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Inflation and the fiscal limit

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ABSTRACT

We use a rational expectations framework to assess the implications of rising debt in an environment with a "fiscal limit". The fiscal limit is defined as the point where the government no longer has the ability to finance higher debt levels by increasing taxes, so either an adjustment to fiscal spending or monetary policy must occur to stabilize debt. We give households a joint probability distribution over the various policy adjustments that may occur, as well as over the timing of when the fiscal limit is hit. One policy option that stabilizes debt is a passive monetary policy, which generates a burst of inflation that devalues the existing nominal debt stock. The probability of this outcome places upward pressure on inflation expectations and poses a substantial challenge to a central bank pursuing an inflation target. The distribution of outcomes for the path of future inflation has a fat right tail, revealing that only a small set of outcomes imply dire inflationary scenarios. Avoiding these scenarios, however, requires the fiscal authority to renege on some share of future promised transfers.

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1. Introduction

Advanced economies are heading into an extended era of unresolved fiscal stress. Aging populations imply that promised old-age benefits are growing relentlessly as a share of the economy. With no credible plans for financing or reforming these entitlements programs, economic agents in many large economies are facing unprecedented uncertainty about the taxes they may face and the transfers they may receive in the future.

Table 1 encapsulates the unresolved fiscal stress in some large economies. An International Monetary Fund (2009) study computes the net present value impacts on fiscal deficits of aging-related spending as a share of GDP. Canada tops the list with a long-term budget imbalance of 726 percent of GDP, but Spain and Korea are close behind. The average imbalance across G-20 countries exceeds 400 percent of GDP. In the United States, the long-term imbalance is about $75 trillion (Gokhale and Smetters, 2007). Evidently, these numbers imply that monetary and fiscal policies must change in the future. Most governments, however, do little to inform their citizens of how policies will change and when they will change.

In the absence of clear and credible policies to resolve the fiscal stress, it is difficult to analyze the long-run macroeconomic consequences of those resolutions. This has led some observers to predict dire consequences. In the United States, the Congressional Budget Office annually produces long-term projections of the federal budget (Congressional Budget Office, 2010b). Their *accounting* exercise produces mile-high debt paths like those in Fig. 1, where the alternative scenario – which embeds tax and spending changes that the CBO deems likely – entails exponentially growing debt-GDP

Table 1
Net present value of impact on fiscal deficit of aging-related spending, in percent of GDP.
Source: International Monetary Fund (2009).

| Country	Aging-related spending
Australia	482
Canada	726
France	276
Germany	280
Italy	169
Japan	158
Korea	683
Spain	652
United Kingdom	335
United States	495
Advanced G-20 countries	409
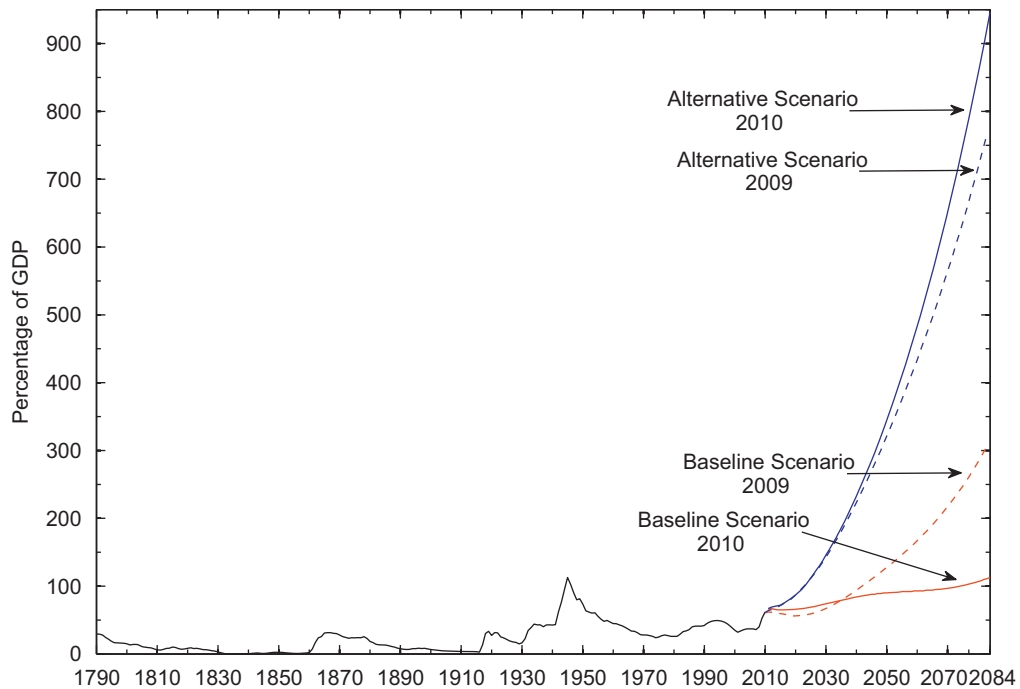
Fig. 1. Projections of U.S. federal government debt as a percentage of GDP from Congressional Budget Office (2009b, 2010b).

ratios.[1] Congressional Budget Office (2010a) is a speculative narrative of how growing U.S. government debt might result in a fiscal crisis and how such a crisis might play out.

Academic economists have also speculated about the consequences of unresolved fiscal stress. Kotlikoff (2006), for example, has argued that the demographic shifts underlying the CBO's projections in Fig. 1 imply that the United States is "bankrupt." And many policy-oriented pieces have been written that point to projections like these and warn of possible fiscal crises (Rubin et al., 2004 and publications by the Committee for a Responsible Federal Budget and Peter G. Peterson Foundation).

One recurring concern is that a fiscal crisis will ultimately lead to high or hyperinflation (Unsigned, 2010). Kotlikoff (2006) has provocatively asserted that the United States "appears to be running the same type of fiscal policies that engendered hyperinflations in 20 countries over the last century" and similar statements appear in Kotlikoff and Burns (2004). An argument against this view, however, is that current long-term inflation expectations, whether from surveys (Federal Reserve

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[1] These are accounting, as opposed to economic, exercises because, by the CBO's own admission, exponentially growing debt is economically infeasible. In fact, these long-term projections build in a variety of assumptions about the economy's evolution over the projection period: within a few years, inflation is constant at 2.5 percent, real interest rates at 3 percent, unemployment at 5 percent, and so on. Taken on face value, the economy chugs along just fine *even as government debt explodes*. The CBO reports then lapse into wordy bits about the dire consequences of rapid growth in government debt.
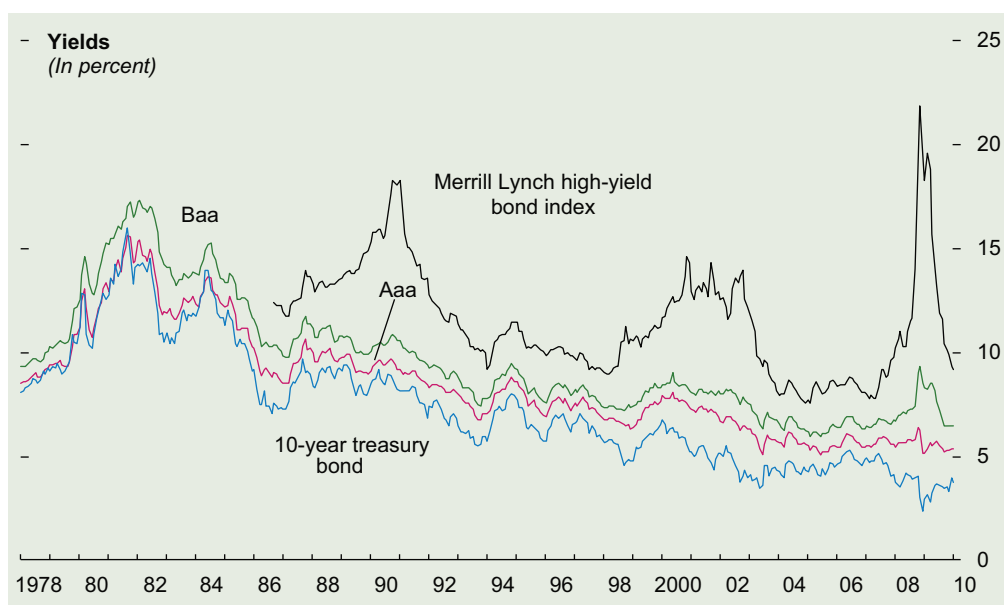
Fig. 2. Monthly yields on U.S. Treasury and Corporate Bonds.
Source: International Monetary Fund (2010).

Bank of Philadelphia, 2010) or financial market data, as in Fig. 2, do not embed dire inflationary scenarios. In fact, policymakers in the United States seem more concerned with deflation than with inflation these days (Bullard, 2010; Chan, 2010).

This paper focuses on the narrow question of whether high or hyperinflation is a necessary outgrowth of fiscal stress. To be sure, one can concoct scenarios in which fiscal policies refuse to adjust to resolve the stress and monetary policy relinquishes its control of inflation by fully accommodating fiscal deficits with money creation, as in Sargent and Wallace (1981). This outcome, however, does not strike us as the most plausible for the advanced economies. These economies struggled for many years to get inflation under control and many have now elevated low and stable inflation to an institutional feature of monetary policy through the adoption of explicit inflation targets. Even in countries like the United States, which have not adopted explicit inflation targets, low and stable inflation is widely accepted as the central bank's primary long-run mandate. Even if extremely high inflation is unlikely, some inflation may be part of the package of policy adjustments that resolve the fiscal stress.

To understand the short- and long-run inflationary consequences of the current fiscal position in advanced countries, we use a rational expectations framework to model the implications of rising debt in an environment with a "fiscal limit." The fiscal limit is defined as the point where the government no longer has the ability to finance higher debt levels by increasing taxes, so either an adjustment to fiscal spending or to monetary policy must occur to stabilize debt. We give households a joint probability distribution over the various policy adjustments that may occur, as well as over the timing of when the fiscal limit is hit. Interactions among policy adjustments and their timing are crucial to understanding the macroeconomic outcomes that may arise.

The policy environment we consider is "orderly" in the sense that each possible regime – defined as the mix of monetary, tax, and transfers policies – would, in a stationary linear model, deliver a unique rational expectations equilibrium. In one regime, tax rates are rising to stabilize debt, while monetary policy is targeting inflation and promised transfer payments are fully honored. At the fiscal limit, when tax rates are fixed, one of two possible policy mixes occurs: either monetary policy continues to target inflation and debt is stabilized by delivering less-than-promised transfers or promised transfers are honored and monetary policy maintains the value of government debt by switching from inflation targeting to pegging the nominal interest rate.

Not examined in this paper are policy combinations in which neither monetary nor fiscal policy is stabilizing government debt. This can happen in a well-defined rational expectations equilibrium, so long as agents believe that such a regime is temporary and the policies will eventually switch to stabilize debt (see Davig and Leeper, forthcoming for an example where the economy temporarily visits a regime in which macro policies are not sustainable). Macroeconomic outcomes could be far more dire in environments in which policy fails to stabilize debt, even temporarily.

There are three main findings of the paper. First, dire inflationary outcomes are possible, but may not dominate measures of long-term inflationary expectations. This can happen because, although rapid bursts of inflation are a feature of the equilibrium, they are very low probability events that affect inflation expectations only through the small probability households attach to those bursts. In some respects, high inflation takes on the features of a "peso problem." The small probability attached to the dire inflation outcome matters for the *path* of inflation because it generates a gradual upward drift in inflation expectations. As households attach more probability to policymakers attempting to stabilize debt with passive

monetary policy, upward drift in inflation expectations and inflation become more pronounced. This outcome poses a substantial challenge to central banks that aim to target inflation. Second, the timing of policy adjustment matters for inflationary outcomes. The binding upper limit on tax rates will necessitate some level of reneging on transfer payments promised to households. We explore how the extent and timing of reneging depends on how fiscal policy adjusts taxes prior to the fiscal limit and the maximum tax rate at the fiscal limit. Third, the mix of policy adjustment matters for inflationary outcomes. We show that inflationary pressures differ according to (i) how aggressively taxes rise in response to rising debt leading up to the fiscal limit, and (ii) the adjustment of fiscal and monetary policy at the fiscal limit.

2. Literature review

Our paper contributes to the large literature on how the uncertainty of policy affects inflation and other macroeconomic variables. The literature is too voluminous to cite every worthy paper here, but our paper is most similar in spirit to that of Drazen and Helpman (1990). They examine a simple endowment economy and show how uncertainty about policy switches between expenditure cuts, tax increases or increases in money growth rates affect economic dynamics. They find that the timing of uncertainty may induce seemingly perverse correlations between the rate of inflation and the budget deficit, at a time when the budget deficit is entirely responsible for inflation. We examine a much richer economic environment and allow for more complex levels of uncertainty. We also focus on the relationship between debt dynamics and inflationary outcomes, and show how the timing of uncertainty plays a crucial role in the relationship between the two variables.

While the focus of the current paper is on the relationship between policy uncertainty and inflation, the consequences of policy uncertainty extend beyond inflation dynamics. One stylized fact that has emerged from the comparative economics literature is that political instability is inversely related to economic growth and foreign direct investment (Aizenman and Marion, 1993; Ramey and Ramey, 1995; Brunetti and Weder, 1998). Measures of uncertainty about fiscal variables – measured as the standard deviation of government consumption, government investment and average tax rates – are shown to be significant and negatively correlated with growth in both developed and developing economies. Aizenman and Marion (1993) and Hopenhayn and Muniagurria (1996) study the effects of policy uncertainty in a neoclassical growth model with capital taxation that switches randomly between high and low regimes. Policy uncertainty is defined as the gap between the two regimes. They find that an increase in the degree of regime persistence and magnitude of policy fluctuations can have quantitatively large effects on growth and welfare. One channel through which uncertainty translates into slower growth arises when investment is irreversible, so that uncertainty generates an option value for waiting (Bernanke, 1983; Dixit, 1989; Pindyck, 1988).

The paper also abstracts from important political economy and distributional considerations. Alesina and Drazen (1991) examine why fiscal policy can be so slow to adjust even when there is agreement among political factions that stabilization policies need to be implemented. They argue that political economy factors are of first-order importance and that stabilization policies typically benefit the politically dominant groups. We find that inflationary outcomes are much more dire the longer it takes to implement the stabilization policy, but we do not explicitly model the distributional consequences of such policy. The generational and distributional effects are emphasized in Auerbach and Kotlikoff (1987), Kotlikoff et al. (1998, 2007), İmrohoroğlu et al. (1995), and Smetters and Walliser (2004). The canonical model used in these papers is an overlapping generations model with each cohort living for 55 periods. The model permits rich dynamics in demographics – population-age distributions, increasing longevity – intra-generational heterogeneity, bequest motives, liquidity constraints, earnings uncertainty, and so forth; this approach also allows for flexibility in modeling fiscal variables and alternative policy scenarios. While we do not assess the distributional effects of alternative policies or political economy aspects of policy choices, we are able to substantially increase the complexity of policy uncertainty faced by individuals relative to the papers cited above. We also examine monetary and fiscal policy interactions, while the papers cited above abstract from monetary policy and are silent on the inflationary consequences of alternative fiscal policy adjustments.

The focus of this paper is expected inflation, but the interpretation is amenable to understand the behavior of bond markets. The failure of the rational expectations hypothesis of the term structure (REHTS) is a well-known result for both U.S. data (Campbell and Shiller, 1987; Evans and Lewis, 1994) and international data (Jondeau and Ricart, 1999). Two hypothesis have been proposed in the literature to reconcile theory with data. The first assumes time-varying risk premia explain the breakdown in the rational expectations interpretation of the term structure (Engle et al., 1987; Dai and Singleton, 2002). Evans and Lewis (1994) argue that this hypothesis seems implausible because it would require risk premia to be highly variable and potentially non-stationary. Following Hamilton (1988), the second hypothesis models regime uncertainty in the U.S. term structure. Allowing for regime switching behavior improves the empirical fit of term structure models but also allows for a "peso problem" interpretation of the REHTS. The peso problem can help explain the failure of the REHTS because it allows for a low probability, disastrous state that will alter agents expectations of future inflation (and bond prices). Due to the low probability of the event, it is unlikely to be observed in the data but agents acting rationally will condition on this regime.[2] Bekaert et al. (2001) show that a peso interpretation, coupled with a low volatility term premium, is consistent with U.S., U.K. and Germany term structure data. A majority of the literature devoted to testing the REHTS is reduced form in nature. We contribute to this literature by providing a structural interpretation of the reduced form econometric analysis.

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[2] Peso problems are analogous to the rare disaster literature (Barro, 2009).

3. Model

We employ a conventional neoclassical growth model with sticky prices, distorting income taxation, and monetary policy. The model is similar to that of Davig et al. (2010).

3.1. Households

An infinitely lived representative household has preferences over consumption, leisure, and real money balances. The household chooses $\{C_t, N_t, M_t, B_t, K_t\}$ to maximize

$$E_t \sum_{i=0}^{\infty} \beta^i \left[\frac{C_{t+i}^{1-\sigma}}{1-\sigma} - \chi \frac{N_{t+i}^{1+\eta}}{1+\eta} + \nu \frac{(M_{t+i}/P_{t+i})^{1-\kappa}}{1-\kappa} \right] \tag{1}$$

subject to the budget constraint

$$C_t + K_t + \frac{B_t}{P_t} + \frac{M_t}{P_t} \leq (1-\tau_t)\left(\frac{W_t}{P_t} N_t + R_t^k K_{t-1} \right) + (1-\delta)K_{t-1} + \frac{R_{t-1}B_{t-1}}{P_t} + \frac{M_{t-1}}{P_t} + \lambda_t z_t + \frac{D_t}{P_t},$$

where $0 < \beta < 1, \sigma > 0, \eta > 0, \kappa > 0, \chi > 0$ and $\nu > 0$. $C_t = [\int_0^1 c_t(j)^{(\theta-1)/\theta} dj]^{\theta/(\theta-1)}$ is a composite good supplied by a final-good producing firm that consists of a continuum of individual goods $c_t(j)$, N_t denotes time spent working, and M_t/P_t are real money balances. K_{t-1} is the capital stock available to use in production at time t, B_t is one-period nominal bond holdings, M_t is nominal money holdings, τ_t is the distorting tax rate, R_t^k is the real rental rate of capital, R_{t-1} is the nominal return to bonds, and D_t are profits made by the monopolistically competitive intermediate goods sector that are returned to the household in the form of dividends.

The specification of the transfers process is distinctive. Transfers are lump sum where z_t represents the amount promised to households and $\lambda_t z_t$ represents the fraction of promised transfers actually received by the households. We elaborate on the process for $\lambda_t z_t$ below.

3.2. Firms

We assume an intermediate goods sector that is monopolistically competitive that produces a continuum of differentiated goods, and a final goods producer which operates in a perfectly competitive environment.

3.2.1. Production of intermediate goods

Intermediate goods producing firm j has access to a Cobb–Douglas production function

$$y_t(j) = k_{t-1}(j)^\alpha n_t(j)^{1-\alpha}, \tag{2}$$

where $y_t(j)$ is output of intermediate firm j and $k_{t-1}(j)$ and $n_t(j)$ are the amounts of capital and labor the firm rents and hires from the representative household. The firm minimizes total cost

$$\min_{n_t, k_{t-1}} w_t n_t(j) + R_t^k k_{t-1}(j) \tag{3}$$

subject to the production technology given in (2), which yields the usual first-order conditions

$$w_t = \Psi_t(j)(1-\alpha)\frac{y_t(j)}{n_t(j)}, \tag{4}$$

$$R_t^k = \Psi_t(j)\alpha \frac{y_t(j)}{k_{t-1}(j)}, \tag{5}$$

where $\Psi_t(j)$ denotes real marginal cost.

3.2.2. Price setting

A final goods producing firm purchases intermediate inputs at nominal prices $P_t(j)$ and produces the final composite good using a constant-returns-to-scale technology given by

$$Y_t = \left[\int_0^1 y_t(j)^{(\theta-1)/\theta} dj \right]^{\theta/(\theta-1)}, \tag{6}$$

where $\theta > 1$ is the elasticity of substitution between goods. The demand for each intermediate good is

$$y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\theta} Y_t. \tag{7}$$

Intermediate goods firm j chooses price $P_t(j)$ to maximize the expected present value of profits

$$E_t \sum_{s=0}^{\infty} \Delta_{t+s} \frac{D_{t+s}(j)}{P_{t+s}}, \tag{8}$$

where Δ_{t+s} is the representative household's stochastic discount factor, $D_t(j)$ are nominal profits of firm j, and P_t is the nominal aggregate price level.

Price adjustment follows Rotemberg (1982) quadratic costs of adjustment, which arise whenever the newly chosen price, $P_t(j)$, implies that actual inflation for good j deviates from the steady state inflation rate, π^*. Real profits are given by

$$\frac{D_t(j)}{P_t} = \left(\frac{P_t(j)}{P_t}\right)^{1-\theta} Y_t - \Psi_t(j) \left(\frac{P_t(j)}{P_t}\right)^{-\theta} Y_t - \frac{\varphi}{2} \left(\frac{P_t(j)}{\pi^* P_{t-1}(j)} - 1\right)^2 Y_t, \tag{9}$$

where $\varphi \geq 0$ parameterizes adjustment costs and we have used the demand function in (7) to replace $y_t(j)$ in firm j's profit function.

In a symmetric equilibrium, every intermediate goods producing firm faces the same marginal costs, Ψ_t, and aggregate demand, Y_t, so the pricing decision is the same for all firms, implying $P_t(j)=P_t$. Note that in (9) the costs of adjusting prices subtracts from profits for firm j. In the aggregate, costly price adjustment shows up in the aggregate resource constraint as

$$C_t + K_t - (1-\delta)K_{t-1} + G_t - \frac{\varphi}{2} \left(\frac{P_t(j)}{\pi P_{t-1}(j)} - 1\right)^2 Y_t = Y_t. \tag{10}$$

3.3. Policy specification

The government finances purchases g_t, and actual transfers, $\lambda_t z_t$, with capital and labor tax revenues, money creation, and the sale of one-period nominal bonds. The government's flow budget constraint is

$$\frac{B_t}{P_t} + \frac{M_t}{P_t} + \tau_t \left(\frac{W_t}{P_t} N_t + R_t^k K_{t-1}\right) = g_t + \lambda_t z_t + \frac{R_{t-1} B_{t-1}}{P_t} + \frac{M_{t-1}}{P_t}. \tag{11}$$

In order to capture the potential non-stationary behavior of the transfers process, we assume transfers follow a Markov switching process with two states,

$$z_t = \begin{cases} (1-\rho_z)z^* + \rho_z z_{t-1} + \varepsilon_t & \text{for } S_{z,t} = 1 \\ \mu z_{t-1} + \varepsilon_t & \text{for } S_{z,t} = 2 \end{cases}, \tag{12}$$

where $z_t = Z_t/P_t$, $|\rho_z| < 1$, $\mu > 1$, $\mu\beta < 1$, $\varepsilon_t \sim N(0, \sigma_z^2)$. Regime 2 is characterized by $\mu > 1$ and $\beta\mu < 1$, this allows the transfers process to be non-stationary, but square-summable in discounted expectation. We use this process to capture the upward trend in transfers. The regimes, S_{zt}, follow a Markov chain that evolves according to

$$\Pi_z = \begin{bmatrix} 1-p_z & p_z \\ 0 & 1 \end{bmatrix}, \tag{13}$$

where the regime with exploding promised transfers is an absorbing state. The expected number of years until the switch from the stationary to non-stationary regime is $(1-p_z)^{-1}$.

The exponential growth in transfers is initially financed by new debt issuance, which is backed by increasing tax rates. However, as emphasized in Davig et al. (2010), there is a "fiscal limit" to the amount of debt that can be financed through tax increases. This is due to either reaching the peak of the Laffer curve or political resistance to tax hikes. We model this as setting $\tau_t = \tau^{\max}$ for $t \geq T$, where T is the date at which the economy hits the fiscal limit. Tax policy sets rates according to

$$\tau_t = \begin{cases} \tau^* + \gamma\left(\frac{B_{t-1}/P_{t-1}}{Y_{t-1}} - b^*\right) & \text{for } S_{\tau,t} = 1, t < T \text{ (Below Fiscal 0.33emLimit)} \\ \tau^{\max} & \text{for } S_{\tau,t} = 2, t \geq T \text{ (Fiscal Limit)} \end{cases}, \tag{14}$$

where b^* is the target debt-output ratio and τ^* is the steady state tax rate.

As in Davig et al. (2010), we assume the probability of hitting the fiscal limit, p_{Lt}, follows a logistic function

$$p_{L,t} = \frac{\exp(\eta_0 + \eta_1(\tau_{t-1} - \tau^*))}{1 + \exp(\eta_0 + \eta_1(\tau_{t-1} - \tau^*))}, \tag{15}$$

where $\eta_1 < 0$. Thus, the probability of hitting the fiscal limit is increasing in taxes. Because taxes respond passively to government debt, the probability of hitting the fiscal limit increases with debt. Households are aware of the maximum tax rate, $\tau^{\max}$, but the precise timing of when that rate takes effect is uncertain.

Monetary policy is conventional in that it sets the short-term nominal interest rate in response to deviations of inflation from its target

$$R_t = R^* + \alpha(\pi_t - \pi^*), \tag{16}$$
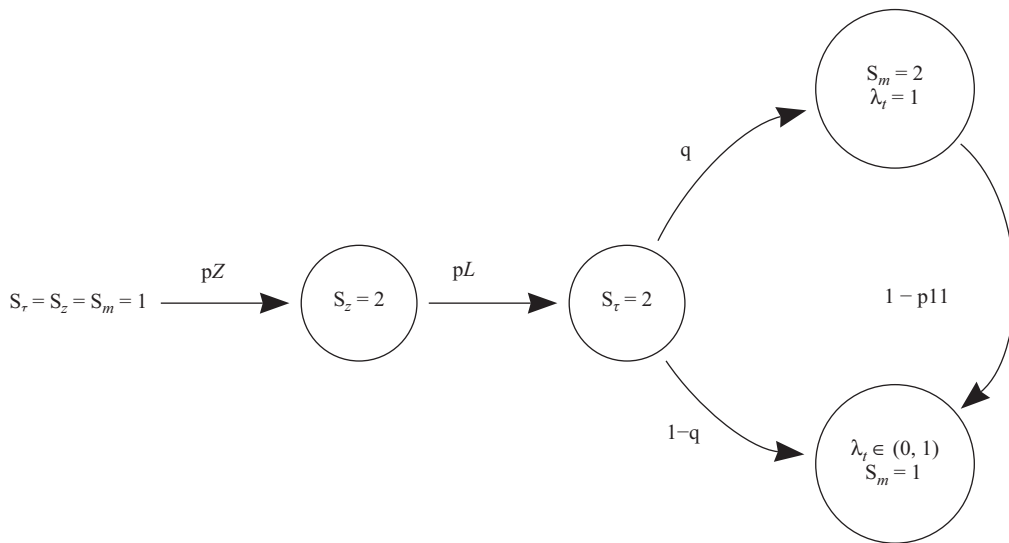
Fig. 3. Evolution of the economy. Policies begin in state 1 with passive tax policy, active monetary policy, and a stationary transfers process. Transfers switch to a non-stationary process ($S_z=2$) with probability p_Z. With probability p_L, the economy hits the fiscal limit and tax policy transits to $S_\tau = 2$. At the fiscal limit, with probability q, monetary policy becomes passive ($S_m=2$) while transfers policy remains active ($\lambda_t = 1$); with probability $1 - q$, monetary policy remains active ($S_m=1$), while transfers policy becomes passive ($\lambda_t \in [0,1)$). With probability p_{11}, the regime remains passive monetary/active transfers policy and with probability $1 - p_{11}$, the economy enters the absorbing state of active monetary/passive transfers policy.

where π^* is the target inflation rate. Following Leeper (1991), monetary policy is "active" when $\alpha > 1/\beta$, so policy satisfies the Taylor principle. We label the active regime as $S_{m,t}=1$. Policy is "passive" when $0 \le \alpha < 1/\beta$, ($S_{m,t} = 2$).

Fig. 3 displays the evolution of the economy. The economy is initialized with stationary transfers, passive fiscal and active monetary policy. With probability p_z, the transfers process becomes non-stationary, $S_z=2$. The economy reaches the fiscal limit with probability p_L, tax policy becomes active $S_\tau = 2$ and transfers are assumed to be reduced by $\lambda_t \in [0,1]$.[3] Upon reaching the fiscal limit, with probability q, monetary policy becomes passive ($S_m=2$) while transfers policy remains active ($\lambda_t = 1$); with probability $1 - q$, monetary policy remains active ($S_m=1$), while transfers policy becomes passive ($\lambda_t \in [0,1)$). We assume that the active monetary /passive transfers regime is an absorbing state. The economy will transition out of the passive monetary /active transfers regime with probability $1 - p_{11}$.

4. Calibration

The parameters over preferences, technology and price adjustment are consistent with the values in Rotemberg and Woodford (1997) and Woodford (2003). We calibrate the model at an annual frequency because the purpose of the model is to study the impact of fiscal policy over a relatively long horizon. Intermediate-goods producing firms markup the price of their good by 15 percent over marginal cost, so $\mu = \theta(1-\theta)^{-1} = 1.15$. The price adjustment parameter is set to imply relatively modest price rigidities, $\varphi = 10$.[4] The annual real interest rate is set to 2 percent, which implies $\beta = 0.98$. Preferences over consumption and leisure are logarithmic, $\sigma = 1$ and $\eta = -1$. We set χ so the steady state share of time spent in employment is 0.33. Steady state inflation is set to 2 percent and the initial steady state debt-output ratio in the regime with stationary transfers is set to 0.4. For real money balances, we set δ so velocity in the deterministic steady state, defined as cP/M, corresponds to the average U.S. monetary base velocity at 2.4.[5] The interest elasticity of real money balances, κ, is set to 2.6, which is consistent with Chari et al. (2000).

Average federal government purchases are a constant 8 percent share of output. In the regime with stationary transfers, z^* is calibrated so steady state transfers are 9 percent of output. We also allow a small, but persistent, stochastic variation in the transfers process, $\rho_Z = 0.9$. Monetary policy is active in the regime with stationary transfers, where the reaction of the nominal interest rate to inflation obeys the Taylor principle, so $\alpha = 1.5$. The inflation target is 2 percent, $\pi^* = 2.0$. Fiscal policy is passive in the regime with stationary transfers with $\gamma = 0.15$. The steady state debt-to-output ratio in the regime with stationary transfers is 0.4, which determines b^* and implies that the average tax rate is 0.198 (i.e. $\tau^* = 0.1980$). This value is

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[3] The amount of reneging is determined endogenously such that the government's flow budget constraint clears.

[4] As an example of the magnitude of this number, suppose that 66 percent of firms cannot reset their price each period in a Calvo setting, then a calibration at a quarterly frequency would suggest φ would be around 70. Prices are more flexible at an annual frequency, so $\varphi = 10$ captures a modest price of cost adjustment.

[5] See Davig and Leeper (2006) for further details.
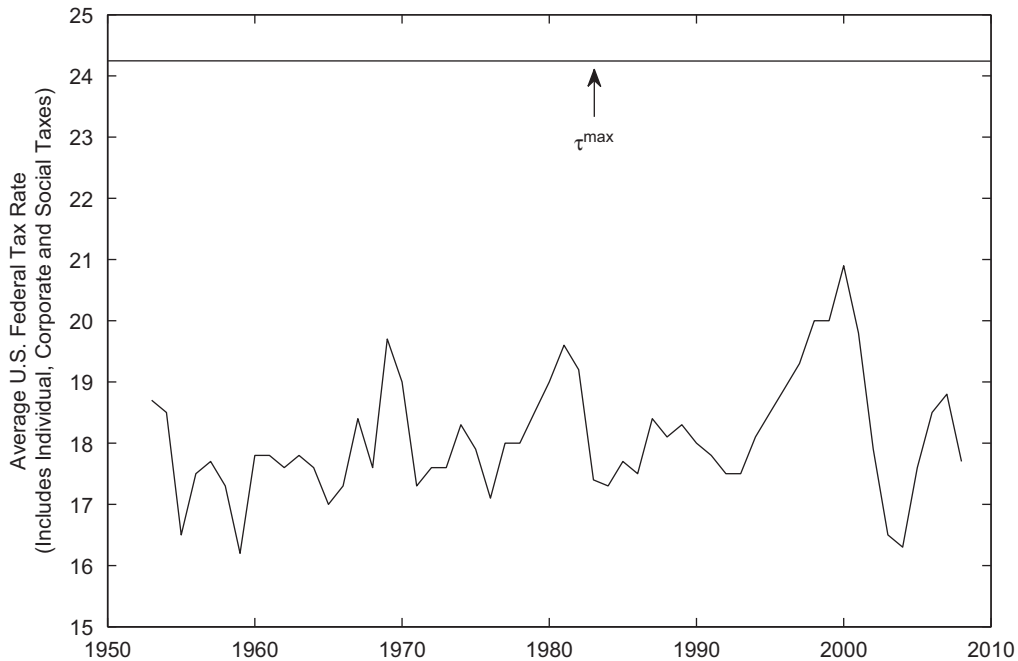
Fig. 4. A measure of the U.S. Federal tax rate. The figure plots total nominal Federal tax revenue, including personal, corporate, and social insurance taxes, divided by nominal GDP. The figure also plots the maximum tax rate for the calibrated model (τ^{max}).

consistent with the average tax rate in the U.S. reported in Fig. 4. The expected duration of the regime with stationary transfers is five years, which gives $p_z=0.8$. This value roughly corresponds to the amount of time that exists before the CBO projects transfers will begin their sustained upward trajectory (Congressional Budget Office, 2009a). Again using CBO estimates, transfers grow at 1 percent per year once the switch from the stationary to non-stationary regime occurs, $\mu = 1.01$.

After the switch to the regime with exponentially growing transfers, the same monetary and fiscal rules remain in place until the economy hits the fiscal limit. The probability of hitting the fiscal limit increases as debt and taxes rise, being driven by the growth in transfers. The probability of hitting the fiscal limit is time-varying and obeys the logistic function (15). η_0 and η_1 are set so that the initial probability of hitting the fiscal limit is 2 percent. The probability rises as debt and taxes increase and reaches roughly 20 percent by 2075.

At the fiscal limit, tax rates are required to remain constant, since the assumption embedded in the model is that further distortionary tax financing beyond a given point is no longer available. The limit is clearly unknown, so we assess different values, but take the benchmark value to be $\tau^{max} = 0.2425$. Fig. 4 shows that this value is well-above the post-war average U.S. Federal tax rate. In the regime with stationary transfers, this tax rate supports a steady state debt-output ratio of 2.3, which is an unprecedented level for the United States. Similarly, an average tax rate of $\tau^{max} = 0.2425$ has no historic precedent, as is evident from Fig. 4. However, since transfers are well-above their value in the stationary regime when the economy hits the fiscal limit, the level at which debt stabilizes is well-below this.

Since higher tax rates are no longer available to stabilize debt at the fiscal limit, we allow two potential resolutions. The first resolution, which is temporary, is a switch to passive monetary policy that is expected to last 10 years. In this scenario, the monetary authority pegs the nominal interest rate ($\alpha = 0$) and the fiscal authority continues to fully deliver on its promised transfers. Promised transfers continue to grow, however, and eventually outstrip the capacity of the government to meet its promised obligations. With probability p_{11}, policy switches to a setting where the fiscal authority reneges on transfers and monetary policy turns active. The second resolution stabilizes debt by reneging on promised transfers payments. Under this scenario, monetary policy remains active. The regime that reneges on transfers is absorbing: eventually, the economy transitions to a state in which lump-sum transfers stabilize debt (i.e. the government reneges on its promised transfers), constant distorting tax rates and active monetary policy. At the fiscal limit, the benchmark calibration places a 50 percent chance on passive monetary policy and on reneging. The path of inflation, however, depends importantly on the weight households attach to each resolutions, so we report the impact on the economy of alternative weights on each outcome.

We solve the model numerically using the monotone map method described in Davig and Leeper (2006).

5. Results

An often cited objection to the possibility that high levels of U.S. debt will be inflated away is that the long-end of the Treasury yield curve does not appear to embed dramatically higher inflation expectations or inflation risk
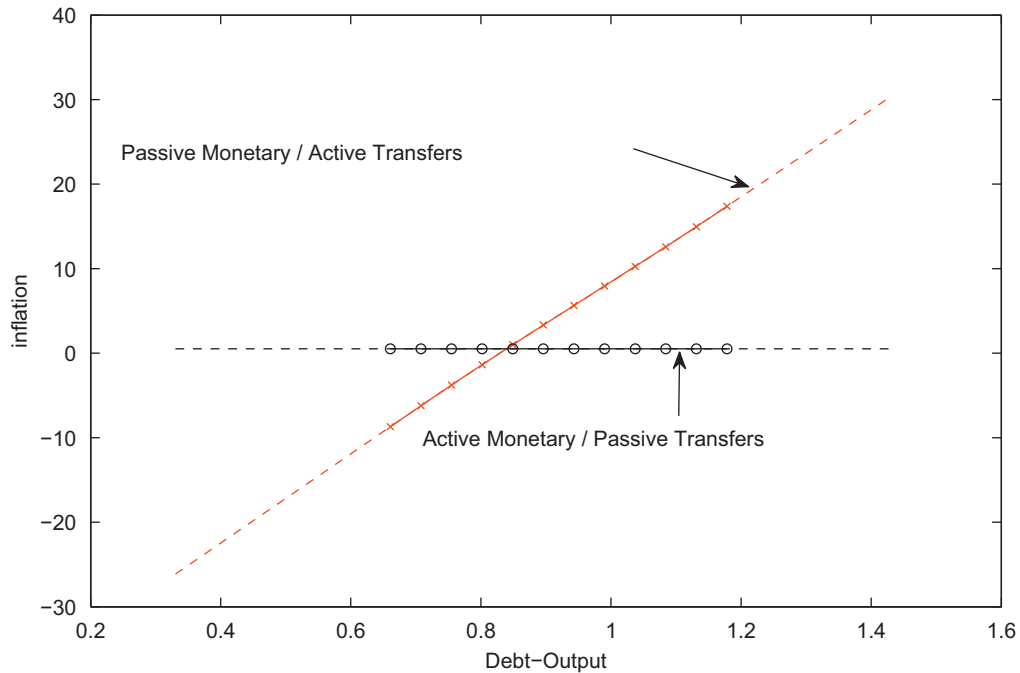
Fig. 5. Relationship between net inflation and debt at the fiscal limit for the passive monetary, active transfers regime, and the active monetary, passive transfers regime.

premia.[6] Similarly, survey-based measures of inflation expectations are stable (Federal Reserve Bank of Philadelphia, 2010). To preview results, we find that the average inflation for the calibrated model is in line with survey expectations and bond market participants. That is, the "unfunded liabilities" problem does not lead to substantial inflationary pressures in our model. However, this is a delicate result. Deviations from policy rules that anchor long-run expectations will push the expectation of mean inflation higher. Moreover, we find that the tail risk associated with long-run fiscal stress to be very large.

5.1. Objects of interest

To understand how various factors affect inflation dynamics in our model, we examine three objects of interest:

1. *Decision rules*: The model is solved using the monotone map method described in Coleman (1991). The first step in the solution algorithm is to discretize the state space around the nonstochastic steady state for each state variable (i.e. $\Theta_t = \{K_{t-1}, z_t, b_{t-1}, R_{t-1}, m_{t-1}, S_{j,t}\}$), where j denotes various regimes. The second step is to conjecture an initial set of decision rules for the capital stock, labor, marginal costs and inflation.[7] Denote the initial rules as $\hat{h}_j^K(\Theta_t) = K_t$, $\hat{h}_j^N(\Theta_t) = N_t$, $\hat{h}_j^\psi(\Theta_t) = \psi_t$ and $\hat{h}_j^\pi(\Theta_t) = \pi_t$ for $j=0$. We then substitute these decision rules into the household's first-order necessary conditions. In turn, the $t+1$ dated endogenous variables depend on Θ_{t+1}. Numerical integration is used to integrate over the exogenous variables. For a given point on the state space, this procedure yields a nonlinear system of equations. Solving this system for state variables at each point in the state space yields updated values for the decision rules (e.g., $\hat{h}_{j+1}^K(\Theta_t) = K_t$). We then repeat this step until the decision rules converge at every point in the state space ($|\hat{h}_j^K(\Theta_t) - \hat{h}_{j+1}^K(\Theta_t)| < \varepsilon$).[8]

   Once the decision rules converge, we can examine how inflation changes with a change in policy regime. As an example, consider Fig. 5, which will explained more fully below. This figure plots inflation against debt for the passive monetary/active transfers regime and the active monetary/passive transfers regime. All other state variables are set to steady state values, which implies the decision rules are to be interpreted as an approximation to equilibrium outcomes. The nodes (circles and stars) represent exact solutions (convergence points) to the model. A finer

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[6] See, for example, Board of Governors of the Federal Reserve System (2010).

[7] We initially solved a simplified version of the model with stationary transfers and either AM/PT or PM/AT policy. We then used weighted combinations of these rules as the initial conjectures.

[8] As evidence of local uniqueness, we perturb the converged decision rules in various dimensions and check that the algorithm converges back to the same solution. We restrict our attention to solutions on the minimum set of state variables.

discretization of the state space and nonlinear interpolation yields the solid lines. The dashed lines represent extrapolation beyond the last point of convergence.

2. *Term structure of inflation*: To understand how altering parameter values or policy rules affects inflation expectations, we run 10,000 Monte Carlo simulations of the economy, with each simulation lasting 40 periods. With the economy calibrated at an annual frequency, each simulation shows the dynamic path of the economy through the year 2050. We report the average of the term structure of expected inflation, computed as

$$s_{t+k,t} = \frac{1}{N} \sum_{n=1}^{N} \left(\frac{1}{k} \sum_{j=1}^{k} E_t \pi_{t+j}^{(n)} \right), \tag{17}$$

where $s_{t+k,t}$ is the average expected rate of inflation over the next k periods, and N denotes the number of simulations. Results reported below are robust to alternative measures of average inflation (e.g., mean values for inflation at various horizons). We use this definition because it corresponds to how survey-based expectations are reported.

3. *Tail expectation of inflation*: As a tail measure of inflation, we use the Monte Carlo simulations to calculate the average of inflation outcomes at each date in the upper 0.005 percentile. If we have N simulations from the model, this statistic is calculated by ordering the $\pi_t^{(n)}$, $n=1,\ldots,N$, at each date and taking the average of the highest $N \cdot 0.005$ inflation realizations. The conditional tail expectation is given by

$$E[\pi_t | \pi_t > \pi^{\mathcal{T}}] = \frac{1}{N \cdot \mathcal{T}} \sum_{n=1}^{N} \pi_t^{(n)} \mathcal{I}_{[\mathcal{T},\infty)}, \tag{18}$$

where $\mathcal{T}$ denotes the percentile of interest, $\pi^{\mathcal{T}}$ denotes the value of inflation at the $\mathcal{T}$th percentile, and $\mathcal{I}_{(\mathcal{T},\infty)}$ is an indicator function that is set to one if the value for inflation is equal to or greater than the $\mathcal{T}$th percentile.[9]

5.2. Fiscal variables and inflation

In order to isolate the expectational effects associated with hitting the fiscal limit, Fig. 5 plots the decision rules for inflation against debt in the two regimes that arise at the fiscal limit. As noted above, we plot decision rules by setting all state variables, with the exception of debt and inflation, to steady state values. The figure shows that for relatively high (low) debt-output ratios, hitting the fiscal limit and switching to a passive monetary policy/active transfers policy produces a sharp increase (decrease) in inflation.

The intuition for this result follows from the equilibrium condition that links the value of nominal government liabilities to the net present value of surpluses plus seigniorage revenue. The value of government debt can be obtained by imposing equilibrium, including the transversality condition for asset accumulation, on the government's flow constraint, taking conditional expectations, and "iterating forward" to arrive at

$$\frac{B_{t-1} + M_{t-1}}{P_t} = E_t \sum_{j=1}^{\infty} \left[\Delta_{t,t+j} \left(\tau_{t+j} [W_{t+j} N_{t+j} + R_{t+j}^k K_{t-1+j}] - g_{t+j} - \lambda_{t+j} z_{t+j} + \frac{r_{t+j}}{1+r_{t+j}} \frac{M_{t+j}}{P_{t+j}} \right) \right], \tag{19}$$

where the stochastic discount factor is given by

$$\Delta_{t,t+j} = \beta^j \left(\frac{C_t}{C_{t+j}} \right)^{\sigma} \frac{\pi_t}{\pi_{t+j}}, \tag{20}$$

and $1 + R_t = [E_t \Delta_{t,t+1}]^{-1}$. The value of nominal government liabilities depends on the expected present value of taxes less the expected present value of transfers and government spending plus seigniorage. An upward revision to tax revenue will raise the value of government debt, while an upward revision to transfers will lower the value of debt.

The mechanism for achieving the equality in (19) depends upon the combination of fiscal and monetary policies in place. A passive fiscal policy is one in which fiscal variables adjust to ensure that (19) holds, which allows monetary policy to effectively target the price level (active monetary policy). Recall that at the fiscal limit, tax policy enters an absorbing regime and is set at $\tau^{\max}$. A passive transfers policy – when agents receive a fraction of promised transfers – is then the only way to achieve the active monetary policy outcome. This explains why the line representing the active monetary/passive transfers (AM/PT) regime in Fig. 5 does not vary with the debt-output ratio. So long as transfers passively adjust to satisfy (19), then monetary policy can effectively target the price level.

If fiscal variables are unable to passively adjust to satisfy (19), then the adjustment must come from the price level P_t and/ or the real interest rate. Cochrane (2010) provides an interpretation of this regime in which "aggregate demand" can be thought of as the mirror image of demand for government debt. Any event that reduces the household's assessment of the value of the government debt they hold (e.g., explosive transfers coupled with a fixed tax rate and high debt-GDP ratio) will cause households to shed debt by converting it into demand for consumption goods, which in turn leads to higher prices.

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[9] Both the tail measure of inflation and the term structure of inflation rely upon convergence properties of the Monte Carlo simulations. Theorem 3.1.1 of Geweke (2005) gives conditions under which the moments are well-approximated by sample counterparts. While we are unable to prove that these conditions are satisfied analytically, several numerical checks where conducted to ensure the conditions are satisfied locally.

Unfortunately, our model cannot be neatly categorized into either the PM/AT regime or the AM/PT regime. Price level determination depends crucially on understanding how agents form conditional expectations over regimes. A rational expectations equilibrium in this model carries with it an assumption of very sophisticated agents. When taking the expectation in (19), agents are placing equal probability, q, on going to the PM/AT regime and the AM/PT regime, once the economy reaches the fiscal limit.

The debt-output ratio plays an important role in expectation formation. Prior to hitting the fiscal limit, agents are aware that the tax sequence and the probability of hitting the fiscal limit are explicit functions of real debt (see, (14) and (15)). Relatively low values of real debt signal to agents (i) a relatively low sequence of future taxes and (ii) a relatively low probability of hitting the fiscal limit. Moreover, (ii) implies that agents are more likely to continue to receive the promised level of transfer payments. A relatively low debt-output ratio is the one that can be supported by current tax policy. Recall that the tax rate at the fiscal limit supports a debt-output ratio of 2.3 at the *initial* steady state level of transfers. However, transfers grow exponentially and the level of debt that the higher tax rate supports will depend on the level of transfers when the fiscal limit is hit. This level will be much lower than the debt-output ratio of 2.3. The PM/AT line crosses the AM/PT line at the point where $\tau^{\max}$ is exactly able to offset the explosive growth in transfers (debt-output ratio of roughly 0.87).

Fig. 5 shows that debt-output levels to the left of this point have deflationary consequences when the regime switches from active to passive monetary policy at the fiscal limit. This is because prior to hitting the fiscal limit, the lower value of debt portends a low sequence of future taxes and a low probability of reneging on transfers. Thus, the adjustment of taxes to the upper bound of $\tau^{\max}$ when the economy hits the fiscal limit generates a large positive reevaluation of debt. The upward revision to the expected path for primary surpluses dampens demand for goods and raises the value of government debt, generating the deflationary outcome depicted in the figure. The positive reevaluation of debt holds in spite of the active transfers policy. This is because agents eventually put probability one on the passive transfers policy regime (since the passive transfers regime is an absorbing state). Therefore the *positive* reevaluation with respect to the change in the tax sequence is much larger than the negative one associated with transfers. This deflationary pressure is amplified by the adjustment of the stochastic discount factor, which, as (20) shows, increases with deflationary pressures.

For high levels of debt, these effects are reversed. Leading up to the fiscal limit, transfers are growing exponentially. As debt accumulates, agents recognize that the increase in taxes to $\tau^{\max}$ at the fiscal limit is not enough to offset the growth in transfers. A switch from active to passive monetary policy generates a downward revision to primary surpluses and a positive wealth effect, which leads to inflation. The *positive* reevaluation with respect to the change in the tax sequence is much smaller now because higher debt levels imply agents place much greater probability on hitting the fiscal limit. This, in turn, generates a positive wealth effect which increases aggregate demand and hence the inflation rate.

5.3. Response of taxes to debt, γ

Much of the recent discussion of fiscal policy centers on fiscal retrenchment (see, Leeper, 2010). On the heels of implementing large and coordinated increases in government spending, the discussion has turned to increasing tax rates and/or reducing government spending. Much of the impetus for the discussion seems to be the long-run considerations discussed in the introduction. Within the context of our model, we are able to address the following question: How will inflation change if taxes respond more aggressively to debt? Prior to hitting the fiscal limit, γ governs the extent to which the tax rate responds to the debt-to-GDP ratio. According to (14), higher values for γ imply the current tax rate responds more aggressively to last period's deviation from the steady state debt level, b^*.

Fig. 6 plots the decision rules for $\gamma = 0.10$ and 0.15. A policy that raises taxes more aggressively in response to rising debt – a higher value for γ – decreases the level of inflation *if* the level of debt is not too high. The intuition for this result is straightforward: a higher tax rate coupled with low debt keeps the economy away from the fiscal limit longer. But the relationship between debt, taxes, and inflation is nonlinear. In this model, a higher distortionary tax reduces work effort which depresses output and increases marginal costs. This leads to an increase in inflationary pressures. Thus, distortionary taxation has two opposing effects on inflation. For relatively low values of debt, higher distorting taxes keep the economy away from the fiscal limit longer. This reduces inflationary pressures and dominates the increase in inflation due to the cost-push shock associated with higher marginal costs. For low or moderate levels of debt, the result continues to hold; the economy with a more aggressive tax policy has lower inflation.

As debt rises to high levels, this result is reversed; the economy with a more aggressive tax policy eventually sees realizations with higher levels of inflation. This is because with high levels of debt, the probability of hitting the fiscal limit is much higher for higher γ. The consequences of hitting the fiscal limit begin to dominate, which, coupled with the inflationary pressures of increasing marginal costs, leads to higher inflation. Comparing two economies with high debt levels, the economy with a less aggressive tax policy has more room to raise taxes and increases revenues to combat the exponential growth in transfers, keeping it away from the fiscal limit longer.

5.4. Probability of passive monetary policy, q

Once the fiscal limit is hit, effectively targeting the price level with monetary policy would require a passive transfers policy (transfers would adjust passively such that (19) holds). From a political economy perspective, the probability of passive transfers may be much more difficult to achieve than the 1/2 probability assumed in the baseline calibration. What if at the
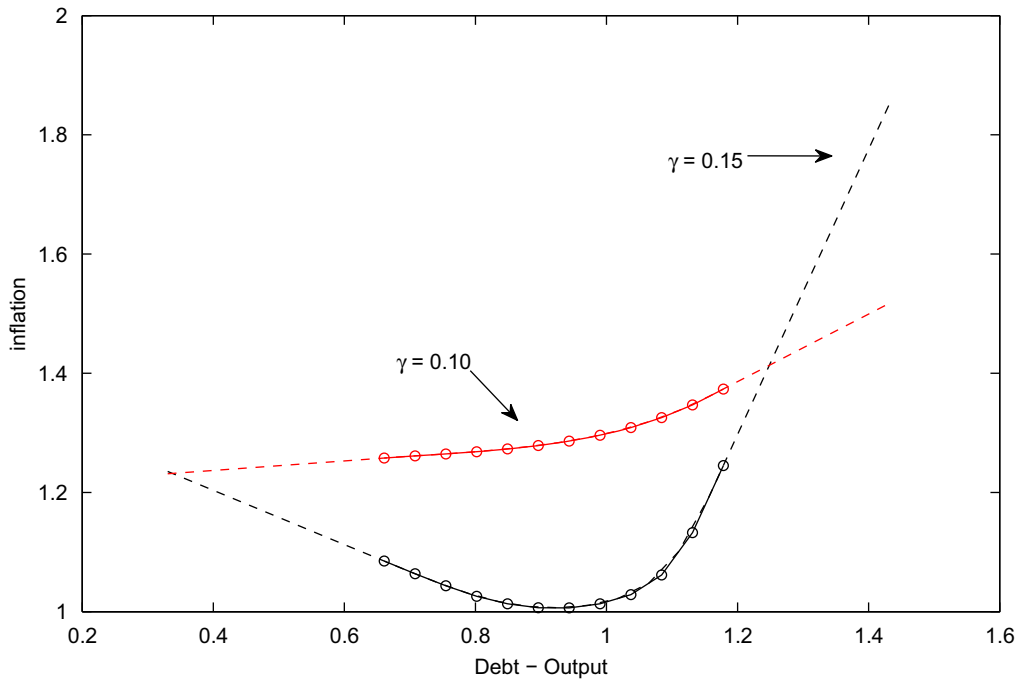
Fig. 6. Comparison of alternative tax rules: higher γ implies a larger response of tax rates to debt before the fiscal limit is reached.
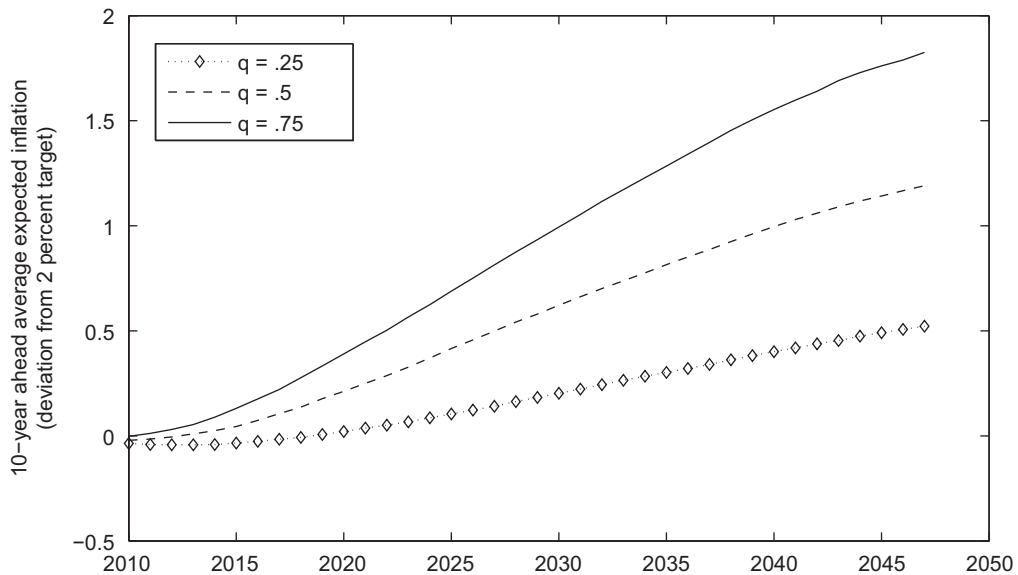

Fig. 7. Average 10-year expected inflation rates. Comparing probability distributions of passive monetary policy at the fiscal limit: higher q implies a higher probability of passive monetary policy at the fiscal limit.

fiscal limit the political economy landscape makes it very difficult to transition into the regime with passive transfers and active monetary policy?

Fig. 7 compares the path of 10-year average expected inflation given by (17) under different assumptions regarding the probability of monetary policy turning passive at the limit. If households place low probability on this transition, such as the scenario that sets $q=0.25$, then households expect with high probability the government to renege on promised transfer payments. By reducing the promised transfers appropriately, monetary policy is able to maintain only a slight deviation from target.

As households place greater probability on passive monetary policy at the fiscal limit, the trajectory of expected inflation bends upward. Under this scenario, households anticipate collecting transfer payments in full even after hitting the fiscal

limit. The deviations from target inflation are still benign even when households expect to transition into the passive monetary/active transfers regime with probability $q=0.75$. One reason for this mild inflationary outcome is due to the assumption that the active monetary/passive transfers regime is an absorbing state. Relaxing this assumption would change the quantitative result but not the main message of Fig. 7: at the fiscal limit, the longer the agents expect to receive the promised level of transfer payments, the larger the wealth effect and the greater the impact on inflation.

5.5. Probability of hitting fiscal limit, p_L

Fig. 8 plots the 10-year average expected rate of inflation under the baseline calibration, which allows the probability to rise as taxes increase, along with a parameterization of the model that assumes the probability of hitting the fiscal limit is
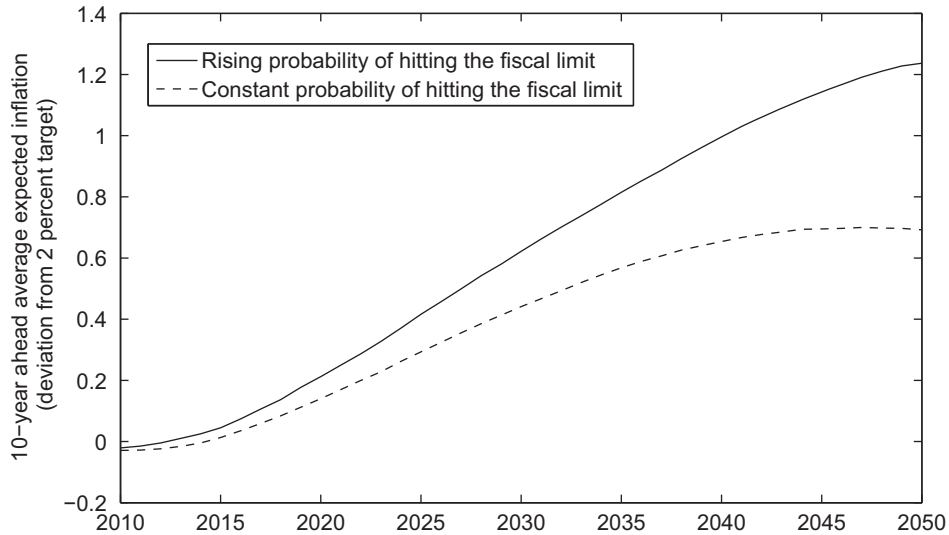

Fig. 8. Average 10-year expected inflation rates. Time-varying probability versus constant probability of hitting the fiscal limit.
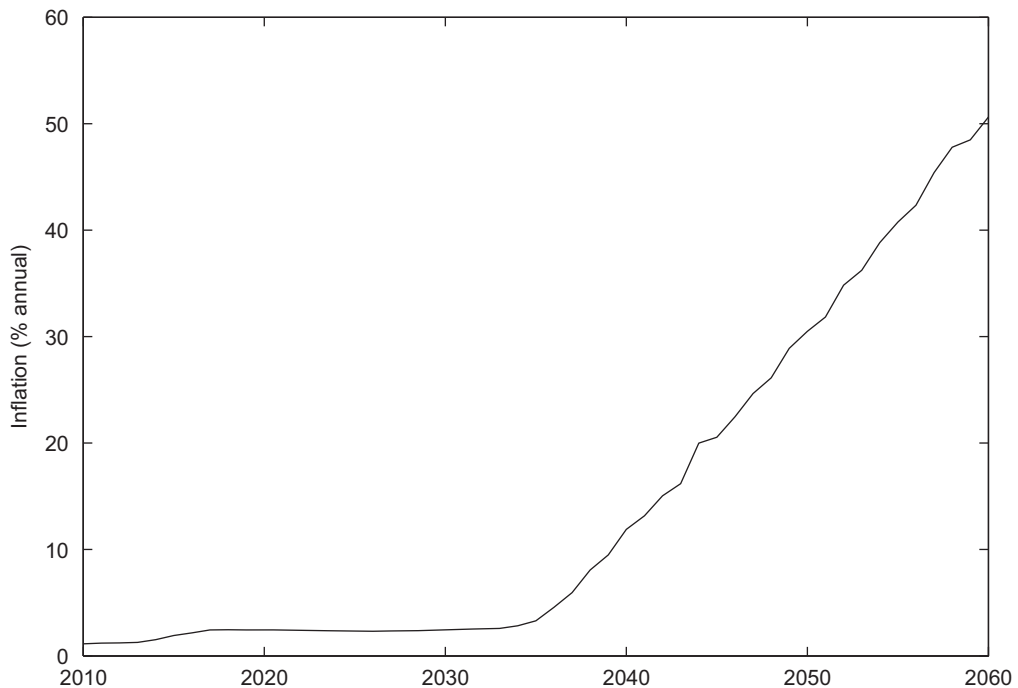

Fig. 9. Right tail of inflation distribution. Reports the average of inflation outcomes at each date in the upper 0.005 percentile tail.

constant (i.e. $p_{L,t}$=0.02 for all t). As debt and taxes rise, the benchmark version of the model that attaches increasing probability mass to hitting the fiscal limit generates a steeper trajectory for expected inflation. The reason for the more rapidly rising inflation expectations is that the household deems that it is more likely that the economy will hit the fiscal limit than under the version of the model that assumes the probability of hitting the fiscal limit is constant.

A surprising implication of all these variations, however, is how benign the various paths appear in terms of the inflation outlook. Clearly, massive inflation due to fiscal profligacy does not appear to be the mean forecast in any of the scenarios. Even settings where passive monetary policy at the fiscal limit is the more likely outcome, as shown by the solid line in Fig. 7, inflation expectations rise only slowly, with 10-year inflation expectations below 4 percent annually. The expected outcome, however, masks the range of inflationary outcomes that can emerge. Under poorly coordinated policy regimes, the next section illustrates that the tail outcomes of the inflationary distribution are quite severe.

5.6. Tail outcomes

Average expectations reported in the previous section mask some important features of the underlying distribution of future inflation. Expected inflation has a fat and long right tail, which expected values or even confidence bands do not fully reveal. To illustrate, Fig. 9 shows the average of the highest 0.005 percentile of inflation outcomes at each date. The takeoff point at which the tail embeds sharply higher rates of inflation occurs around 2035. At this date, the tax rate at the fiscal limit, which is set to 0.2425, is not sufficient to back the existing debt stock without an increase in the price level. If the maximum tax rate is higher (lower), the takeoff point in tail inflation outcomes would be later (earlier) than the 2035 date.

The tail outcomes emerge under scenarios where the government does not renege on any promised benefits and monetary policy turns passive at fiscal limit. The simulations reveal that the worst inflation outcomes will arise if fiscal policy delivers on all its promised transfers, raises taxes steadily and is able to limp by without hitting the fiscal limit for approximately 25 years. At around 2035, the high inflation outcomes will then begin emerging if monetary policy turns passive. High inflation outcomes can be quite bad by the standards of most countries in recent years, possibly getting as high as 50 percent at the end of the simulation period.

Fig. 9 is misleading in some respects, however, because it reports the worst inflation outcome at each date in the Monte Carlo simulation and not the worst single path of inflation. To illustrate the worst-case scenarios, Fig. 10 reports particular realized paths of inflation, where each path differs in when the economy hits the fiscal limit. The longer debt and taxes grow without hitting the limit, the larger is the resulting spike in the price level if monetary policy turns passive. Ever-increasing inflation spikes arise from their correspondingly higher level of debt: the longer the economy persists before hitting the fiscal limit, the more debt accumulates, and the larger is the burst of inflation. Fig. 10 essentially reports the upper envelope of the bursts of inflation that occur at each date for the simulations that draw a passive monetary policy at the fiscal limit.

A central message emerging from the model is that high inflation is a tail event and as a consequence, exerts only a modest influence on measures of average expected inflation. These dynamics may nonetheless prove dangerous if policymakers
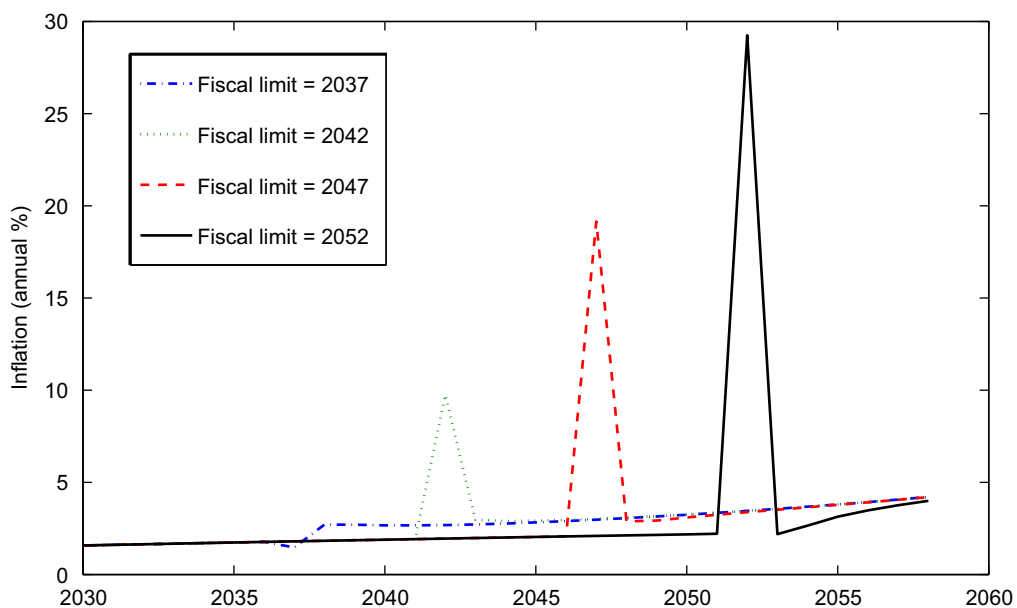

Fig. 10. Actual inflation paths. Realized inflation when the fiscal limit is hit at various years.

discount the prospects for high inflation because measures of inflation expectations *could* remain mostly stable. If the dangers are discounted and no policy reforms are taken – all promised transfers are delivered and monetary policy is active – then these are precisely the set of outcomes that give rise to the tail events.
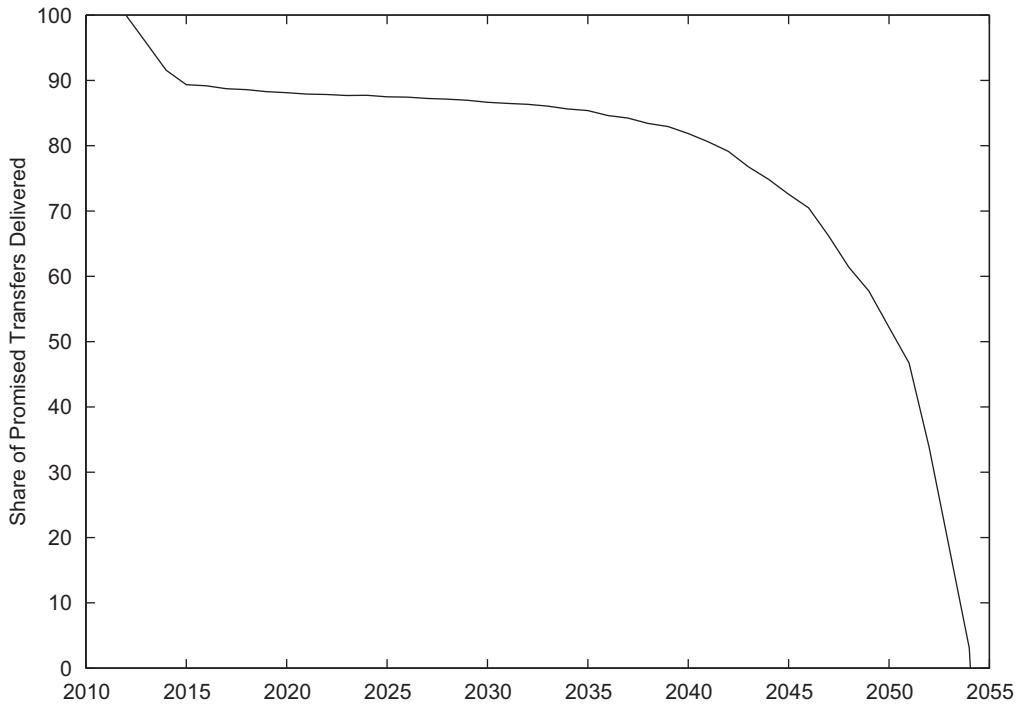

Fig. 11. Left tail of λ_t in the transfers policy. Reports the average λ_t outcomes at each date in the lower 0.005 percentile tail.
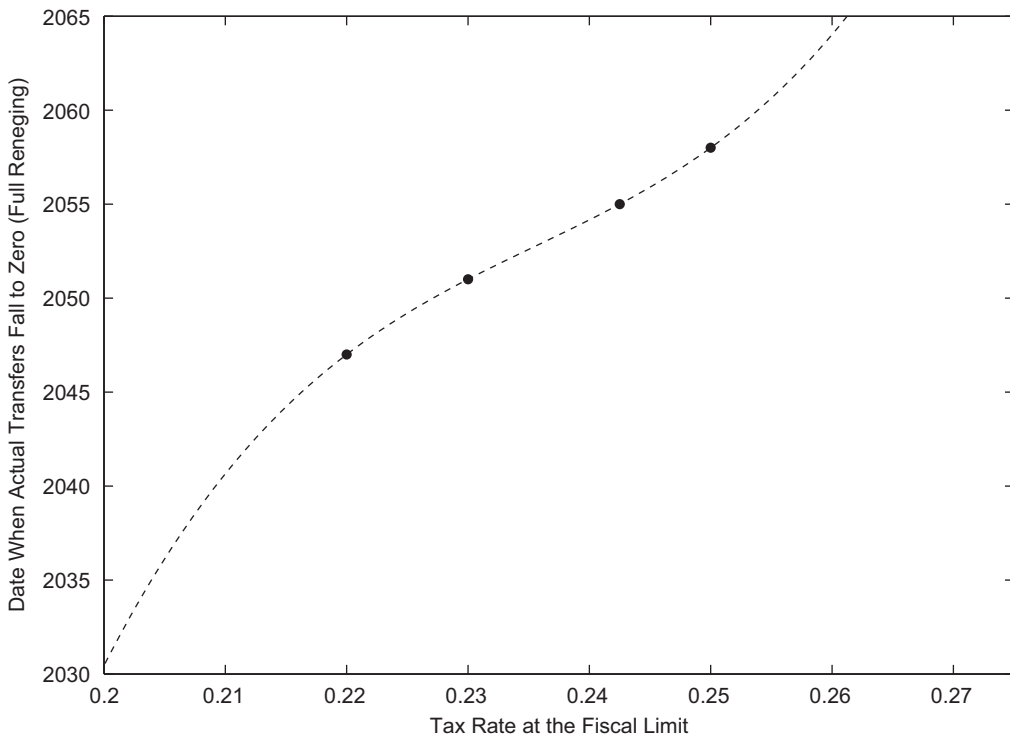

Fig. 12. Date when actual transfer fall to zero (i.e. Full reneging—$\lambda_t = 0$) for alternative fiscal limits (dashed line is a spline interpolation).

To guard against these tail outcomes for inflation, in this model the fiscal authorities must renege on some share of promised benefits. Given the calibration of the model, the extent of reneging does not need to be extreme over the next 20 or so years. For example, Fig. 11 reports the mean of the 0.005 percentile tail of the distribution for the variable that measures the extent of transfer reneging, the λ_t appearing in the household's and the government's budget constraints. In the most extreme simulations, modest reneging begins shortly after 2012 and continues through 2035. Reneging then accelerates after 2035 due to the inability of fiscal policy to further raise taxes to fund transfers. Ultimately, in the face of exponential growth of transfers, reneging is complete ($\lambda_t = 0$) and the economy settles into a new steady state equilibrium. Under a scenario where fiscal policy begins reneging on transfers to stabilize debt, monetary policy is freed to pursue its inflation target, which removes the threat of a tail inflationary outcome.

One key dimension of uncertainty is the tax rate associated with the fiscal limit. The baseline parameterization sets the value to 0.2425, which is consistent with a steady state debt equal to 230 percent of output at the level of transfers in 2010. To assess how the future paths of inflation, transfers and debt may evolve under alternative maximum tax rates, we turn to a sensitivity analysis to this parameter.

Fig. 12 reports the path of transfers under different values for the maximum tax rate at the fiscal limit. In the case of a relatively low rate at the limit, the maximum tax rate available to the fiscal authorities is 0.22, which is consistent with steady state debt equal to 170 percent of output at the level of transfers at 2010. In this case, actual transfers begin to fall below their promised levels within the next few years and are completely reneged upon starting in 2046. In the case of the least binding fiscal limit we consider, the tax rate is 0.25 and corresponds to steady state debt equal to 260 percent of output. In this case, transfers are not fully reneged on until after 2055.

6. Concluding remarks

Advanced economies are heading into an extended era of unresolved fiscal stress. Is hyperinflation a necessary outgrowth of this stress? Within the context of a rational expectations model, we find that dire inflationary outcomes are possible, but may not be very likely outcomes for advanced economies. Although rapid bursts of inflation are a feature of the equilibrium, they are very low probability events that affect inflation expectations only through the small probability households attach to those bursts. However, as households attach more probability to policymakers attempting to stabilize debt with passive monetary policy, upward drift in inflation expectations and inflation become more pronounced. This finding sends a warning to policymakers aiming to target inflation. Without significant and meaningful fiscal policy adjustment, the task of meeting inflation targets will become increasingly difficult.

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