rate rule determines the nominal interest rate as a linear function of model variables, written as

$$\hat{i}_t = f_i\left(\hat{\pi}_t, \widehat{\psi_t^{-1}}, \hat{\tau}_t\right) + u_t^{MP} \tag{7}$$

where u_t^{FP} and u_t^{MP} are Gaussian and mutually orthogonal with u_t^{IS}, u_t^{AS} and u_t^{GBC}.

Dilution is jointly determined by monetary and fiscal authorities who implement individual tax and interest rate policies. It is a linear function of model variables, written as

$$\widehat{\psi_t^{-1}} = f_\psi\left(\hat{\pi}_t, \hat{i}_t, \hat{\tau}_t\right) + u_t^{\psi} \tag{8}$$

where u_t^{ψ} is mutually orthogonal with u_t^{GBC}, u_t^{FP} and u_t^{MP}.

Given tax policy (6), interest rate policy (7), and debt policy (8), inflation is determined by the present value condition (5).

4 A Structural Vector Autoregression

I use the model described in Section 3 to motivate a structural VAR at a quarterly frequency to ask three questions: 'How do monetary and tax policy affect dilution?,' 'How does dilution affect inflation?,' and 'Does the addition of dilution eliminate the 'price puzzle' effect from a monetary policy tightening?' As in work by Sims (1992), Bernanke and Blinder (1992), and Blanchard and Perotti (2002), policy decisions are made conditional on lagged information. Specifically, I disallow fiscal and monetary policy rules from being affected by contemporaneous shocks with the exception that the Fed may react to contemporaneous tax policy innovations. Debt policy responds to tax and interest rate shocks contemporaneously to implement monetary and fiscal policy.

Finally, I apply the present value condition (5) to allow inflation $\hat{\pi}_t$ to be affected by contemporaneous shocks to each variable. This leaves me with a recursively identified impact matrix. The full SVAR is written as

$$\boldsymbol{z}_t = \boldsymbol{B}_0^{-1}\boldsymbol{C} + \underbrace{\boldsymbol{B}_0^{-1}\boldsymbol{B}\left(L\right)}_{\boldsymbol{A}(L)}\boldsymbol{y}_{t-\rho} + \underbrace{\boldsymbol{B}_0^{-1}\boldsymbol{u}_t}_{\boldsymbol{v}_t} \tag{9}$$

where $\boldsymbol{z}_t = \left[\hat{\tau}_t \; \hat{i}_t \; \hat{\psi_t^{-1}} \; \hat{\pi}_t\right]'$ and where $\rho = 4$ lags. I list the identification scheme in Table 1.

	u_t^{FP}	u_t^{MP}	u_t^{ψ}	u_t^{GBC}
$\hat{\tau}$	X			
$\hat{i}$	X	X		
$\hat{\psi^{-1}}$	X	X	X	
$\hat{\pi}$	X	X	X	X

Table 1: VAR identification strategy. An X indicates where a shock from the top row is allowed to contemporaneously affect a variable from the left column.

where an X indicates which shocks from the top row are allowed to contemporaneously affect variables from the left column.

Data from 1949Q1–2022Q4 is quarterly. I calculate tax rates as U.S. receipts over U.S. GDP. Interest rates are average NY Fed discount rates from 1949Q1–1954Q2 and average Fed Funds rates from 1954Q3–2022Q4. Inflation is annualized growth rates in NIPA's GDP deflator. Finally, the inverse dilution rate is calculated as previous-quarter long-term debt over short-term debt, where short-term debt is defined as (total reserves) + (outstanding Treasurys maturing within 1 quarter) and long-term debt is defined as (Treasurys maturing after 1 quarter). All data is seasonally adjusted and in terms of percentage log deviations from their mean. As in the theory, tax rates are net rates, and interest, dilution and inflation rates are in gross terms. A full data description is available in Appendix D.

5 Results

I apply the Minnesota prior from Sims's (1980) work to plot IRFs using the Matlab code made available by Ferroni and Canova (2025) using Ferroni and Canova's (2025) default hyperparameters. The full set of IRFs can be found in Appendix C.

I answer the first question, 'How do monetary and tax policy affect dilution?' using IRFs from fiscal u_t^{FP} (left panel) and monetary u_t^{MP} (right panel) shocks on inverse dilution in Figure 1. An unexpected one percent deviation from the mean in tax rates causes a contemporaneous and transitory jump of less than one percent deviation from the mean in inverse dilution in the same direction at the 68% credible level. Conversely, an unexpected one percent deviation from the mean in interest rates causes a contemporaneous and highly persistent jump of almost a 4 percent deviation from the mean in inverse dilution in the same direction, lasting for 32 quarters at the 90%

credible level.

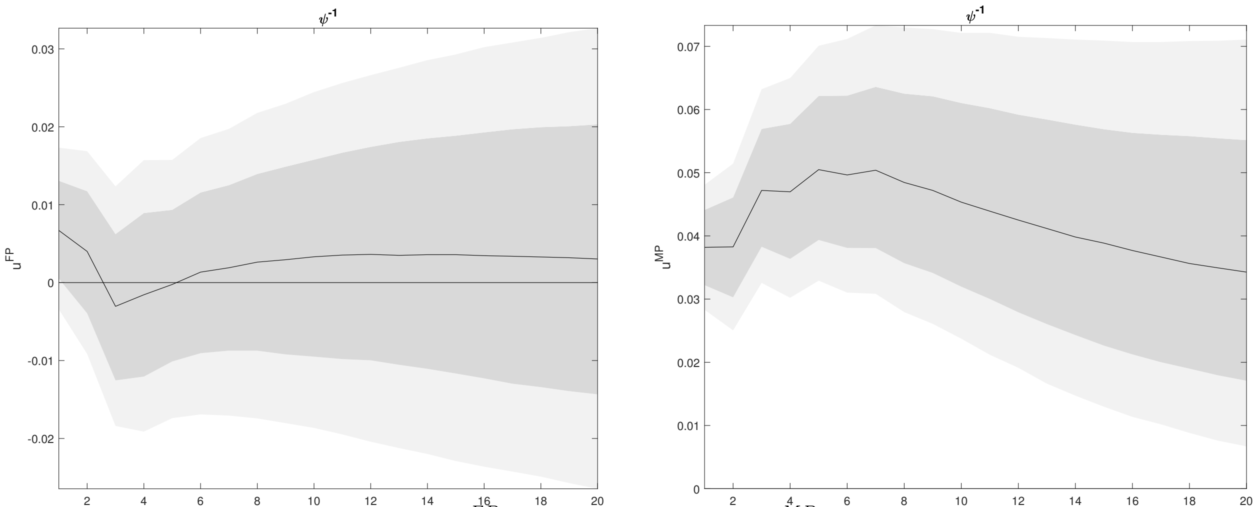

Figure 1: Impulse response functions of fiscal u_t^{FP} (left panel) and monetary u_t^{MP} (right panel) shocks on inverse dilution. All data in percentage deviations from mean. Dark and light bands represent 68% and 90% credible intervals, respectively. The response horizon is 20 quarters.

Government debt is used to intertemporally smooth taxes and inflation. Figure 1 uncovers a distinction in the way fiscal and monetary policy implements their policy through debt management.

When fiscal surpluses surprisingly fall, the joint government opts to temporarily dilute long-term debt holders by shifting the U.S.'s debt position short.

The Fed sells Treasurys (decreasing dilution) with surprise contractionary policy and buys Treasurys (increasing dilution) with expansionary policy. The joint government appears to follow suit because these relationships shine through in Figure 1's right panel.

I answer the second and third questions, 'How does dilution affect inflation?' and 'Does the addition of dilution eliminate the 'price puzzle' effect from a monetary policy tightening?' using IRFs from inverse dilution u_t^{ψ} (left panel) and monetary policy u_t^{MP} (right panel) shocks on inflation in Figure 2.

An unexpected one percent deviation from the mean in the inverse dilution rate causes between a 0.1 and 0.2 percent contemporaneous deviation from the mean in inflation in the same direction, lasting for two quarters at the 90% credible level. The same unexpected shock increases long-run inflation at the 68% credible level, doing so over quarters 22–112. Additionally, an unexpected one percent deviation from the mean in the Fed's policy rate causes between a 0.1 and 0.25 percent contemporaneous and transitory deviation from the mean in inflation in the same direction, also at the 90% credible level.

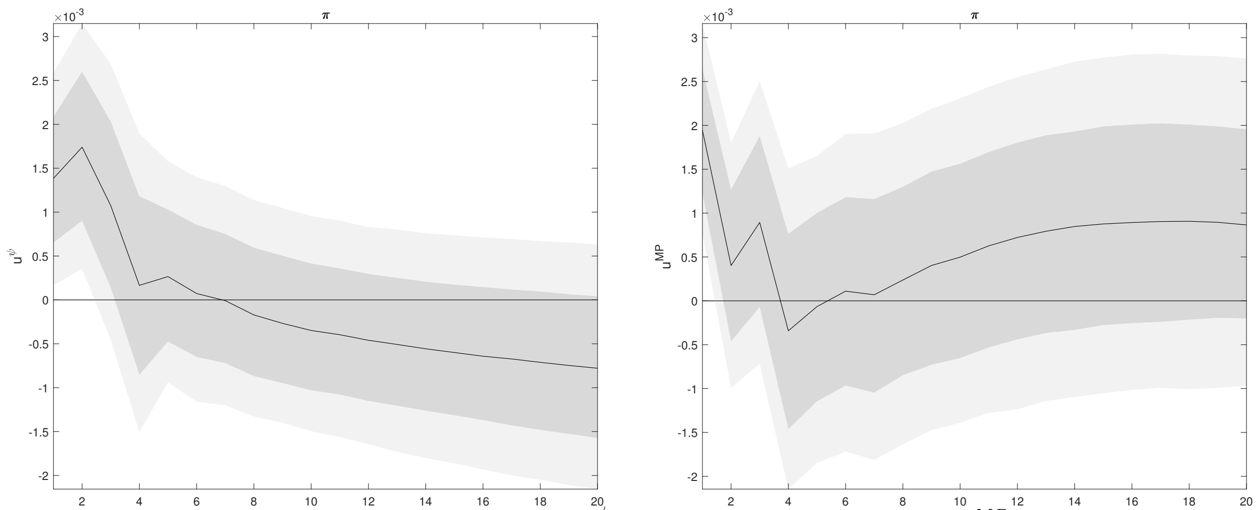

Figure 2: Impulse response functions of inverse dilution u_t^{ψ} (left panel) and monetary policy u_t^{MP} (right panel) shocks on inflation. All data in percentage deviations from mean. Dark and light bands represent 68% and 90% credible intervals, respectively. The response horizon is 20 quarters.

An increase in dilution (decrease in inverse dilution) reduces inflation in the short run and increases inflation in the long run – a result in line with Section 2's theoretical predictions. The exact timing of these effects suggests that surprise debt dilution may be an effective tool to fight inflation: the positive effects are immediate, while the negative effects only begin to surface in five years.

Despite this dilution result, the pesky 'price puzzle' plaguing modern macroeconomics remains: contractionary monetary policy has immediate and transitory inflationary consequences which are 90% credible in quarter 1. The selection of directional responses is listed in Table 2 in more detail.

Variable	Direction	Shock	Credible IRF Response Range (qtrs)	
			68%	90%
$\hat{\psi^{-1}}$	↑	u_t^{FP}	1	None
$\hat{\psi^{-1}}$	↑	u_t^{MP}	1–99	1–32
$\hat{\pi}$	↑	u_t^{MP}	1	1
$\hat{\pi}$	↑	u_t^{ψ}	1–3	1–2
$\hat{\pi}$	↓	u_t^{ψ}	22–112	None

Table 2: Statistically credible IRF ranges. This is the range during which a response of given variable in given direction is credible when responding to given shock. Shock occurs at quarter 1.

6 Conclusion

This paper introduces a new concept to the literature on public debt management. The dilution rate of government debt measures the amount of currently outstanding short-term debt to previously-issued, unmatured long-term debt. Such a concept is useful for three reasons. First, it can be widely applied to economic models with nominal debt. Second, it survives log-linear approximations common in much of modern macroeconomics. Third, it comes with clean interpretations and tractable algebra. Such an innovation improves on Woodford's (2001) constantly geometrically-declining structure because it allows for analysis of dynamic maturity responses to unexpected economic shocks.

I apply this concept to U.S. post-war data using a SVAR motivated by a flexible-price economy with inflation, fiscal policy, monetary policy and debt management policy. Four main findings arise. First, a surprise tax cut causes a contemporaneous, transitory increase in debt dilution. Second, a surprise interest rate cut causes a contemporaneous and highly persistent increase in dilution. Third, in line with the model's theoretical predictions, an unexpected increase in dilution causes a contemporaneous, somewhat persistent decrease in inflation at the cost of a gradual, highly persistent long-run rise in inflation. Fourth, dilutive effects do not fully resolve the "price puzzle" originally described in Sims (1992) – an unexpected monetary tightening causes a contemporaneous, transitory increase in inflation.

These results may spark new debate in government policy because they imply that open market purchases decrease inflation while open market sales increase inflation: QE contributes to suppressed prices during recessions wile QT counteracts contractionary monetary policy by increasing the price level. Could it have been the case that inflation was kept below the Fed's 2% target during the 2010s, at least in part, as a result of QE? Or that the Treasury suppressed inflation when it issued short-term debt in 2024 during QT? The results from this paper suggest so.

Moving forward, it may be useful to apply the dilution rate of government debt to existing theories of optimal debt management, such as those with complete markets economies like Buera and Nicolini (2004) and incomplete markets economics like Lustig, Sleet, and Yeltekin (2008), Debortoli, Nunes, and Yared (2017) and Faraglia et al. (2019). Such a re-interpretation may connect those theories to yet-to-come linearized theories of optimal debt responses to shocks.

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A Appendix: Deriving the Rewritten Present Value Condition

This section derives the rewritten present value condition (3) from the text, as in the paper by Cochrane (2001). I begin with the well-known present value condition (2):

$$\underbrace{\frac{B_{t-1}^{(t)}}{P_t} + \mathbb{E}_t \frac{B_{t-1}^{(t+1)}}{r_{t,t+1}P_{t+1}}}_{MV(\text{Debt})/P_t} = \underbrace{\mathbb{E}_t \sum_{i=0}^{\infty} \frac{s_{t+i}}{r_{t,t+i}}}_{\mathbb{E}[PV(\text{Prim. Spls.})]}$$

and subtract both sides by the market value of unmatured debt:

$$\frac{B_{t-1}^{(t)}}{P_t} = \mathbb{E}_t \sum_{i=0}^{\infty} \frac{s_{t+i}}{r_{t,t+i}} - \mathbb{E}_t \frac{B_{t-1}^{(t+1)}}{r_{t,t+1}P_{t+1}}$$

then multiply the right-most term by $1 = B_t^{(t+1)}/B_t^{(t+1)}$ to write:

$$\frac{B_{t-1}^{(t)}}{P_t} = \mathbb{E}_t \sum_{i=0}^{\infty} \frac{s_{t+i}}{r_{t,t+i}} - \mathbb{E}_t \left(\frac{B_{t-1}^{(t+1)}}{r_{t,t+1}B_t^{(t+1)}} \right) \frac{B_t^{(t+1)}}{P_{t+1}}$$

noticing that $B_t^{(t+1)}/P_{t+1}$ is $B_{t-1}^{(t)}/P_t$ iterated one period into the future.

Apply Section 2's definition of the nominal dilution rate to write:

$$\frac{B_{t-1}^{(t)}}{P_t} = \mathbb{E}_t \sum_{i=0}^{\infty} \frac{s_{t+i}}{r_{t,t+i}} - \mathbb{E}_t \left(\frac{\Psi_{t,t}^{-1}}{r_{t,t+1}} \right) \frac{B_t^{(t+1)}}{P_{t+1}}$$

and forward-iterate once on this condition:

$$\frac{B_{t-1}^{(t)}}{P_t} = \mathbb{E}_t \sum_{i=0}^{\infty} \frac{s_{t+i}}{r_{t,t+i}} - \mathbb{E}_t \left(\frac{\Psi_{t,t}^{-1}}{r_{t,t+1}} \right) \left[\sum_{i=0}^{\infty} \frac{s_{t+1+i}}{r_{t+1,t+1+i}} - \left(\frac{\Psi_{t+1,t+1}^{-1}}{r_{t+1,t+2}} \right) \frac{B_{t+1}^{(t+2)}}{P_{t+2}} \right]$$

which simplifies to:

$$\frac{B_{t-1}^{(t)}}{P_t} = \mathbb{E}_t \sum_{i=0}^{\infty} \frac{s_{t+i}}{r_{t,t+i}} - \mathbb{E}_t \Psi_{t,t}^{-1} \sum_{i=0}^{\infty} \frac{s_{t+1+i}}{r_{t,t+1+i}} + \mathbb{E}_t \left(\frac{\Psi_{t,t+1}^{-1}}{r_{t,t+2}} \right) \frac{B_{t+1}^{(t+2)}}{P_{t+2}}$$

and continuing this forward-iteration reveals:

$$\frac{B_{t-1}^{(t)}}{P_t} = \mathbb{E}_t \sum_{i=0}^{\infty} \frac{s_{t+i}}{r_{t,t+i}} - \mathbb{E}_t \Psi_{t,t}^{-1} \sum_{i=0}^{\infty} \frac{s_{t+1+i}}{r_{t,t+1+i}} + \mathbb{E}_t \Psi_{t,t+1}^{-1} \sum_{i=0}^{\infty} \frac{s_{t+2+i}}{r_{t,t+2+i}} - \mathbb{E}_t \Psi_{t,t+2}^{-1} \sum_{i=0}^{\infty} \frac{s_{t+3+i}}{r_{t,t+3+i}} + \cdots - \cdots$$

so that I can write:

$$\frac{B_{t-1}^{(t)}}{P_t} = s_t + \left(\mathbb{E}_t \frac{s_{t+1}}{r_{t,t+1}} - \Psi_{t,t}^{-1}\mathbb{E}_t \frac{s_{t+1}}{r_{t,t+1}}\right) + \left(\mathbb{E}_t \frac{s_{t+2}}{r_{t,t+2}} - \Psi_{t,t}^{-1}\mathbb{E}_t \frac{s_{t+2}}{r_{t,t+2}} + \mathbb{E}_t \Psi_{t,t+1}^{-1} \frac{s_{t+2}}{r_{t,t+2}}\right) + \cdots$$

where, starting with the term $\mathbb{E}_t \Psi_{t,t+1}^{-1} \frac{s_{t+2}}{r_{t,t+2}}$, expectations of future debt policy may be correlated with that of future primary surpluses. If we allow this covariance to be zero, we can freely factor $\Psi_{t,t+i}^{-1}$ out of every $\mathbb{E}_t \Psi_{t,t+i-1}^{-1} \frac{s_{t+i}}{r_{t,t+i}}$ term and group terms by s_{t+i} to write equation (3):

$$\underbrace{\frac{B_{t-1}^{(t)}}{P_t}}_{(\text{Mat. Debt})/P_t} = \underbrace{s_t + \mathbb{E}_t \sum_{i=1}^{\infty} \frac{s_{t+i}}{r_{t,t+i}} \left(1 + \sum_{h=1}^{i} -\Psi_{t,t+h-1}^{-1}\right)}_{\mathbb{E}[PV(\text{Diluted Primary Surpluses})]} \tag{3}$$

such that the household TVC holds and that the long-run condition $|B_t^{(t+1)}| > \beta |B_t^{(t+2)}|$ as $t \to \infty$ holds.

B Appendix: Deriving the Log-Linearized Present Value Condition

This section is dedicated to deriving the log-linearized present value condition (5) found in Section 3. I begin with the well-known present value condition (2):

$$\underbrace{\frac{B_{t-1}^{(t)}}{P_t} + \mathbb{E}_t \frac{B_{t-1}^{(t+1)}}{r_{t,t+1}P_{t+1}}}_{MV(\text{Debt})/P_t} = \underbrace{\mathbb{E}_t \sum_{i=0}^{\infty} \frac{s_{t+i}}{r_{t,t+i}}}_{\mathbb{E}[PV(\text{Prim. Spls.})]}$$

and define real (deflated) debt as $b_t^{(t+j)} = B_t^{(t+j)}/P_t$ and gross inflation as $\pi_t = P_t/P_{t-1}$ to write this equation as:

$$\frac{1}{\pi_t}\left[b_{t-1}^{(t)} + \frac{b_{t-1}^{(t+1)}}{i_t}\right] = \mathbb{E}_t \sum_{i=0}^{\infty} \frac{s_{t+i}}{r_{t,t+i}}$$

where the short-term nominal rate is $i_t = \mathbb{E}_t r_{t,t+1}\pi_{t+1}$.[7]

Then I use Section 3's definition of the real dilution rate ψ_t and the fact that real rates are constant $r_{t,t+1} = \beta^{-1}$ to write:

$$b_{t-1}^{(t)} = \pi_t \mathbb{E}_t \sum_{i=0}^{\infty} \beta^i s_{t+i} - \frac{\psi_t^{-1}}{i_t} b_t^{(t+1)}$$

and continually forward-iterate on b_t^{t+1} to get:

$$b_{t-1}^{(t)} = \pi_t \mathbb{E}_t \sum_{i=0}^{\infty} \beta^i s_{t+i} - \frac{\psi_t^{-1}}{i_t}\mathbb{E}_t \pi_{t+1} \sum_{i=0}^{\infty} \beta^{1+i} s_{t+1+i} + \frac{\psi_t^{-1}}{i_t}\mathbb{E}_t \frac{\psi_{t+1}^{-1}}{i_{t+1}} \pi_{t+2} \sum_{i=0}^{\infty} \beta^{2+i} s_{t+2+i}$$

$$- \frac{\psi_t^{-1}}{i_t}\mathbb{E}_t \frac{\psi_{t+1}^{-1}\psi_{t+2}^{-1}}{i_{t+1}i_{t+2}} \pi_{t+3} \sum_{i=0}^{\infty} \beta^{3+i} s_{t+3+i} + \cdots - \cdots \quad (10)$$

I examine a constant inflation, surplus and dilution steady state where $\pi_t = \pi = 1$, $s_t = s$, and $\psi_t = \psi$ to write:

$$b_{t-1}^{(t)} = \left(\frac{1}{1-\beta}\right) s - \beta\psi^{-1}\left(\frac{1}{1-\beta}\right) s + \beta^2\psi^{-2}\left(\frac{1}{1-\beta}\right) s - \beta^3\psi^{-3}\left(\frac{1}{1-\beta}\right) s + \cdots - \cdots$$

[7] Solving the model will reveal a tight connection between the nominal interest rate and debt maturity management. Both must be consistent with the same expectation $\mathbb{E}_t[\pi_{t+1}]$ according to the Fisher equation and the time $t+1$ intertemporal condition. In a richer model with real and nominal rigidities, such a restriction loosens.

which simplifies to the real-valued version of (4):

$$b_{t-1}^{(t)} = \left(\frac{1}{1-\beta}\right)\left(\frac{1}{1+\beta\psi^{-1}}\right)s$$

so long as $|\psi| < \beta^{-1}$ holds.

From here, notice that ψ_t^{-1}/i_t can be factored out of all but the first term on the RHS of (10), and that π_t only affects the first term on the RHS of (10). I write (10) in terms of log-deviations, treating $b_{t-1}^{(t)}$ as a constant:

$$0 = (1+\hat{\pi}_t)\left(\frac{1}{1-\beta}\right)s + (1+\hat{s})\,s - \left(1+\widehat{\psi_t^{-1}}\right)\left(1-\hat{i}_t\right)\beta\left(\frac{1}{1-\beta}\right)\left(\frac{1}{1-\beta\psi^{-1}}\right)s + \mathbb{E}_t$$

where $\mathbb{E}_t$ includes only terms dated from $t+1$ onward.

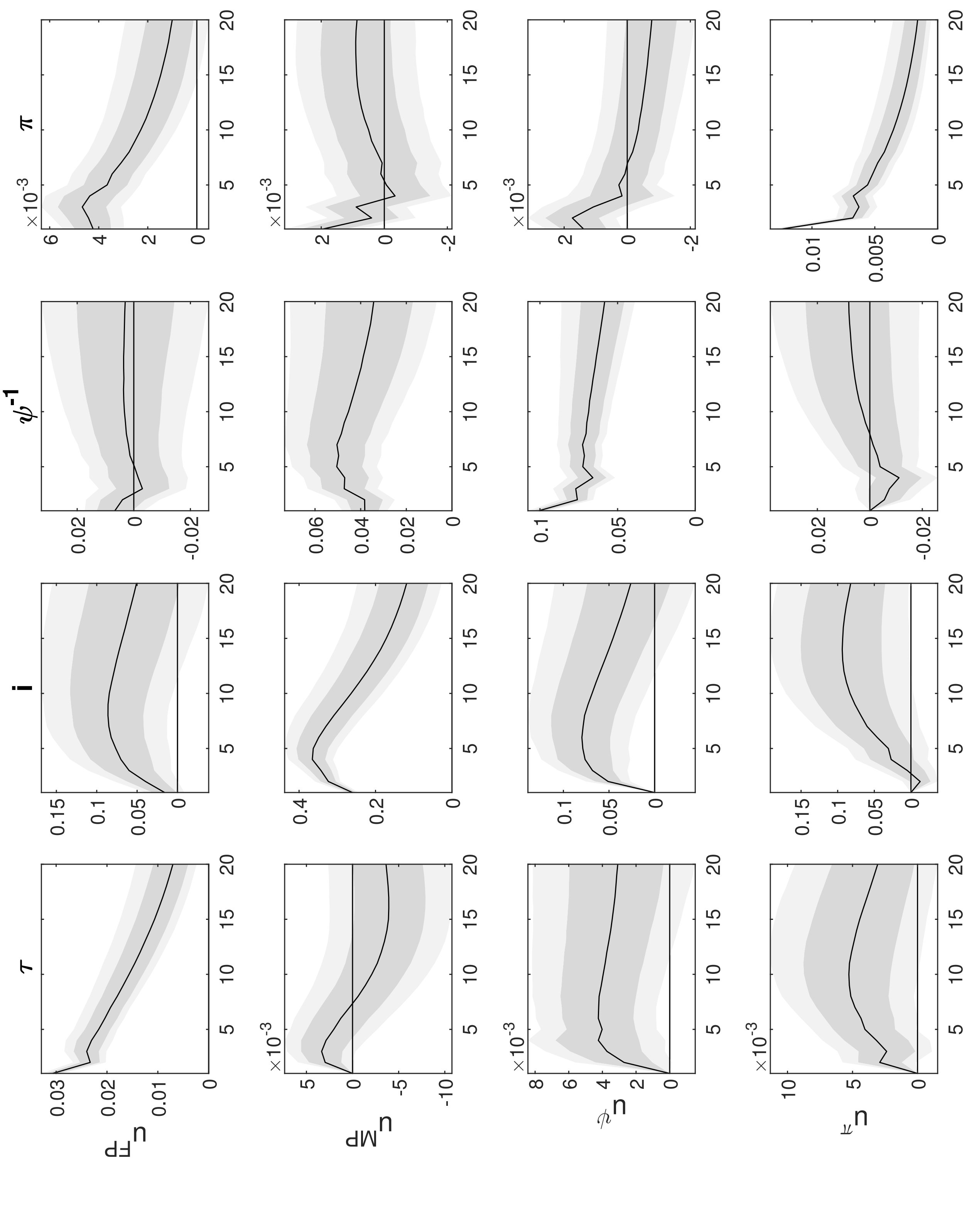
Approximating second order terms to zero and applying the steady state condition (4) yields:

$$0 = \left(\frac{1}{1-\beta}\right)s\hat{\pi}_t + s\hat{s} - \beta\left(\frac{1}{1-\beta}\right)\left(\frac{1}{1-\beta\psi^{-1}}\right)s\left(\widehat{\psi_t^{-1}} - \hat{i}_t\right) + \mathbb{E}_t$$

where dividing everywhere by s, multiplying everywhere by $1-\beta$, substituting $\hat{\tau}_t$ for $\hat{s}_t$ and adding the shock u_t^{GBC} yields log-linearized equation (5) in Section 3:

$$0 = \hat{\pi}_t + (1-\beta)\,\hat{\tau}_t - \left(\frac{\beta}{1-\beta\psi^{-1}}\right)\left(\widehat{\psi_t^{-1}} - \hat{i}_t\right) + \boldsymbol{E}_t + u_t^{GBC} \tag{5}$$

C Appendix: Complete IRF Listing



D Appendix: Data Sources and Construction

This paper uses four main time series from 1949Q1–2022Q4: U.S. tax rate, Fed's policy rate, U.S. real debt dilution rate, and U.S. price levels. Their construction and data sources are below:

- U.S. Tax Rate, constructed as total U.S. receipts over U.S. GDP:
  - Receipts: Section 3, table T30200-Q, line 40 in the National Income and Product Accounts (NIPA) from the BEA and found at `https://apps.bea.gov/iTable/?isuri=1&reqid=19&step=4&categories=flatfiles&nipa_table_list=1`.
  - GDP: Gross domestic product. Section 1, table T10105-Q, line 1 in the National Income and Product Accounts (NIPA) from the BEA. Found at `https://apps.bea.gov/iTable/?isuri=1&reqid=19&step=4&categories=flatfiles&nipa_table_list=1`.
- Fed's Policy Rate, average NY Fed discount rates from 1949Q1–1954Q2 and average Fed Funds rates from 1954Q3–2022Q4:
  - NY Fed discount rates: National Bureau of Economic Research, Release: NBER Macrohistory Database. `https://fred.stlouisfed.org/series/M13009USM156NNBR`
  - Fed Funds effective rate: Source: Board of Governors of the Federal Reserve System (US), Release: H.15 Selected Interest Rates. `https://fred.stlouisfed.org/series/FEDFUNDS`
- U.S. Inflation (1943–2023)
  - Growth rate in annual GDP deflator. Section 1, table T10109-A, line 1 in the NIPA from the BEA. Found at `https://apps.bea.gov/iTable/?isuri=1&reqid=19&step=4&categories=flatfiles&nipa_table_list=1`
- U.S. Real Dilution Rate
  - Constructed as previous-period [(long-term debt outstanding)/(price level)] divided by [(short-term debt outstanding)/(price level)].
  - Long-term debt is Privately-Held Treasurys maturing in more than one quarter.

- Short-term debt calculated as (Reserves Outstanding) + (Privately-Held Treasurys maturing in less than one quarter).
  - Privately-Held Debt (1948Q4–2022Q4). Center for Research in Security Prices (CRSP) U.S. Treasury Database
  - Reserves Outstanding (1949Q1–2002Q4). Calculated as the average reserves outstanding/GDP from 2002–2022 multiplied by GDP from 1942–2001. Member Bank Reserve Account. Source: Center for Financial Stability Release: The Federal Reserve System's Weekly Balance Sheet Since 1914. `https://fred.stlouisfed.org/series/LDMB`
  - Reserves Outstanding (2003Q1–2022Q4). Calculated as (Federal Reserve Notes, Net of F.R. Bank Holdings) + (Deposits with F.R. Banks, Other Than Reserve Balances) + (Other Deposits at the Fed) + (Term Deposits Held by Depository Institutions) - (U.S. Treasury, Supplementary Financing Account) - (Treasury balance in TGA) + (Reverse Repurchase Agreements).
    - Federal Reserve Notes, Net of F.R. Bank Holdings. Table H.4.1.T5 on the Fed's weekly balance sheet and found at `https://fred.stlouisfed.org/series/WLFN`.
    - Deposits with F.R. Banks, Other Than Reserve Balances. Table H.4.1.T5 on the Fed's weekly balance sheet and found at `https://fred.stlouisfed.org/series/WDFOL`.
    - Other Deposits at the Fed. Table H.4.1.T5 on the Fed's weekly balance sheet and found at `https://fred.stlouisfed.org/series/WLODL`.
    - Term Deposits Held by Depository Institutions. Table H.4.1.T5 on the Fed's weekly balance sheet and found at `https://fred.stlouisfed.org/series/TERMT`.
    - U.S. Treasury, Supplementary Financing Account. Table H.4.1.T5 on the Fed's weekly balance sheet and found at `https://fred.stlouisfed.org/series/WLSFAL`.
    - Treasury balance in TGA. Daily Treasury Statements, found at `https://fsapps.`

fiscal.treasury.gov/dts/issues.

- Reverse Repurchase Agreements. Table H.4.1.T5 on the Fed's weekly balance sheet and found at https://fred.stlouisfed.org/series/WLRRAL.

MERCATUS SPECIAL STUDY

A FISCAL ACCOUNTING OF COVID INFLATION

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ABSTRACT

Federal COVID-related spending was largely financed through government borrowing with minimal discussion of repayment strategies. Inflation surged in 2021 and remains higher than target. The fiscal theory of the price level helps us examine the intricate interplay of fiscal and monetary policies in shaping this inflation episode.

We focus on two accounting methodologies. *Backward accounting* dissects changes in the government debt–GDP ratio throughout the COVID period, attributing it to changes in primary deficits, interest rates, inflation, and economic growth. Forward accounting links the market value of debt to expected discounted primary surpluses to interpret current inflation and bond prices in terms of changing beliefs about future fiscal and monetary policy actions.

COVID-related spending, predominantly in the form of transfers to individuals and businesses, in combination with the lack of anticipated tax increases, led to increased consumer expenditure, a swift economic recovery, and ensuing inflation. This work underscores how fiscal policy, monetary policy and household expectations shaped inflation dynamics during and after the COVID crisis.

JEL codes: E50, E52, E60, E61, E62, E63, E65, E66

Keywords: COVID inflation, fiscal policy during COVID, monetary policy during COVID, 2021 inflation, 2022 inflation, 2023 inflation, fiscal policy and inflation, monetary policy and inflation, fiscal theory of the price level, fiscal policy monetary policy

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1 INTRODUCTION

When American inflation began its upward march in 2021, economic analysts lined up the usual suspects. Among the suspects for the source of inflation were overheated markets, supply-chain disruptions, shifts in consumer demand from services to goods, food and energy price rises, excessive corporate profits, and the perennial favorite: price gouging. Many of these candidates affected the evolution of inflation. None caused it.

We focus on the single cause: a large increase in federal COVID-related spending financed by new government borrowing, with little to no discussion of how ultimately to pay for the spending.

Rarely does the economy offer up something close to a natural experiment. COVID is an exception. By typical indicators, 2019 was a good year for the economy: the unemployment rate was 3.7 percent, real gross domestic product (GDP) grew 2.3 percent, overall prices rose by 1.8 percent, and the 10-year Treasury yield sat at 2.1 percent. Then the COVID pandemic hit. Then the federal government responded.[1]

Causal attribution demands economic theory. Data alone cannot do the trick. We draw on the fiscal theory of the price level that Leeper (1991), Sims (1994), Woodford (1995), and Cochrane (2023) developed. The fiscal theory springs from the uncontentious premise that government debt derives its value in large part from how people expect the debt will be repaid. It points to unconventional channels through which fiscal policy affects the economy and underscores the need to bring both monetary and fiscal policy into any examination of inflation.

1. Because policy reacted to an event that was external to the American economy, it is reasonable to attribute many of the subsequent economic developments to that policy response. Because we do not know the counterfactuals—economic outturns after the policy response but without COVID; outcomes with COVID but without the policy response—the experiment is not perfectly controlled. Barro and Bianchi (2023) and Bianchi, Faccini, and Melosi (2023) examine the issue more formally.

Our framework starts with the fact that government accounts must add up. Total spending must equal total revenues plus borrowing. This government budget identity alone permits a "backward accounting" that reports the empirical sources of changes in the government debt–GDP ratio. Backward accounting follows Hall and Sargent's (2011, 2022) procedure to attribute changes in the debt–GDP ratio over the COVID period to actual outcomes for deficits, interest rates, inflation rates, and economic growth.

An alternative approach couples the budget identity with the behavior of debt-market participants to deliver a valuation expression that links the value of debt today to the present value of expected primary government budget surpluses. This "forward accounting" connects the evolution of nominal debt, debt prices, the price level, and real GDP to changing beliefs about future fiscal and monetary policy actions.

The two accountings answer different questions. Backward accounting tracks why government debt evolved as it did during COVID. Forward accounting describes how the value of debt could have evolved under alternative fiscal and monetary policies. Both accountings shed fresh light on COVID inflation to offer insights different from those that the usual suspects deliver. With new insights come starkly different policy implications.

Economic behavior lies behind the accounting. If government sends you a $1,000 check but tells you that your taxes will rise by $1,000 plus interest in the future, you will be less inclined to spend the full amount. This diminishes the stimulus to demand. Much of the COVID spending was transfers to individuals and businesses, and the tenor of public discourse sent the message that Americans should not expect tax hikes for the foreseeable future. Transfer recipients perceived they could permanently raise their consumption, which created a powerful aggregate stimulus to demand. As people spent their new government-provided wealth, production and prices rose. The result was a swift economic recovery from the COVID recession, followed by inflation.

The $5 trillion in new federal COVID-related spending helped raise the nominal value of total government debt a stunning 43 percent from 2019Q4 to 2023Q2. The *value* of that debt as a share of the economy increased only 14 percent. That 29 percentage point devaluation in debt–GDP is the fiscal theory of the price level in action. Government communications about the new spending focused on the emergency nature of the spending, which emphasized that this spending was different. It would not be offset by higher taxes or cuts in other spending. With no expectations of higher future surpluses, debt's market value cannot rise to keep pace with its nominal value, triggering falling debt prices and a rapidly rising price level—higher inflation. This is the accounting.

The mechanisms just highlighted bear little resemblance to the usual suspects. Some economists suggested that COVID spending would be inflationary, operating entirely through a Phillips curve relationship; accordingly, fiscal expansion pushes resource utilization rates high enough to produce inflation (prominent examples include Blanchard 2021; Summers 2021; Bernanke and Blanchard 2023). That view downplays—or ignores—the fiscal financing that lies at the heart of this brief.

2 LEGISLATION DURING COVID

Legislation ratified during the pandemic financed vaccine research, extended forgivable loans to businesses, and sent checks directly to households, along with a host of other measures. This section documents this legislative response.

2.1 Spending Amounts

From March 2020 to December 2021, the height of the pandemic, eleven spending bills were enacted. Headlined by the Coronavirus Aid, Relief, and Economic Security (CARES) Act and the American Rescue Plan (ARP), these bills increased federal spending authorization by about $6 trillion. Of that total, $5.7 trillion has been committed to be spent and $4.9 trillion has been disbursed. Table 1 breaks down the spending by bill.

TABLE 1. SPENDING BREAKDOWN BY LEGISLATION

Legislation	Ratification Date	Allowed ($B)	Committed ($B)	Disbursed ($B)
Coronavirus Supplemental Appropriations Act	3/6/20	8	7	2
Families First Act	3/18/20	247	244	312
CARES Act	3/27/20	2,107	2,030	1,887
PPP & Health Care Enhancement Act	4/24/20	803	692	666
Emergency Aid for Returning Americans Act	7/13/20	.009	.009	.009
September 2020 Continuing Resolution	10/1/20	32	31	31
Response & Relief Act	12/27/20	924	854	650
American Rescue Plan (ARP)	3/11/21	1,857	1,774	1,355
Prevent Cuts Act	4/14/21	12	12	12
September 2021 Continuing Resolution	9/30/21	.096	0	0
Protecting Medicare Act	12/10/21	8	8	8
Total		5,998	5,652	4,923

Note: Totals are rounded. CARES = Coronavirus Aid, Relief, and Economic Security; PPP = Paycheck Protection Program.
Source: Committee for a Responsible Federal Budget. Data as of July 21, 2023. https://www.covidmoneytracker.org/.

TABLE 2. ALLOCATION OF COVID SPENDING

Recipient	Allowed ($B)	Committed ($B)	Disbursed ($B)
Households	2,350	2,256	2,033
Businesses	1,984	1,855	1,793
Health spending	467	425	257
State and local governments	1,029	1,003	764
Federal Agencies	168	114	76
Total	5,998	5,652	4,923

Source: Committee for a Responsible Federal Budget. Data as of July 21, 2023. https://www.covidmoneytracker.org/.

2.2 Spending Allocations

Spending on vaccine research and at-home testing had real, positive effects on production. Employees went back to work and places of business reopened their doors earlier. Higher production and income raised the tax base to help revenues recover without changes in tax rates.

The government also gave out stimulus checks to households and bolstered social programs. These transfers expanded American household budgets. For those hit hard by the pandemic, this additional income was used to catch up on overdue hospital or credit card bills. For those more indirectly affected by COVID, these payments were seen as "free money" and were used to purchase additional goods. As immunizations grew, more households went from the first to the second category.

Table 2 outlines how spending was allocated throughout the pandemic. The CARES Act devoted $843 billion (40 percent of the bill) to household transfers, while the ARP, a bill that passed a year later, allocated $979 billion (53 percent of the bill) to households. Total COVID spending was evenly split between households and businesses at $2 trillion each, with state and local governments the next largest recipients at $1 trillion. Very little federal spending was earmarked for health—only 5 percent of the disbursed $5 trillion—but some of the transfers to state and local governments went toward health expenditures.

2.3 Bipartisanship and Deficit Management

As part of the Budget Enforcement Act of 1990, Congress included a pay-as-you-go (PAYGO) rule. Every spending bill that Congress passed had to be accompanied by legislation that would ensure the deficit consequences were offset. If it wanted to cut taxes or raise military spending, Congress needed to enact a law that raised revenues or cut spending somewhere else by an equal

TABLE 3. S-PAYGO SCORING

Legislation	Ratification Date	S-PAYGO
Coronavirus Supplemental Appropriations Act	3/6/20	Partial
Families First Act	3/18/20	Partial
CARES Act	3/27/20	None
PPP & Health Care Enhancement Act	4/24/20	Partial
Emergency Aid for Returning Americans Act	7/13/20	Full
September 2020 Continuing Resolution	10/1/20	Partial
Response & Relief Act	12/27/20	Full
American Rescue Plan (ARP)	3/11/21	Full
Prevent Cuts Act	4/14/21	Full
September 2021 Continuing Resolution	9/30/21	Full
Protecting Medicare Act	12/10/21	None

Note: S-PAYGO = Statutory Pay-As-You-Go Act; CARES = Coronavirus Aid, Relief, and Economic Security; PPP = Paycheck Protection Program.

Source: Individual laws from https://www.congress.gov/.

amount. PAYGO was well honored by Congresses until it was repealed in 2002 (see Blinder 2022).

A different version of this rule was passed in the Statutory Pay-As-You-Go (S-PAYGO) Act of 2010, which is still in effect. S-PAYGO requires that sequestration of current spending offset any new deficit-raising legislation.[2] Every law is subject to this rule by default, but the Senate can exempt individual bills from the S-PAYGO rule with a 60-vote majority, leaving no explicit plan to finance the associated spending. Table 3 reports which COVID bills were subject to S-PAYGO.

A large portion of COVID spending was deliberately unbacked by revenue increases or spending cuts. The CARES Act was entirely exempt from S-PAYGO. And while the ARP is subject to S-PAYGO, the timing of the resulting sequestration continually gets pushed into the future (Protecting Medicare and American Farmers from Sequester Cuts Act, 2021; Consolidated Appropriations Act, 2022). Because of the ARP's size, there is not enough nonexempt funding to cover the required sequestration (see Swagel 2021). What happens when the sequestrations required by law exceed the available funding?

National crises often bring Republicans and Democrats together while presidential elections move them apart. The pattern was no different in 2020–2021. Bills like the Families First Act, CARES Act, and Paycheck Protection

2. Many programs are exempt from this sequestration. Some examples are Social Security, Medicaid, and the Supplemental Nutrition Assistance Program (SNAP). Medicare can be sequestered by 4 percent. These exemptions leave only a small pool of funds available to cut.

TABLE 4. LEGISLATION VOTE SPLITS

Legislation	Ratification Date	House Yea %	Senate Yea %
Coronavirus Supplemental Appropriations Act	3/6/20	99.5	99.0
Families First Act	3/18/20	90.1	91.8
CARES Act	3/27/20	98.6	100
PPP & Health Care Enhancement Act	4/24/20	98.7	100
Emergency Aid for Returning Americans Act	7/13/20	100	100
September 2020 Continuing Resolution	10/1/20	86.3	89.4
Response & Relief Act	12/27/20	87.1	93.9
American Rescue Plan (ARP)	3/11/21	51.0	50.5
Prevent Cuts Act	4/14/21	90.1	97.8
September 2021 Continuing Resolution	9/30/21	59.2	65.0
Protecting Medicare Act	12/10/21	51.2	62.8

Source: Individual laws from https://www.congress.gov/.

Program (PPP) Act passed with strong bipartisan support. After the 2020 election, bills were more hotly contested: the ARP and others narrowly passed Congress. Table 4 breaks down the final passing vote splits in both the House and the Senate for each COVID-related bill.

Tables 3 and 4 show that American political leaders initially reacted to the crisis with little discussion of how new spending would be financed. And after the administration of President Joseph Biden took office in January 2021, much of the bipartisanship disappeared. The prevailing political atmosphere, together with past congressional behavior, were the bases on which Americans formed expectations about fiscal financing.

3 MEASURING GOVERNMENT INDEBTEDNESS

Fiscal accounting tracks how total federal indebtedness to the private sector gets financed. Both the Treasury and the Federal Reserve issue debt instruments that the public buys.

Government obligations to the private sector can be separated into two bins: longer-term securities that the Treasury sells and short-term instruments that the Fed issues.[3] We refer to the Treasury bin, which includes notes, bills, and bonds, as “longer-term privately held debt.” Fed liabilities comprise bank reserves, currency, reverse repurchase agreements, term deposits, and foreign official reserves, which tend to be of short maturity. We call the sum of the two bins “total privately held debt.”

3. The Federal Reserve Bank of Dallas constructs a variety of Treasury debt measures. We supplement their measure of privately held Treasury debt with our measure of Fed debt.

Figure 1 presents several measures of debt over the past twenty years. Figure 1a plots the market values of longer-term privately held and the total privately held debt-to-GDP ratios. The Treasury-based ratio at the beginning of the pandemic is identical to that at the end. Adding short-term government debt yields a ratio that rose 14 percentage points through 2023Q2. Large Fed purchases of government debt during the pandemic make up the difference, as figure 1b shows. The green line is Treasury-only issuances. Adding bank reserves yields the red line, while the blue line adds the remaining Fed liabilities.

Shifting from longer-term debt (Treasury securities) to short-term debt (bank reserves and currency) does not eliminate debt from the consolidated government's ledger. All government debt must be financed in one way or another, which is the topic of the next section.

4 GOVERNMENT BUDGET IDENTITY FRAMEWORK

Government finances must add up. The adding-up condition goes by several names, including the government's "budget constraint" or "budget identity." Hall and Sargent (2011, pp. 193–214) refer to this condition as the "least controversial equation of macroeconomics."

We adopt the accounting convention that gathers all government liabilities into a single object called "total privately held government debt." Two government entities lie behind the budget condition—the Treasury and the Federal Reserve. Each entity has its own budget. Because the entities are part of the same government, economic analyses often consolidate the two budgets into a single "government" budget. Total government liabilities to the private sector include Treasury bills and bonds, currency, and bank reserves. Fed purchases of Treasury securities in the open market do not reduce total government indebtedness. They merely alter the maturity structure, ownership, and labeling of privately held debt.[4]

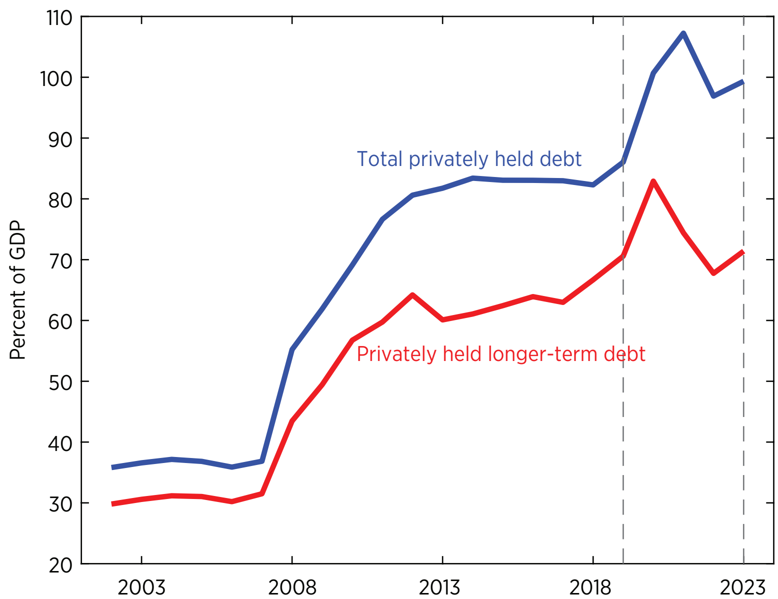
The consolidated government budget identity may be written as[5]

$$\frac{Q_t^P B_t^P}{P_t} + T_t = G_t + \frac{Q_t^P B_{t-1}^P}{P_t},$$

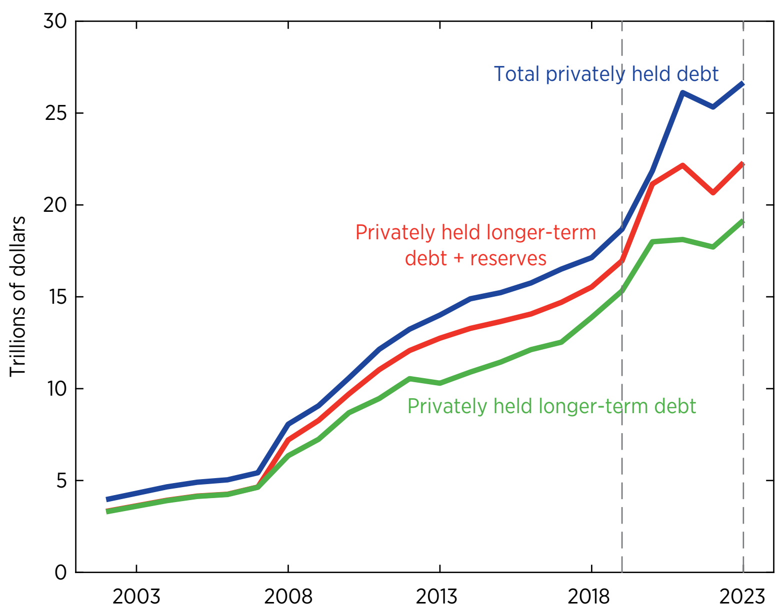
4. In a series of important papers, Hall and Sargent (2011, 2022, 2023) adopt a different convention that focuses on privately held government bills and bonds, treating Fed holdings of Treasury securities as seigniorage.

5. Appendix A describes how to arrive at this form of the consolidated budget identity. We exclude the Fed's holdings of private securities from our accounting. Hall and Sargent (2023) take a more expansive approach and compute the unrealized losses on those assets in 2022.

FIGURE 1. MEASURES OF FEDERAL GOVERNMENT DEBT



(a) Market values of debt–GDP



(b) Face values of three measures of debt

Note: Vertical lines mark 2019 to 2023.

where

$Q_t^P =$ market price of total privately-held government—Treasury plus Federal Reserve—debt portfolio at t,

$B_t^P =$ total nominal privately-held government debt at t,

$P_t =$ aggregate price level at t,

$T_t =$ real value of tax receipts at t,

$G_t =$ real government outlays, excluding interest payments, at t.

Total privately held debt-to-GDP, what we label $Q_t^P B_t^P / P_t Y_t$, is the blue line in figure 1a. The face value of total nominal of privately held debt, B_t^P, is the blue line in figure 1b. The difference between the blue and green lines in that figure is the face value of Federal Reserve debt.

The left side of the budget identity reflects total sources of revenue broadly construed: tax revenues, T_t, and the stock of debt held by the public, B_t^P, at the portfolio price of Q_t^P. Those revenues must equal total outlays: government spending plus redemptions of outstanding debt.

It is natural to measure government debt relative to the size of the economy by scaling everything in the budget identity by real GDP at time t, Y_t. Imposing this and manipulating the right side of the identity leads to useful interpretations of the spending side of the budget.

$$\frac{Q_t^P B_t^P}{P_t Y_t} + \frac{T_t}{Y_t} = \frac{G_t}{Y_t} + i_{t-1,t}^P \frac{Q_{t-1}^P B_{t-1}^P}{(1+\pi_t)(1+g_t) P_{t-1} Y_{t-1}} + \frac{Q_{t-1}^P B_{t-1}^P}{(1+\pi_t)(1+g_t) P_{t-1} Y_{t-1}},$$

where the new notation is

$1 + i_{t-1,t}^P =$ gross one-period nominal weighted holding period return on the total government portfolio between $t-1$ and t,

$1 + \pi_t =$ gross rate of inflation $= P_t / P_{t-1}$,

$1 + g_t =$ gross growth rate of real GDP $= Y_t / Y_{t-1}$.

On the right are three types of spending as shares of GDP—expenditures on goods, services, and transfers; interest on outstanding borrowing; and reduction in debt–GDP due to inflation and economic growth.

A final simplification of the budget identity defines the primary surplus, S_t, as total revenues less total spending—excluding interest payments on the debt—to give us

$$\frac{Q_t^P B_t^P}{P_t Y_t} + \frac{S_t}{Y_t} = \left(\frac{1 + i_{t-1,t}^P}{(1+\pi_t)(1+g_t)} \right) \frac{Q_{t-1}^P B_{t-1}^P}{P_{t-1} Y_{t-1}}. \tag{1}$$

This budget identity lays out precisely how policy can meet its obligations. Start with the obvious ways: government can raise revenues or cut spending to increase the primary surplus, or it can borrow more by selling new debt instruments at the price Q_t^P. These obvious ways receive most of the attention in policy discussions.

But the terms on the right side of the identity embody three other sources of financing. First, the holding period return, $i_{t-1,t}^P$, is negative when debt prices at t fall below those in the previous period. By reducing returns on debt, debt-service costs and the debt–GDP ratio fall. Second, higher inflation—P_t and π_t—has two effects: it reduces the real return on existing debt, and it reduces the real value of new debt. Most government debt instruments are a promise to repay in dollars. By eroding the purchasing power of those dollars, higher inflation makes repayment cheaper in terms of goods and services. Finally, because the identity expresses debt relative to total goods and services the economy produces, higher real GDP—Y_t and g_t—reduces both the (growth-adjusted) return and the debt's share of the economy.

We use versions of budget identity (1) to conduct fiscal accounting of COVID inflation.

5 BACKWARD ACCOUNTING OF FISCAL FINANCING

Backward accounting uses a framework that does not rely on particular assumptions about economic behavior.[6] We view identity (1) as reporting how the debt–GDP ratio evolves over time. It accounts for debt's evolution by quantifying the contribution to observed movements in debt of each component in the condition—surpluses, nominal returns, inflation, and growth. The procedure answers the question: Why did the debt–GDP ratio change from 2019Q4 to 2023Q1? The goal is to explain how government finances behaved using outcomes of economic variables.

The evolution of debt-to-GDP over time brings a *dynamic* component to government finance. Movements in the ratio occur not only through taxes and spending; they also depend on debt price movements, the growth rate of the economy, and the inflation rate, as expression (1) shows. Here is some intuition for these effects:

1. If financing comes from higher taxes or lower outlays, then not as much debt is needed to pay the government's bills. The ratio falls.

6. This approach is based on Hall and Sargent (2022). Appendix A contains derivations.

TABLE 5. CONTRIBUTIONS TO THE EVOLUTION OF THE MARKET VALUE OF TOTAL PRIVATELY HELD DEBT-TO-GDP RATIO BETWEEN 2019Q4 AND 2023Q1 (PERCENTAGE)

End of 2019Q4	End of 2023Q1	Change	Returns on Reserves	Returns on Treasury securities	Inflation	Real Growth	Deficit	Other
86.0	100.7	14.7	0.3	−7.0	−15.1	−6.8	26.1	17.1

2. Unmatured debt is valued at market prices. If prices of debt decrease, the market value of the debt falls even without changes to the debt's face value. The ratio falls.
3. When the economy grows, outstanding government debt becomes a smaller share of the economy. The ratio falls.
4. A government that owes $10 to a lender before a high-inflation quarter still owes $10 to that lender afterward. But inflation erodes the real (inflation-adjusted) debt obligations of the government. The ratio falls.

The total privately held debt-to-GDP rose 15 percentage points from the beginning of COVID to 2023Q1. The country began 2020 with an 86 percent debt-to-GDP ratio and ended 2023Q1 at 100.7 percent.

Table 5 breaks down the movement in the debt-to-GDP ratio from 2019Q4 to 2023Q1 by quantifying the contributions of each component of the budget identity in (1). The first three columns document how the debt-to-GDP ratio changed over time. The next six columns report the contributions of interest payments on reserves, nominal returns on Treasury securities (interest payments and changes in debt prices), inflation, real growth, the primary deficit (spending minus revenues), and other funding sources to the change in debt-to-GDP.[7] Negative numbers contribute to reducing the debt-to-GDP ratio while positive ones contribute to increasing the ratio.

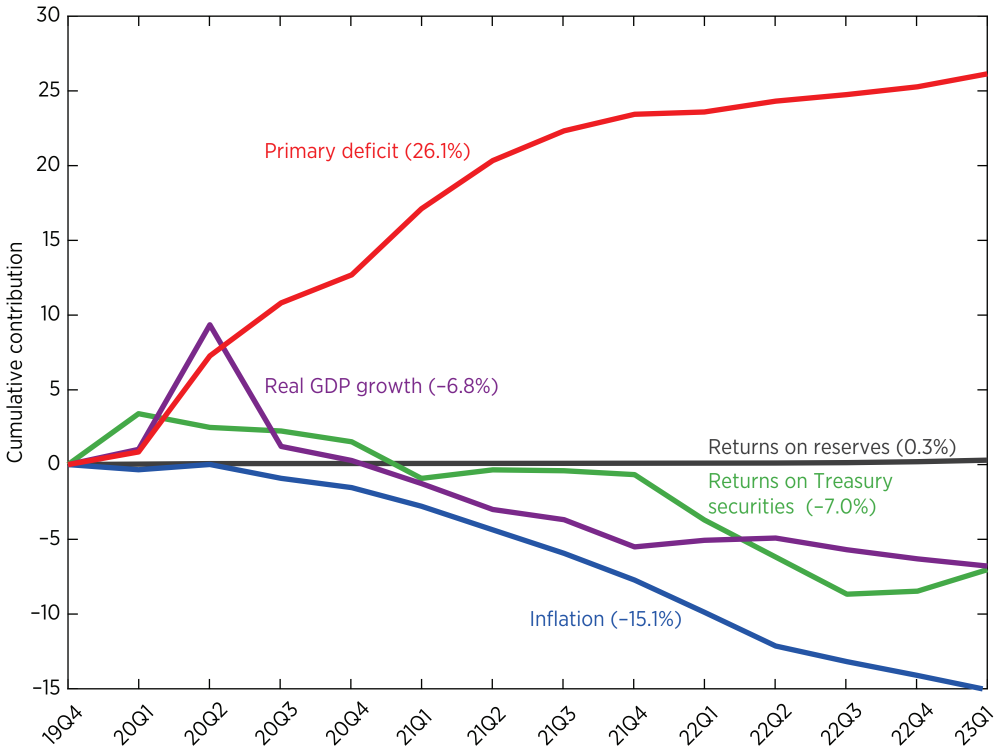
Most striking is that the primary deficit (government spending minus direct taxation) accounted for a whopping 26 percentage point increase in the ratio. If the government had financed all spending through debt *and if* debt prices, inflation, and economic growth all remained constant, the debt-to-GDP ratio would have shot up over 110 percent.

But the government did not finance its spending using only debt. Debt price movements, positive real GDP growth, and high inflation all tempered upward movements in the ratio, combining to finance 29 percent of debt-to-GDP and more than offsetting the deficit's contribution.

Inflation was the largest source of debt financing during COVID. The high-inflation episode beginning in 2021 was equivalent to a large tax on holders

7. Appendix C describes data sources.

FIGURE 2. CONTRIBUTIONS TO THE EVOLUTION OF THE MARKET VALUE OF PRIVATELY HELD DEBT-TO-GDP RATIO BETWEEN 2019Q4 AND THE DATE ON THE HORIZONTAL AXIS



Note: Numbers in parentheses are the percentage of the change in debt–GDP between 2019Q4 and 2023Q1 due to each component, as table 5 reports.

of US bonds, bills, notes, currency, bank reserves, and, other nominal deposits. Whatever the government owed them before COVID bought fewer goods and services after COVID. So even though explicit taxes were not increased during the pandemic, the country experienced a substantial inflation (implicit) tax hike (see discussion in Hall and Sargent 2023).

Figure 2 plots how the numbers in table 5 evolved. The sharp decline in real GDP in the second quarter of 2020 and the subsequent recovery are both apparent. Growth helps to finance spending starting in 2020Q4. Inflation (the implicit debt-holder tax) persistently decreases the debt-to-GDP ratio over the period.

Interest payments on reserves did not contribute much to the debt-to-GDP ratio. Had interest rates on reserves remained low, the contribution would have been about 0.1 percentage points. But the Fed's decision to increase the rate on reserves beginning in 2022Q2 pushed the contribution to 0.3 percentage points.

Nominal returns on longer-term debt (debt price movements and interest payments) rose at the onset of the pandemic but slowly fell throughout 2021 and 2022. Figure 3a displays the movements in the price of debt over this period (the ratio of the red to the blue line). A falling market value of debt relieves pressure on the government's outstanding obligations without any adjustment to the debt's face value. The interest rate on the government's portfolio ($i^P_{t-1,t}$ in identity (1)) is the percentage change in this price over time. The return was negative for most of 2020Q1 to 2023Q1. People and institutions who held government debt in its various forms not only paid the inflation tax, they also found their assets lost value. Both effects helped finance government spending.

6 FISCAL THEORY FRAMEWORK

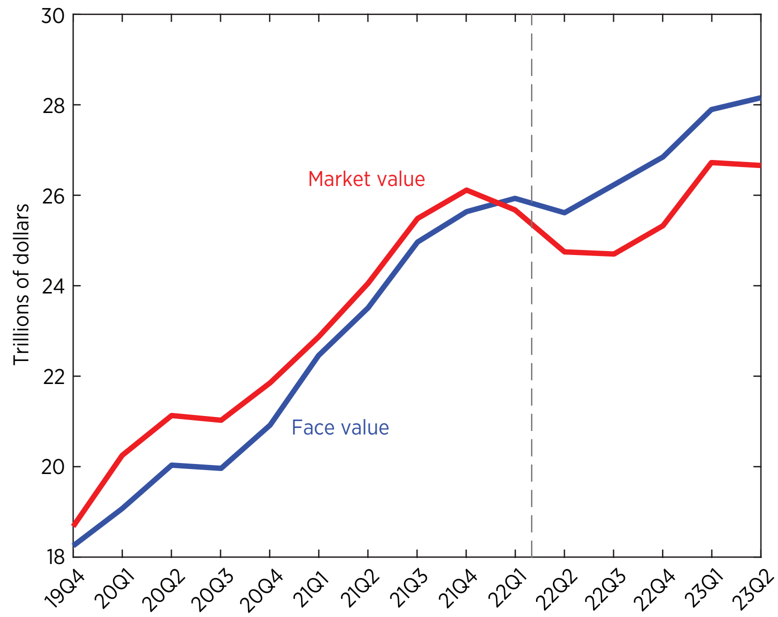
We also interpret the accounting of COVID inflation through the framework that the fiscal theory of the price level (FTPL) provides. The FTPL springs from a few key premises:

1. Like any asset, government liabilities—Treasury bills and bonds, Federal Reserve bank reserves, and currency—derive their value in large part from expected cash flows, discounted to the present.[8] For government-issued debt instruments, those cash flows are primary surpluses: total tax revenues less total expenditures excluding interest payments on outstanding government debt.
2. Because the primary surpluses that back current outstanding debt occur in the future, traders in government debt markets must form expectations of future surpluses and discount rates.
3. The vast majority of government liabilities simply promise to pay in *dollars* rather than purchasing power. Their "value" depends on both their dollar price and the value of the dollar itself.
4. Any interpretation of inflation developments must be consistent with monetary *and fiscal* behavior because both policies affect how the government finances its debt.

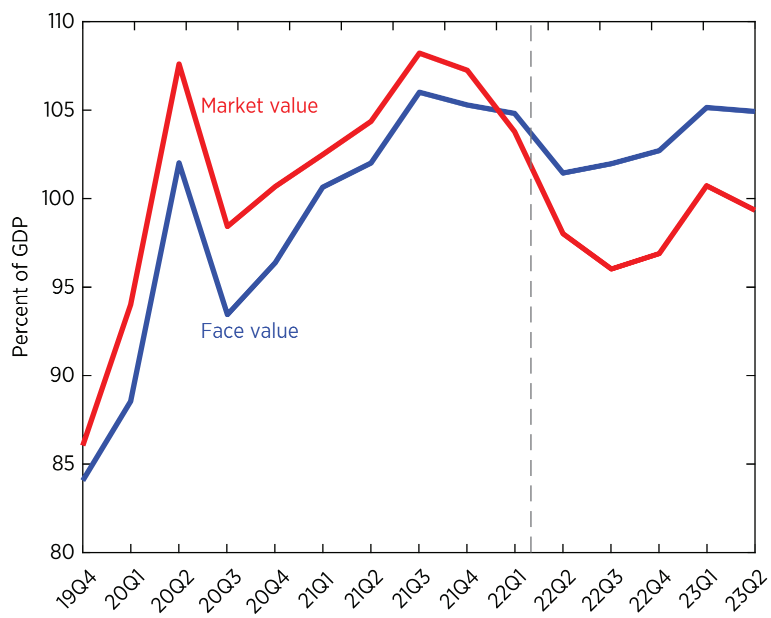
Real primary surpluses represent the government's command over resources that can be used to pay off debt while maintaining debt's purchasing power. Primary surpluses back government debt. If the government sells new bonds today that increase the debt–GDP ratio by 1 percent, then investors expect the government will raise future surpluses (in present value) by 1 percent

8. "In large part" because those assets may also yield transactions service flows that have independent value.

FIGURE 3. FACE VALUE AND MARKET VALUE OF TOTAL PRIVATELY-HELD DEBT IN DOLLARS AND AS PERCENT OF GDP



(a) In dollars



(b) As share of GDP

Note: Vertical lines mark beginning of interest rate hikes.

of current GDP. If instead investors believe the present value of surpluses will not change, then with no increased backing, the value of debt cannot increase. Even if the government sells more nominal bonds, their real value and share of GDP cannot change. Prices of debt and of goods and services must adjust to realign the value of debt with its backing.

We summarize how debt instruments are valued with an expression, derived from the government budget identity and some behavioral assumptions, that links the current value of the total government debt–GDP ratio to the present value of future surplus–GDP ratios:[9]

$$\frac{Q_t^P B_t^P}{P_t Y_t} = \text{Expected discounted stream of } \frac{S_{t+1}}{Y_{t+1}}, \frac{S_{t+2}}{Y_{t+2}}, \frac{S_{t+3}}{Y_{t+3}}, \cdots \tag{2}$$

Expression (2) is an asset-pricing relation for government debt that lurks in most macroeconomic models. It says that the value of debt relative to the size of the economy can rise or fall only if the current value of expected backing—in the form of future real surpluses relative to GDP—rises or falls.

Valuation equation (2) provides a framework for interpreting the COVID inflation. Using round numbers, Congress disbursed $5 trillion in new spending—over one-fifth of 2020 GDP—much of it in the form of transfer payments to individuals, businesses, and state and local governments and all of it financed by new Treasury borrowing. Total privately held debt was 100 percent of GDP in 2020, so the increase in borrowing produced an equivalent increase in debt: B_t^P in equation (2) rose 20 percent. If people expected a commensurate increase in the present value of surpluses, then equation (2) could continue to be satisfied with no changes in debt prices, price level, or real GDP but a debt–GDP ratio of 120 percent.

Section 2 documents the unusual legislative atmosphere surrounding COVID spending bills. Congress suspended procedures like S-PAYGO. President Donald Trump insisted his name appear on the Treasury's relief checks. The atmosphere was encapsulated by a later statement by the Biden White House press secretary, Jen Psaki: "It's important to note that [funding] should be provided on an emergency basis, not something that would require offsets" (White House 2022). Government communication about COVID-relief funds was designed to encourage people to spend their relief checks by convincing them that emergency spending would not be offset by higher taxes. Presidents do not put their names on checks that come attached to IOUs for future tax bills.

9. We assume investors make choices that eliminate all arbitrage opportunities across assets and that they do not overaccumulate saving.

People who receive transfers with no offsetting taxes attached will convert the Treasury check into consumption, now or in the future. Higher overall demand raises production and prices, driving up nominal GDP, $P_t Y_t$, in equation (2). If debt prices are unchanged, nominal GDP must eventually rise 20 percent to keep the debt–GDP ratio consistent with no expected change in future surpluses.

Early in 2022, the Fed began to raise interest rates rapidly. An elevated path of interest rates drove down debt prices, Q_t^P, to reduce the market value of outstanding debt and attenuate the expansion in nominal GDP. Section 7 performs this accounting with data.

The fiscal theory frames inflation as a *joint* monetary-fiscal phenomenon. That jointness means that Fed policy alone cannot always combat inflation successfully. We return to that theme in section 8.

7 FORWARD ACCOUNTING OF FISCAL FINANCING

Forward accounting uses valuation equation (2) to answer the question: What beliefs about future policies are consistent with the current value of outstanding government debt? This is the question most relevant to policy making. Backward accounting tracks what has already happened; forward accounting infers what people believe will happen. Policymakers today cannot change the past. But they can influence beliefs, which feed back to affect current economic outcomes.

Figure 3a reports that both the face value (B^P) and the market value $(Q^P B^P)$ of privately held debt rose over the period we study. Market value fell below face value once it became clear the Fed would raise interest rates.

What if we account for inflation and economic growth? Figure 3b contrasts the face $(B_t^P / P_t Y_t)$ and market $(Q_t^P B_t^P / P_t Y_t)$ values of debt–GDP over the COVID period. Although the face value of debt–GDP rose 22 percentage points from 2019Q4 to 2023Q2, the market value increased 14 percentage points. Declining debt prices explain the difference. Viewed through the relation in expression (2), over the three-year period, investors expected a less-than-full increase in discounted primary surpluses. Because they do not anticipate enough additional backing to support COVID-related debt sales, prices must adjust to align with the incomplete backing.

Forward accounting looks at the total market value of privately held government debt-to-GDP and its four components. Valuation equation (2) informs

TABLE 6. TOTAL MARKET VALUE OF PRIVATELY HELD DEBT-TO-GDP AND ITS FOUR COMPONENTS AT THREE DATES

		Percentage Change Relative to Values in 2019Q4			
Date	Debt-GDP ($Q^P B^P/PY$)	Nominal Debt (B^P)	Debt Price (Q^P)	Price Level (P)	Real GDP (Y)
2020Q2	22.4	9.3	3.0	0.0	–10.1
2021Q3	22.9	31.3	–0.3	5.8	2.3
2023Q2	14.4	43.4	–7.8	15.2	6.0

the interpretations of the accounting. Drawing on the red line in figure 3b, we focus on three calendar dates: 2020Q2, 2021Q3, and 2023Q2. Table 6 reports the accounting.

The first two dates roughly line up with the two large spending bills: the CARES Act and ARP. Debt value was almost the same in 2020Q2 and 2021Q3, about 22.5 percent above its 2019Q4 value. Nominal debt grew only 9.3 percent up to 2020Q2, but debt prices rose and real GDP fell sharply as businesses closed down, driving debt–GDP up dramatically. Debt prices rose as the Fed swiftly reduced interest rates. At this early stage of the pandemic, bond traders believe that newly issued debt would be backed.

Much of the backing came from the Fed's unscheduled meeting on March 15, 2020. The Fed announced both the drop in the federal funds rate to near zero and its programs to buy Treasury and private securities and extend a host of repurchase and reverse repurchase agreements. The announcement communicated that interest rates would remain low through the crisis. Lower interest rates reduce discount rates, raising the current value of a given stream of primary surpluses to boost the value of debt.

Five quarters later in 2021Q3, debt–GDP was essentially unchanged, but the composition of its value shifted. Nominal debt had grown 31.3 percent, yet debt–GDP was only 22.9 percent higher. Debt lost value through lower debt prices and a higher price level. And as the economy pulled out of the 2020 recession, higher real GDP reduced debt's share of the economy. Although the expected backing was the same as in 2020Q2, bondholders were beginning to expect the Fed to raise interest rates to combat price increases.

Fast-forward to 2023Q2, three years after the initial date. Debt–GDP has fallen from its earlier peaks and sits at 14.4 percentage points higher than in 2019Q4. Nominal debt has grown an astounding 43.4 percent, leaving 29 percentage points of nominal debt to be devalued relative to GDP. Inflation was the biggest factor that devalued debt, coming in at 15.2 percent higher. Debt prices fell 7.8 percent, driving the market value well below face value, particularly once the Fed began to raise interest rates (see figure 3). Economic growth of 6 percent also contributed to reducing debt's share of the economy.

What do we make of declining debt–GDP in the face of steadily rising nominal debt? The fiscal theory attributes the discrepancy to bondholders' beliefs that policy will not raise the present value of surpluses to fully back new debt issuance. Again, monetary policy enters into the calculus. Fed tightening raises real interest rates in the short run, which transmit to higher discount rates. When discount rates rise, a $1 payment in the future is worth less today: today's value of future surpluses declines and, with it, the value of government debt.

A simple version of the fiscal theory of the price level predicts that nominal debt and the market value of debt–GDP would rise by identical percentages if people believed fiscal policy would fully back debt with higher primary surpluses. The 29 percentage point gap between the two debt measures suggests that people believed a significant chunk of debt-financed COVID spending would be unbacked by primary surpluses, which is consistent with the public discourse at the time. As of 2023Q2, two-thirds of new debt was not expected to be backed by higher primary surpluses. Debt–GDP declines over the period as people's beliefs in incomplete backing of the debt become more firm.

8 MONETARY POLICY IN THE COVID ERA

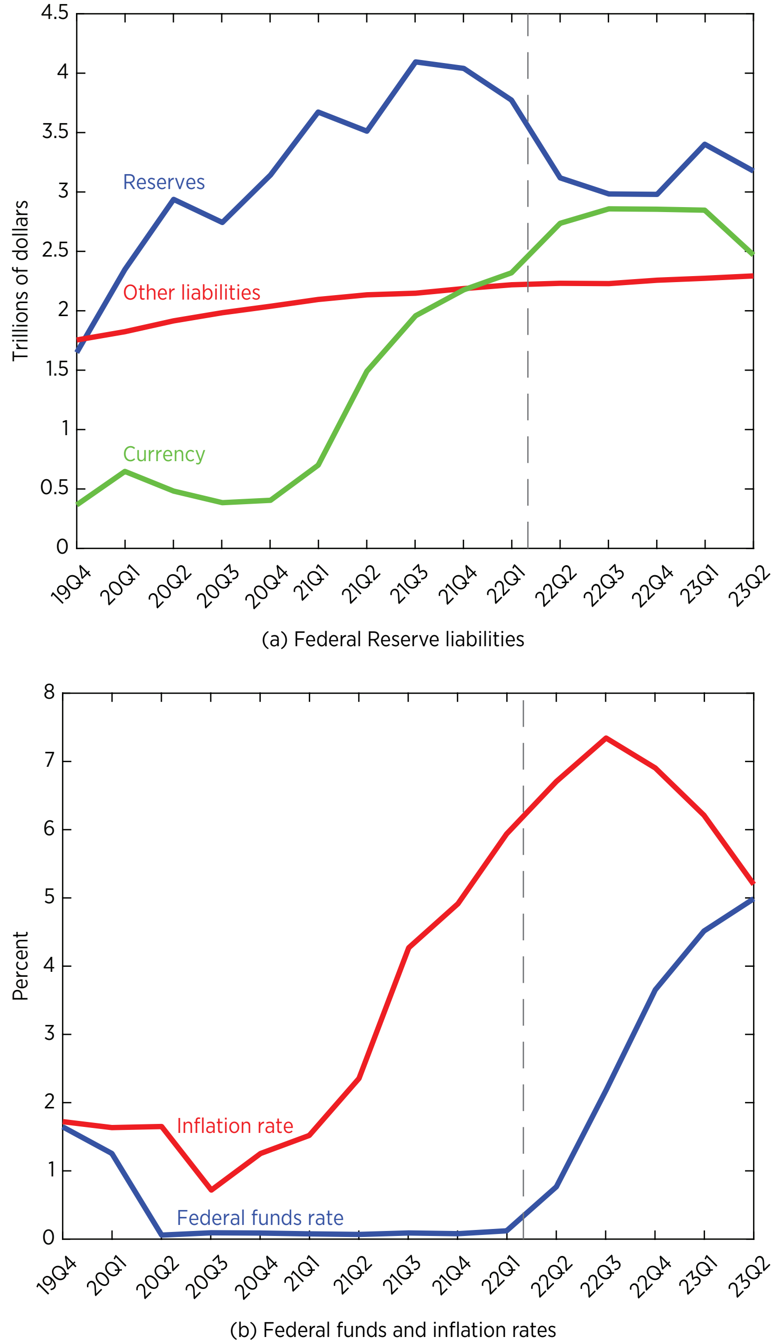
Federal Reserve actions affected the evolution of inflation and the fiscal accounting of inflation over the period.

8.1 The Fed's COVID Response

The Fed responded strongly and swiftly to the COVID crisis. It sought to stimulate the economy by lowering the federal funds rate and to stabilize financial markets through large-scale asset purchases and liquidity provision. It ensured that liquidity was readily available for households and businesses during a time when private lending was scarce.

Figure 4 plots the three components of Fed liabilities. In March 2020, the Fed began what turned into a large open market purchase initiative. It initially bought $500 billion in treasury securities and $200 billion in government-sponsored mortgage-backed securities (MBS); it followed that up by purchasing

FIGURE 4. FEDERAL RESERVE POLICY RESPONSES AND THE INFLATION RATE



Note: Vertical lines mark beginning of interest rate hikes.

$80 billion in Treasury securities and $40 billion in MBS per month starting in June 2020. The resulting change in reserves is shown as the blue line in figure 4a. By the time the Fed reversed course and began to shrink its balance sheet in November 2021, it had added, through a variety of initiatives, $4.6 trillion of new liquidity to the economy.

In addition to asset purchases, the Fed dropped the interest rate on reserves to 0.15 percent in March 2020, where it remained until March 2022. Flooding the market with liquidity and keeping interest on reserves low ensured that the federal funds rate hit its target near zero (figure 4b).

Inflation rose quickly. It started below 2 percent before COVID hit, peaked at over 7.5 percent in 2022Q2, and remains about 3.5 percent, above the Fed's target for inflation (figure 4b).

8.2 How Monetary Policy Affects Government Debt

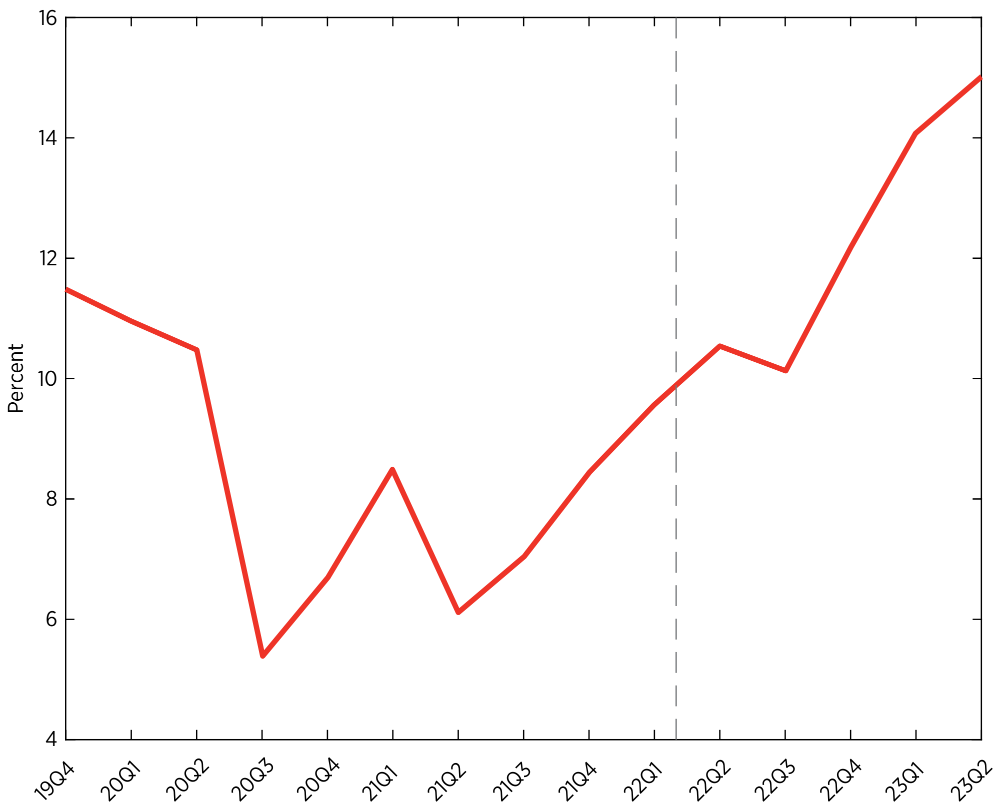
When the Fed cuts the federal funds rate and the rate on reserves, both short-term rates, it reduces incentives for the banking industry to sit on its liquidity and collect interest. The lower the rate, the stronger the incentives for households and businesses to borrow to finance their consumption and investment choices. This is the conventional channel for monetary stimulus, which the Fed pursued for two years starting in March 2020.

The short-term policy interest rate is woven into the fabric of financial markets. Current and expected future rates cascade to affect decisions that banks, firms, and households make. All interest rates tend to rise or fall with the path of short rates. Easier monetary policy in 2020 raised bond prices and reduced interest payments from the Treasury to debt holders. Fed tightening triggered opposite movements. Figure 5 plots interest payments as a share of noninterest federal expenditures. Payments rose slowly in 2021 as borrowing expanded but interest rates remained low. Since the Fed started to tighten in 2022, interest payments have risen rapidly.

Going forward, it matters how the government chooses to finance rising interest payments. Will primary surpluses rise, or will government borrow to meet interest needs? If Congress chooses to roll interest payments into more rapid growth in nominal debt, we can expect more inflation in the future, after contemporaneous revaluation effects wear off.

Both forward and backward accounting emphasize the debt revaluation impacts of monetary policy. A higher expected path of interest rates reduces

FIGURE 5. INTEREST PAYMENTS ON TREASURY BONDS AS PERCENTAGE OF FEDERAL EXPENDITURES LESS INTEREST PAYMENTS



Note: Vertical line marks beginning of interest rate hikes.

bond prices, so the market value of debt declines with no change in face value. The immediate impact on inflation is beneficial because the price level can fall along with bond prices to maintain the debt–GDP ratio in valuation equation (2). But this is only the immediate impact.

Fed tightening raises real rates in the short run and future interest payments over longer horizons. The shorter the maturity structure of government debt, the sooner the interest-rate impacts on interest payments show up. As monetary policy's impacts on real rates diminish, we are left only with higher interest payments on the debt. Eventually, a higher average funds rate manifests as a higher inflation rate. Fed efforts to combat fiscal inflation are ephemeral: tighter monetary policy pushes inflation into the future, but it cannot eliminate the inflation that COVID spending triggered.

9 CONCLUDING REMARKS

The perspective on COVID inflation that the fiscal theory of the price level offers differs starkly from conventional views put forth by Fed policymakers, prominent macroeconomists, and economic journalists. Why?

Conventional analyses embed a dirty little secret: future fiscal policy will always adjust as needed to fully back government debt with primary surpluses. By assuming that fiscal policy is self-neutralizing, conventional analyses assume away the issues this brief highlights.

To sharpen the contrast between conventional views and ours, we posit that primary surpluses do not change at all. Reality probably lies somewhere between no surplus adjustments and full neutralization. How things play out rests entirely with elected officials. It is not a problem the Federal Reserve can fix on its own.

If the COVID spending bills included legislation that adjusts taxes or other spending to pay for COVID relief, then we would not have seen inflation rise substantially. Bond prices would not have needed to fall to devalue debt. If Congress now were to adopt policies that fund increasing interest payments, we would be more sanguine about the prospects for getting inflation back to target.

If fiscal policy continues to refrain from raising revenues or reducing spending and the Fed continues to combat above-target inflation with ever-higher interest rates, there is little reason to expect inflation will return to prepandemic levels.

You cannot extinguish a fiscal fire with only a monetary policy hose.

APPENDIX A: CONSOLIDATED GOVERNMENT BUDGET IDENTITY

To be explicit about the timing of payoffs, in what follows, the interest rate $i_{t,t+1}$ denotes the nominal return between t and $t+1$. $i_{t,t+1}$ may or may not be known at t.

We start by writing the government's flow budget identity as

$$M_t + Q_t^R R_t + \sum_{j=1}^{\infty} Q_t(t+j)B_t(t+j) + P_t s_t = M_{t-1} + R_{t-1} + \sum_{j=1}^{\infty} Q_t(t+j-1)B_{t-1}(t+j-1), \quad (3)$$

where

$M_t =$ currency in circulation at t,

$Q_t^R =$ price of bank reserves, reverse repurchase agreements, and other deposits at t,

$R_t =$ bank reserves, repurchase agreements, and other deposits at t,

$Q_t(t+j) =$ dollar price of a bond sold at t that matures at $t+j$,

$B_t(t+j) =$ face value of bonds privately held at t that mature at $t+j$,

$P_t =$ aggregate price level at t,

$s_t =$ real primary surplus at t.

Define nominal government liabilities at the beginning of t by

$$W_t = M_{t-1} + R_{t-1} + \sum_{j=1}^{\infty} Q_t(t+j-1)B_{t-1}(t+j-1), \quad (4)$$

and at the beginning of period $t+1$ by

$$W_{t+1} = M_t + R_t + \sum_{j=1}^{\infty} Q_{t+1}(t+j)B_t(t+j). \quad (5)$$

Note that W_{t+1} is not known at t because bond prices at $t+1$ are not observed until $t+1$.

It turns out to be most convenient to express the law of motion for nominal liabilities in terms of holding period returns rather than asset prices. Define the one-period holding period return on Treasury bonds between t and

$t+1$, $i^B_{t,t+1}$, as

$$1+i^B_{t,t+1} \equiv \frac{\sum_{j=1}^{\infty} Q_{t+1}(t+j)B_t(t+j)}{\sum_{j=1}^{\infty} Q_t(t+j)B_t(t+j)}.$$

The one-period holding period return on reserves between t and $t+1$ is immediate:

$$1+r^R_{t,t+1} \equiv \frac{1}{Q^R_t}.$$

The law of motion for the supply of total government liabilities is

$$W^s_{t+1} = (1+i^B_{t,t+1})\left[W^s_t - P_t s_t - \frac{i^B_{t,t+1}}{1+i^B_{t,t+1}} M_t - \left(\frac{1}{1+i^R_{t,t+1}} - \frac{1}{1+i^B_{t,t+1}}\right) R_t\right]. \tag{6}$$

Expression (6) reveals that the value of government liabilities as a share of GDP at the beginning of period t, W_t/P_tY_t, depends on expected discounted streams of

$$\text{primary surpluses} = \frac{s_{t+j}}{Y_{t+j}},$$

$$\text{currency seigniorage} = \frac{i^B_{t,t+1}}{1+i^B_{t,t+1}} \frac{M_{t+j}}{P_{t+j}Y_{t+j}},$$

$$\text{reserves seigniorage} = \left(\frac{1}{1+i^R_{t,t+1}} - \frac{1}{1+i^B_{t,t+1}}\right) \frac{R_{t+j}}{P_{t+j}Y_{t+j}}.$$

We now derive the compact formulation for the budget identity in expression (1) that appears in the text. Define the nominal market value of total government debt at the end of period t by

$$Q^P_t B^P_t \equiv M_t + Q^R_t R_t + \sum_{j=1}^{\infty} Q_t(t+j)B_t(t+j),$$

and its corresponding value at the beginning of period t

$$Q^P_t B^P_{t-1} \equiv M_{t-1} + R_{t-1} + \sum_{j=1}^{\infty} Q_t(t+j-1)B_{t-1}(t+j-1).$$

Define the holding period return on total government debt from $t-1$ to t as

$$1+i^P_{t-1,t} \equiv \frac{M_{t-1} + R_{t-1} + \sum_{j=1}^{\infty} Q_t(t+j-1)B_{t-1}(t+j-1)}{M_{t-1} + Q^R_{t-1}R_{t-1} + \sum_{j=1}^{\infty} Q_{t-1}(t+j-1)B_{t-1}(t+j-1)}.$$

Employing the compact notation, (3) becomes

$$Q^P_t B^P_t + P_t s_t = (1+i^P_{t-1,t})Q^P_{t-1}B^P_{t-1}.$$

Dividing this expression through by nominal GDP, P_tY_t, yields expression (1) in the text.

APPENDIX B: BACKWARD-ACCOUNTING FRAMEWORK DERIVATION

From the derivation of the government budget constraint in section 4, we have the consolidated budget identity

$$M_t + Q_t^R R_t + Q_t B_t^P + P_t\left(T_t - G_t\right) = M_{t-1} + R_{t-1} + Q_t B_{t-1}^P,$$

which is an expanded version of (1) in the text.

We also have an expression for the holding period return on Treasury bonds from $t-1$ to t,

$$1 + i_{t-1,t}^B = \frac{Q_t B_{t-1}}{Q_{t-1} B_{t-1}},$$

and an expression for the holding period return on reserves between $t-1$ and t:

$$1 + i_{t-1,t}^R = \frac{1}{Q_{t-1}^R}.$$

Combine these three equations to write

$$M_t + Q_t^R R_t + Q_t B_t + P_t\left(T_t - G_t\right) = M_{t-1} + \left(1 + i_{t-1,t}^R\right) Q_{t-1}^R R_{t-1} + \left(1 + i_{t-1,t}^B\right) Q_{t-1} B_{t-1}.$$

Divide both sides by nominal GDP, P_tY_t:

$$\frac{M_t}{P_tY_t} + \frac{Q_t^R R_t}{P_tY_t} + \frac{Q_t B_t}{P_tY_t} + \frac{P_t\left(T_t - G_t\right)}{P_tY_t} = \frac{M_{t-1}}{P_tY_t} + \frac{\left(1 + i_{t-1,t}^R\right) Q_{t-1}^R R_{t-1}}{P_tY_t} + \frac{\left(1 + i_{t-1,t}^B\right) Q_{t-1} B_{t-1}}{P_tY_t}.$$

Approximate growth in $\left(P_tY_t\right)^{-1}$ is expressed as

$$\left(P_tY_t\right)^{-1} \approx \left(1 - \pi_t - g_t\right)\left(P_{t-1}Y_{t-1}\right)^{-1},$$

where π_t is inflation and g_t is real GDP growth, both from time $t-1$ to t.

Using the approximation, the identity becomes

$$\frac{P_tG_t}{P_tY_t} + \frac{\left(1 - \pi_t - g_t\right) M_{t-1}}{P_{t-1}Y_{t-1}} + \frac{\left(1 - \pi_t - g_t\right)\left(1 + i_{t-1,t}^R\right) Q_{t-1}^R R_{t-1}}{P_{t-1}Y_{t-1}} + \frac{\left(1 - \pi_t - g_t\right)\left(1 + i_{t-1,t}^B\right) Q_{t-1} B_{t-1}}{P_{t-1}Y_{t-1}} = \frac{M_t}{P_tY_t} + \frac{Q_t^R R_t}{P_tY_t} + \frac{Q_t B_t}{P_tY_t} + \frac{P_tT_t}{P_tY_t}.$$

Rearrange to derive an expression for the change in market value of total debt–GDP from $t-1$ to t, as follows:

$$\underbrace{\frac{M_t + Q_t^R R_t + Q_t B_t}{P_t Y_t} - \frac{M_{t-1} + Q_{t-1}^R R_{t-1} + Q_{t-1} B_{t-1}}{P_{t-1} Y_{t-1}}}_{\text{change in debt-to-GDP}}$$

$$= \underbrace{i_{t-1,t}^R \frac{Q_{t-1}^R R_{t-1}}{P_{t-1} Y_{t-1}}}_{\text{nominal return on reserves}} + \underbrace{i_{t-1,t}^B \frac{Q_{t-1} B_{t-1}}{P_{t-1} Y_{t-1}}}_{\text{nominal return on Treasury securities}}$$

$$- \underbrace{\pi_t \frac{M_{t-1} + Q_{t-1}^R R_{t-1} + Q_{t-1} B_{t-1}}{P_{t-1} Y_{t-1}}}_{\text{inflation}} - \underbrace{g_t \frac{M_{t-1} + Q_{t-1}^R R_{t-1} + Q_{t-1} B_{t-1}}{P_{t-1} Y_{t-1}}}_{\text{real growth}}$$

$$- \underbrace{i_{t-1,t}^R (\pi_t + g_t) \frac{Q_{t-1}^R R_{t-1}}{P_{t-1} Y_{t-1}} - i_{t-1,t}^B (\pi_t + g_t) \frac{Q_{t-1} B_{t-1}}{P_{t-1} Y_{t-1}}}_{\text{residual}} + \underbrace{\frac{P_t (G_t - T_t)}{P_t Y_t}}_{\text{primary deficit}} .$$

Section 5 employs a multi-period version of this equation to account for the change in debt–GDP from 2019Q4 to 2023Q2.

APPENDIX C: DATA DESCRIPTION

This appendix outlines data sources for the analysis in this paper. Much of this data comes from the Dallas Fed's calculation on the market value of US government debt at https://www.dallasfed.org/research/econdata/govdebt#data, hereafter referred to as DF.

For comparison, analogous data definitions used in Hall and Sargent (2022) are listed where applicable. Much of this data comes from the dataset described in Hall et al. (2022) and found on George Hall's website at https://people.brandeis.edu/~ghall/, hereafter referred to as HPSS.

B_t Face value of gross longer-term debt (Treasury securities).

- This paper: Par value, gross federal debt. Column B in DF found at https://www.dallasfed.org/research/econdata/govdebt#data.
- Hall and Sargent (2022): Total gross debt, par value. Column F in HPSS found at https://people.brandeis.edu/~ghall/.

B_t^P Face value of privately held longer-term debt (Treasury securities).

- This paper: par value, privately held gross federal debt. Column C in DF found at https://www.dallasfed.org/research/econdata/govdebt #data.

- Hall and Sargent (2022): Calculated as (Debt held by private investors, par value) – (Treasury balance in TGA) – (Noninterest bearing debt)
    - Debt held by private investors, par value. Column H in HPSS found at https://people.brandeis.edu/~ghall/.
    - Treasury balance in TGA. Daily Treasury statements found at https://fiscaldata.treasury.gov/datasets/daily-treasury-statement/operating-cash-balance.
    - Noninterest-bearing debt. Column E in HPSS found at https://people.brandeis.edu/∼ghall/.

$Q_t B_t$ Market value of gross longer-term debt (Treasury securities).

- This paper: Market value, gross federal debt. Column E in DF found at https://www.dallasfed.org/research/econdata/govdebt#data.
- Hall and Sargent (2022): Total gross debt, market value. Column G in HPSS found at https://people.brandeis.edu/~ghall/.

$Q_t^P B_t^P$ Market value of privately held longer-term debt (Treasury securities).

- This paper: Market value, privately held gross federal debt. Column F in the dataset found at https://www.dallasfed.org/research/econdata/govdebt#data.
- Hall and Sargent (2022): Calculated as (Debt held by private investors, market value) – (Treasury balance in TGA) – (Noninterest bearing debt)
    - Debt held by private investors, market value. Column I in HPSS found at https://people.brandeis.edu/~ghall/.
    - Treasury balance in TGA. Daily Treasury statements found at https://fiscaldata.treasury.gov/datasets/daily-treasury-statement/operating-cash-balance.
    - Noninterest-bearing debt. Column E in HPSS found at https://people.brandeis.edu/∼ghall/.

R_t Face value of reserve deposits held at the Fed.

- This paper: Other deposits held by depository institutions. Table H.4.1.T5 on the Fed's weekly balance sheet and found at https://fred.stlouisfed.org/series/WLODLL.

M_t Noninterest-earning currency and other deposit liabilities.

- This paper: Calculated as (Federal Reserve notes, net of F.R. Bank Holdings) + (Deposits with F.R. Banks, other than reserve balances) +

(Other deposits at the Fed) + (Term deposits held by depository institutions) − (US Treasury, Supplementary Financing Account) − (Treasury balance in TGA) + (Reverse repurchase agreements):

  - Federal Reserve notes, net of F.R. Bank Holdings. Table H.4.1.T5 on the Fed's weekly balance sheet and found at https://fred.stlouisfed.org/series/WLFN.
  - Deposits with F.R. Banks, other than reserve balances. Table H.4.1.T5 on the Fed's weekly balance sheet and found at https://fred.stlouisfed.org/series/WDFOL.
  - Other deposits at the Fed. Table H.4.1.T5 on the Fed's weekly balance sheet, found at https://fred.stlouisfed.org/series/WLODL.
  - Term deposits held at depository institutions. Table H.4.1.T5 on the Fed's weekly balance sheet and found at https://fred.stlouisfed.org/series/TERMT.
  - US Treasury, Supplementary Financing Account. Table H.4.1.T5 on the Fed's weekly balance sheet, found at https://fred.stlouisfed.org/series/WLSFAL.
  - Treasury balance in TGA. Daily Treasury statements, found at https://fiscaldata.treasury.gov/datasets/daily-treasury-statement/operating-cash-balance.
  - Reverse repurchase agreements. Table H.4.1.T5 on the Fed's weekly balance sheet and found at https://fred.stlouisfed.org/series/WLRRAL.
- Hall and Sargent (2022): Calculated as (Noninterest-bearing debt) + (Market value of interest-bearing debt, marketable, held by the Federal Reserve) + (Fed-held mortgage-backed securities):
  - Noninterest-bearing debt. Column E in HPSS found at https://people.brandeis.edu/∼ghall/.
  - Market value of interest-bearing debt, marketable, held by the Federal Reserve. Column U in HPSS found at https://people.brandeis.edu/~ghall/.
  - Fed-held mortgage-backed securities. Table H.4.1.T5 on the Fed's weekly balance sheet and found at https://fred.stlouisfed.org/series/WSHOMCB.

i_t^R Interest rate on reserves.

- This paper: Found before 7/29/21 at https://fred.stlouisfed.org/series/IOER and after 7/29/21 at https://fred.stlouisfed.org/series/IORB.

Q_t^R Price of reserve deposits at the central bank.

- This paper: Calculated as $\frac{1}{1+i_t^R}$.

$Q_t^R R_t$ Market value of reserve deposits at the central bank.

Q_t^P Price of privately held longer-term debt (Treasury securities).

- This paper: Calculated as $\frac{Q_t^P B_t^P}{B_t^P}$.

i_t^P Nominal holding period return on privately held longer-term debt (Treasury securities).

- This paper: Approximated as $\ln\left(Q_t^P\right) - \ln\left(Q_{t-1}^P\right)$.
- Hall and Sargent (2022): Aggregated monthly holding period returns on US Treasury debt held by the public as described by Hall and Sargent (2011) and found at https://people.brandeis.edu/~ghall/. Returns are calculated (and reweighed) using data from both CRSP and HPSS. The CRSP Treasury database can be read about at https://www.crsp.org/products/research-products/crsp-us-treasury-database.

$P_t Y_t$ Nominal GDP.

- This paper: Gross domestic product. Section 1, table T10105-Q, line 1 in the National Income and Product Accounts (NIPA) from the BEA. Found at https://apps.bea.gov/iTable/?isuri=1&reqid=19&step=4&categories=flatfiles&nipa_table_list=1.
- Hall and Sargent (2022): Gross domestic product. Section 1, table T10105-A, line 1 in the NIPA from the BEA. Found at https://apps.bea.gov/iTable/?isuri =1&reqid=19&step=4&categories=flatfiles &nipa_table_list=1.

$\frac{1}{P_t}$ Inverse of the price deflator.

- This paper: Gross domestic product. Section 1, table T10109-Q, line 1 in the NIPA from the BEA. Found at https://apps.bea.gov/iTable/?isuri=1&reqid=19&step=4&categories=flatfiles&nipa_table_list=1.
- Hall and Sargent (2022): Gross domestic product. Section 1, table T10109-A, line 1 in the NIPA from the BEA. Found at https://apps.bea.gov/iTable/?isuri =1&reqid=19&step=4&categories=flatfiles &nipa_table_list=1.

P_tY_t Real GDP.

- This paper: Calculated as $\frac{P_tY_t}{P_t}$.
- Hall and Sargent (2022): Calculated as $\frac{P_tY_t}{P_t}$.

P_tG_t Nominal government spending.

- This paper: Calculated as (Total expenditures) – (Interest payments) + (Interest receipts) – (Federal employee pension interest accrual).
  - Total expenditures. Section 3, table T30200-Q, Line 43 in the NIPA from the BEA and found at https://apps.bea.gov/iTable/?isuri=1&reqid=19&step=4&categories=flatfiles&nipa_table_list=1.
  - Interest payments: Section 3, table T30200-Q, line 33 in the NIPA from the BEA and found at https://apps.bea.gov/iTable/?isuri=1&reqid=19&step=4&categories=flatfiles&nipa_table_list=1.
  - Interest receipts: Section 3, table T30200-Q, line 14 in the NIPA from the BEA and found at https://apps.bea.gov/iTable/?isuri=1&reqid=19&step=4&categories=flatfiles&nipa_table_list=1.
  - Federal employee pension interest accrual: Section 3, table T31800(A,B)-Q, line 22 in the NIPA from the BEA and found at https://apps.bea.gov/iTable/?isuri=1&reqid=19&step=4&categories=flatfiles&nipa_table_list=1.
- Hall and Sargent (2022): Calculated as (Total expenditures) – (Interest payments) + (Interest receipts) – (Federal employee pension interest accrual).
  - Total expenditures. Section 3, table T30200-A, line 43 in the NIPA from the BEA and found at https://apps.bea.gov/iTable/?isuri=1&reqid=19&step=4&categories=flatfiles&nipa_table_list=1.
  - Interest payments: Section 3, table T30200-A, line 33 in the NIPA from the BEA and found at https://apps.bea.gov/iTable/?isuri=1&reqid=19&step=4&categories=flatfiles&nipa_table_list=1.
  - Interest receipts: Section 3, table T30200-A, line 14 in the NIPA from the BEA and found at https://apps.bea.gov/iTable/?isuri=1&reqid=19&step=4&categories=flatfiles&nipa_table_list=1.
  - Federal employee pension interest accrual: Section 3, table T31800(A,B)-A, line 22 in the NIPA from the BEA and found at https://apps.bea.gov/iTable/?isuri=1&reqid=19&step=4&categories=flatfiles&nipa_table_list=1.

G_t Real government spending.

- This paper: Calculated as $\frac{P_t G_t}{P_t}$.
- Hall and Sargent (2022): Calculated as $\frac{P_t G_t}{P_t}$.

$P_t T_t$ Nominal government receipts.

- This paper: Section 3, table T30200-Q, line 40 in the NIPA from the BEA and found at https://apps.bea.gov/iTable/?isuri=1&reqid=19&step=4&categories=flatfiles&nipa_table_list=1.
- Hall and Sargent (2022): Section 3, table T30200-A, line 40 in the NIPA from the BEA and found at https://apps.bea.gov/iTable/?isuri=1&reqid=19&step=4&categories=flatfiles&nipa_table_list=1.

T_t Real government receipts.

- This paper: Calculated as $\frac{P_t T_t}{P_t}$.
- Hall and Sargent (2022): Calculated as $\frac{P_t T_t}{P_t}$.

π_t Inflation. Approximated as $\ln(P_t) - \ln(P_{t-1})$.

g_t Real economic growth. Approximated as $\ln(Y_t) - \ln(Y_{t-1})$.

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