"Unfunded Liabilities" and Uncertain Fiscal Financing[*]

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October 25, 2009

ABSTRACT

We develop a rational expectations framework to study the consequences of alternative means to resolve the "unfunded liabilities" problem—the projected exponential growth in federal Social Security, Medicare, and Medicaid spending with no known plan for financing the transfers. Resolution requires specifying a probability distribution for how and when monetary and fiscal policies will change as the economy evolves through the 21st century. Beliefs based on that distribution determine the existence of and the nature of equilibrium. We consider policies that in expectation combine reaching a fiscal limit, some distorting taxation, modest inflation, and some reneging on the government's promised transfers. In the equilibrium, inflation-targeting monetary policy and debt-targeting tax policy cannot anchor expectations on those target variables. Expectational effects are always present, but need not have large impacts on inflation and interest rates in the short and medium runs. In the economy's stationary distribution, the capital stock may grow or shrink and substantial probability falls on little or no reneging.
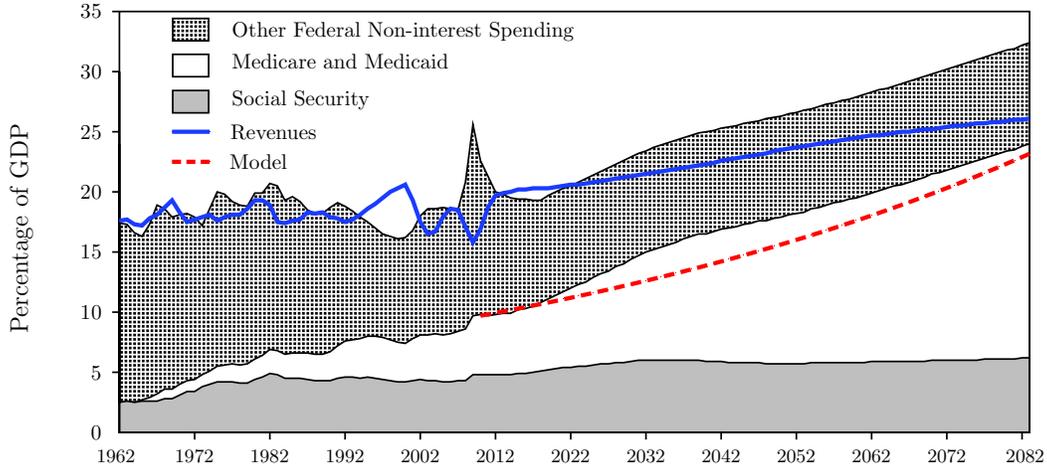
Figure 1: Projected and actual federal expenditures decomposed into Medicare, Medicaid, and Social Security spending and other non-interest spending. The solid line represents actual and projected revenues under the Extended-Baseline scenario. The dashed line is the calibration of the transfers process. Source: Congressional Budget Office (2009b).

1 INTRODUCTION

Profound uncertainty surrounds monetary and fiscal policy behavior in the United States. Even in normal times, the multiple objectives that guide Federal Reserve decisions and the absence of *any* mandates to guide federal tax and spending policies conspire to make it very difficult for private agents to form expectations of monetary and fiscal policies.

In the wake of the financial crisis and recession of 2007-2009, monetary and fiscal policies have not been normal and, as long-term projections by the Congressional Budget Office (CBO) make plain, in the absence of dramatic policy changes, policies are unlikely to return to normalcy for generations to come. Figure 1 reports actual and CBO projections of federal transfers due to Social Security, Medicaid, and Medicare as a percentage of GDP [Congressional Budget Office (2009b)]. Demographic shifts and rising relative costs of health care combine to grow these transfers from about 10 percent of GDP today to about 25 percent in 70 years. One much-discussed consequence of this growth is shown in figure 2, which plots actual and CBO projections of federal government debt as a share of GDP from 1790 to 2083.[1] Relative to the future, the debt run-ups associated with the Civil War, World War I, World War II, the Reagan deficits, and the current fiscal stimulus are mere hiccups.[2]

Of course, the CBO's projections are accounting exercises, not economic forecasts. The accounting embeds the assumption that current policies will remain in effect over the projection period. Because current policies have no provision for financing the projected transfers—

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[1]Appendix A provides details on the data underlying figures 1 and 2.

[2]Although this paper focuses on the American situation, the issues apply globally. For example, the Japanese government-debt ratio is at 200 percent and growing. Japan, Australia, New Zealand, and many European countries have populations that are aging even more rapidly than in the United States. Some, but not all countries, have planned for the the rising share of transfer payments through government savings in superannuation funds.
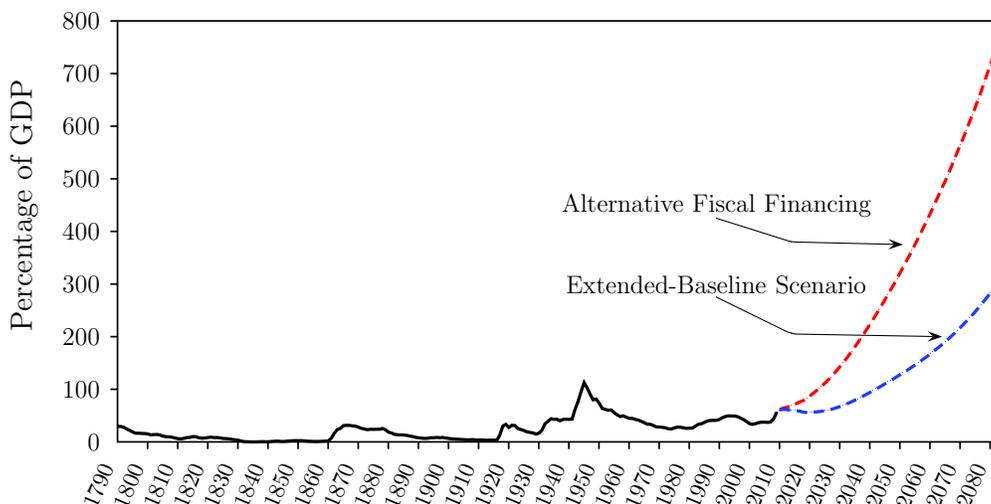
Figure 2: CBO's projections of Debt-to-GDP ratio under Alternative Fiscal Financing and Extended-Baseline Scenario.

hence the term "unfunded liabilities"—the accounting exercise converts those transfers into government borrowing, with no resulting adjustments in prices or economic activity.

"Unfunded liabilities" is a term that gets bandied about in discussions of the U.S. fiscal position. The "unfunded" component refers to the fact that *if current tax and spending policies were to remain in effect,* there would be insufficient surpluses to prevent an explosive path of federal debt. "Liabilities" presumes that the government's promised transfers will be fulfilled *with probability one.* Rational expectations makes it difficult to rationalize "unfunded liabilities" without strong and implausible assumptions about information.[3]

What can we learn from figure 2? Very little. In an economy populated by at least some forward-looking agents who participate in financial markets, long before an explosive trajectory for debt is realized, bond prices will plummet, sending long-term interest rates skyward. Why, even though the information contained in figures 1 and 2 has been known for many years, do investors continue to acquire U.S. government bonds bearing moderate yields?[4] Evidently, financial market participants do not believe that current policies will continue indefinitely. They also seem not to believe that future policy adjustments are likely to generate substantial inflation in the near term.

As the term implies, there are two potential margins along which to rationalize "unfunded liabilities" without abandoning the assumption that economic agents are well informed and

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[3]Few public policy issues have received as much media attention, economic analysis, and political pontification as the periodic pronouncements of the bankruptcy of Social Security and the explosive growth in medical spending. Given the intense attention these issues have received, equilibria in which private agents are unaware of the problems arising from these transfers programs are wholly implausible.

[4]For example, the CBO has produced similar projections for well over a decade [O'Neill (1996), Congressional Budget Office (2002)] and economists like Auerbach and Kotlikoff had been discussing the "coming generational storm" long before Kotlikoff and Burns's (2004) book by that title appeared [(Auerbach and Kotilikoff, 1987, ch. 11), Kotlikoff and Gokhale (1994), Auerbach, Gokhale, and Kotlikoff (1994, 1995), and Auerbach, Gokhale, and Kotlikoff (1995); Bryant (2004) studies how the effects of demographic shifts on public pensions manifest in open economies].

forward looking. Either "unfunded liabilities" are not unfunded—agents expect that some policies will adjust to raise sufficient surpluses—or they are not liabilities—the government is expected to (partially) renege on its promises—or some combination of both margins. Although not implied by the term, because the bulk of U.S. government debt used to finance deficits is nominal, another potential margin is surprise price-level increases that revalue outstanding debt to be in line with the expected present value of surpluses.

American policy institutions do nothing to inform economic agents about which margins are likely to be exploited and when the policy adjustments will occur. Modeling the uncertainty created by uninformative policy institutions is this paper's primary contribution.

Any study of long-term fiscal issues, including accounting exercises, is highly speculative, building in a great many tenuous assumptions about economic and policy developments many decades into the future. The discipline of general equilibrium analysis and rational expectations, however, requires still more speculation. For the exploding promised transfers path in figure 1 to be consistent with a rational expectations equilibrium, we must take stands on how policy may adjust in the future, the contingencies under which they may adjust, and how much economic agents know about those adjustments. But to move beyond hand-wringing about "unfunded liabilities" and make progress on the macroeconomic consequences of alternative policy adjustments, we are compelled to take *some* such stands. This paper offers a framework for studying how alternative policy adjustments and beliefs about those adjustments affect the evolution of the macro economy. Our aim is to *describe* potential policies and their consequences—not to *prescribe* particular policy solutions.

1.1 Modeling Policy Uncertainty

The core model is a neoclassical growth economy with an infintely lived representative household, capital accumulation, elastic labor supply, costly price adjustment, monetary policy, distorting taxes levied against labor and capital income, and a process describing the evolution of promised transfers from the government.

Into this model we build several layers of uncertainty. The promised transfers process is stochastic and persistent, and initially follows a stationary process. At a random date, the transfers process switches to the explosive process labeled "Model" in figure 1, which is treated as an absorbing state for promised transfers. Both before and after the switch to the explosive transfers process, tax policy passively adjusts the distorting tax rate to try to stabilize government debt, while monetary policy is active, obeying a Taylor rule that aims to target the inflation rate.[5] Over this period the "unfunded liabilities" are funded by direct tax revenues and borrowing from the public.

If these policies were to persist forever, eventually the tax rate would reach the peak of the Laffer curve.[6] At this fiscal limit, tax rates have reached their maximum and, with no

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[5] Applying Leeper's (1991) definitions, in the context of a fixed-regime version of our model, "active" monetary policy targets inflation, while "passive" monetary policy weakly adjusts the nominal interest rate in response to inflation; "active" tax policy sets the tax rate independently of government debt and "passive" tax policy changes rates strongly enough when debt rises to stabilize the debt-GDP ratio; "active" transfers policy makes realized transfers equal promised transfers, while "passive" transfers policy allows realized transfers to be less than promised.

[6] In a monetary economy there may also be a Laffer curve for seigniorage revenues. While this is a reasonable alternative source of financing, and one that Sargent and Wallace (1981) emphasize, we do not allow for a distinct "unpleasant monetarist arithmetic" regime in which the printing press becomes an important revenue source, in part because, like direct taxation, seigniorage cannot permanently finance

financing help from the active monetary policy, government debt would take on the kind of explosive trajectory shown in figure 2. Rational agents would expect this outcome and refuse to accumulate debt that cannot be backed by future surpluses and seigniorage revenues. No equilibrium exists.

Although the peak of the Laffer curve is the *economic* fiscal limit, it is likely that in the United States the *political* limit will be reached at much lower tax rates. The fiscal limit, though, is unknown and represents another layer of uncertainty: as tax rates rise, agents place higher probability on policy regime change, but the exact date at which regime changes and the precise policies that will be adopted at that date remain uncertain.

When tax rates reach their limit and remain fixed at some level, one of two possible regimes is realized: either the government partially reneges on its promised transfers, in effect making transfers policy passive, or monetary policy switches from being active to being passive, adjusting the nominal interest rate only weakly in response to inflation. At the fiscal limit, a random variable determines whether transfers policy or monetary policy becomes passive. When transfers policy is passive, "unfunded liabilities" are no longer liabilities because the government chooses not to honor some fraction of its original promises.[7] When monetary policy becomes passive, although realized transfers equal promised transfers, a different kind of reneging occurs as the price level jumps unexpectedly and the real value of outstanding government debt drops. Like reneging on promised transfers, this policy regime essentially transfers wealth from the private sector to the government.

After the economy reaches the fiscal limit, it never returns to a regime in which tax rates are adjusted to stabilize debt. Instead, the economy bounces randomly between the passive transfers regime and the passive monetary policy regime. It is not feasible to remain permanently in the passive monetary policy regime, with no prospect of returning to the passive transfers regime, because both promised and actual transfers continue to grow explosively. So long as the probability of transiting to a passive transfers policy is positive, however, the economy can remain in the passive monetary policy regime indefinitely because *expected* transfers will remain below actual transfers. On the other hand, the passive transfers regime could be an absorbing state, albeit an uninteresting one. Asymptotically, actual transfers will have to go to zero and the economy will settle into a steady state with a constant primary surplus, inflation rate, and real interest rate.

1.2 What the Layers of Uncertainty Deliver   We solve for a rational expectations equilibrium in which economic agents know the true probability distributions governing policy behavior and they observe current and past realizations of policy decisions, including the regimes that produce the policies. In contrast to much existing work on long-term fiscal policy, agents do not have perfect foresight and must form expectations over all possible future policy regimes. These expectations are what allow an equilibrium to exist, even in the presence of exploding promised government transfers. Expectations of possible future policy regimes also play an important role in determining the nature of equilibrium in the prevailing regime. Davig and Leeper (2006, 2007) show that these expectations formation

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promised transfers.

[7]Reneging need not take the form of outright refusal by the government to pay promised transfers. It could consist of changing eligibility criteria for Social Security, Medicare, and Medicaid or changing the coverage or payout rates for Medicare and Medicaid.

effects can uniquely determine the equilibrium even when the prevailing regime, if it were permanent, would produce an indeterminate equilibrium. By extension, effects that arise in some future regime can spill over into the current regime to produce equilibrium behavior that would not arise if only the current regime were possible.

Expectations about future adjustments in monetary and fiscal policies play a central role in creating sustainable policies. For example, in the period leading up to the fiscal limit—when actual transfers are growing exponentially, monetary policy is actively targeting inflation, and taxes are passively rising with expanding debt—the debt-GDP nonetheless rises relentlessly. If it were in place forever, this policy mix would be unsustainable and no rational expectations equilibrium would exist. But long-run expectations, which are driven by beliefs about policy behavior beyond the fiscal limit, are anchored by the knowledge that policy will fluctuate between a regime in which debt is revalued through jumps in the price level and a regime in which the government may renege on its promised transfers. Because debt is expected to be stabilized in the long run, the pre-fiscal limit expansion in debt can be consistent with equilibrium.

Other key findings are:

1. In an environment with exploding promised transfers, the conventional policy mix—monetary policy targets inflation and tax policy targets debt—cannot anchor private expectations on those policy targets. Before the economy has hit the fiscal limit, rising government debt raises tax rates and the probability of hitting the limit. As that probability rises, actual and expected inflation both increase. Failure of the usual mix to work in the usual way stems from sustainability considerations that create the expectation that policy regime will have to change in the future.

2. Even in a rational expectations equilibrium, where the expectational effects are always present, they need not have large impacts on inflation and real and nominal interest rates in the short to medium runs.

3. In the stationary distribution of the economy, the capital stock may be higher or lower than its initial value.

4. Although the expectation that the government may renege on its promised transfers plays a critical role in the equilibrium, substantial probability mass in the stationary distribution of the economy falls or little or no reneging.

Because changes in policy regime are intrinsically non-linear, we solve the full non-linear model numerically using the monotone map method. Before turning to that complex model, we develop intuition for the nature of the numerical solution by solving a considerably simpler model analytically.

2 Contacts with the Literature

One of the key contributions of the paper is to examine how uncertainty about fiscal and monetary policy can affect equilibrium outcomes. Sargent (2006) depicts policy uncertainty by replacing the usual probability triple, $(\Omega, \mathcal{F}, \mathcal{P})$, with $(?, ?, ?)$. He argues that the "prevailing notions of equilibrium" (i.e., exogenous state-contingent rules, time-inconsistent Ramsey

problems, Markov-perfect equilibria, and recursive political equilibria) all assume agents have a complete description of the underlying uncertainty, while Knightian uncertainty or ambiguity about future policy might be a better description of reality. The agents in our model are rational and condition on a well specified probability triple. However, our model has several layers of uncertainty uncommon to the literature, which bridges the gap between a rational expectations model and the ideas of Sargent (2006).

The importance of understanding how uncertainty about monetary and fiscal policy shapes economic outcomes is obviously not a new concept.[8] However, most of the early work introducing fiscal policy into modern dynamic general equilibrium models was conducted either in a non-stochastic environment or under the assumption that agents had perfect foresight [Hall (1971), Brock and Turnovsky (1981), Abel and Blanchard (1983), Becker (1985)]. Bizer and Judd (1989) and Dotsey (1990) are among the first papers to model fiscal policy uncertainty in a dynamic general equilibrium framework. These papers emphasize the importance of uncertainty when examining welfare considerations, fiscal outcomes such as debt dynamics, and the behavior of investment, consumption, prices and interest rates. Like Bizer and Judd (1989) and Dotsey (1990), our paper argues for a more realistic stochastic process with respect to policy variables. We also find that adding important layers of uncertainty has profound effects on equilibrium.

In a series of papers, Auerbach and Hassett (2002b, 2001, 2002a, 2007), Hassett and Metcalf (1999) ask questions related to those posed here: What are the short-run and long-run economic effects of random fiscal policy? How does policy stickiness—infrequent changes in fiscal policy—affect investment and consumption decisions? With uncertainty about factors affecting fiscal variables, like demographics, what is the range of possible policy outcomes? The baseline model used by Auerbach, Hassett and Metcalf to answer some of these questions is a dynamic stochastic overlapping generations model with uncertain lifetimes and policy stickiness. Auerbach and Hassett (2007) find that introducing time-varying lifetime uncertainty and policy stickiness changes the nature of the equilibrium and of optimal policy dramatically. Our framework for addressing these questions is quite different from that of Auerbach and Hassett. We re-interpret their concept of stickiness by assuming that several policy instruments can switch randomly according to a Markov chain. Instead of a one-time change in policy that is known, agents face substantial uncertainty about *when* policies will adjust and *which* policies will adjust. This allows for a broad range of potential policy outcomes, as advocated by Auerbach and Hassett.

One dimension in which our model suffers is that it does not take into account the important generational and distributional effects emphasized in Auerbach and Kotlikoff (1987), Kotlikoff, Smetters, and Walliser (1997, 1998, 2001, 2007), İmrohoroğlu, İmrohoroğlu, and Joines (1995), İmrohoroğlu, İmrohoroğlu, and Joines (1999), Huggett and Ventura (1999), Cooley and Soares (1999), De Nardi, İmrohoroğlu, and Sargent (1999), Altig, Auerbach, Kotlikoff, Smetters, and Walliser (2001), and Smetters and Walliser (2004). The canonical model used in these papers is an overlapping generations model with each cohort living for 55 periods. This model permits rich dynamics in demographics—population-age distributions, increasing longevity—intra-generational heterogeneity, bequest motives, liquidity

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[8]An early literature examined how risk profiles changed in a portfolio choice model when taxes where levied on returns [Domar and Musgrave (1944), Tobin (1958), Feldstein (1969), Stiglitz (1969)].

constraints, earnings uncertainty, and so forth; this approach also allows for flexibility in modeling fiscal variables and alternative policy scenarios. Due to the richness and complexity of the model, only perfect foresight equilibria (or slight deviations from perfect foresight) are computed. A majority of the papers cited above analyze the distributional consequences of Social Security reform. While we cannot assess the distributional effects of alternative policies in our model, we substantially increase the complexity of the policy uncertainty faced by individuals.

The type of uncertainty we examine is similar in some respects to the institutional uncertainty described by North (1990, p. 83): "The major role of institutions in a society is to reduce uncertainty by establishing a stable (but not necessarily efficient) structure to human interaction. The overall stability of an institutional framework makes complex exchange possible across both time and space." 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—measures as the standard deviations of government consumption and investment and average tax rates— are shown to be significant and negatively correlated with growth in both developed and developing economies. Hopenhayn (1996) and Aizenman and Marion (1993) 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)]. As described in section 5, we have similar expectational effects operating in our model. Agents know precisely the range of possible policy adjustments but do not know the *timing* of the adjustment. At each date, agents update the conditional expectation of a change in policy. Similar to the "wait and see" result in the real options literature, the timing of the resolution of uncertainty is important in our setup.

3 The Full Model

We employ a conventional neoclassical growth model with sticky prices, distorting income taxation, and monetary policy.

3.1 Households

An infinitely lived representative household chooses $\{C_t, N_t, M_t, B_t, K_t\}$ to maximize

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

with $0 < \beta < 1, \sigma > 0, \eta > 0, \kappa > 0, \chi > 0$ and $\nu > 0$. $C_t = \left[\int_0^1 c_t(j)^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}}$ 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.

The household's budget constraint is

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

where 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, z_t are lump-sum transfers promised by the government, λ_t is the fraction of promised transfers actually received by the household and D_t is profits. The household's optimality conditions are

$$C_t^{-1} = \beta E_t\left[\left((1 - \tau_{t+1})R_{t+1}^k + 1 - \delta\right)C_{t+1}^{-1}\right],$$

$$C_t^{-1} = \beta E_t\left[\frac{R_t}{\pi_{t+1}}C_{t+1}^{-1}\right],$$

$$m_t = \left[\nu C_t\left(\frac{R_t}{R_t - 1}\right)\right]^{1/\kappa},$$

$$\chi c_t n_t^\eta = (1 - \tau_t)w_t.$$

3.2 Firms

There are two types of firms: monopolistically competitive intermediate goods producers who produce a continuum of differentiated goods and competitive final goods producers.

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. 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 the following constant-returns-to-scale technology

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

where $\theta > 1$ is the elasticity of substitution between goods. Profit-maximization by the final goods producing firm yields a demand for each intermediate good given by

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

Monopolistically competitive intermediate goods producing firm j chooses price $P_t(j)$ to maximize the expected present-value of profits

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

where, because the household owns the firms, 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. Real profits are

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

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. Price adjustment is subject to 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^*. The first-order condition for the firm's pricing problem is

$$\begin{aligned}
0 = {} & (1-\theta)\Delta_t\left(\frac{P_t(j)}{P_t}\right)^{-\theta}\left(\frac{Y_t}{P_t}\right) + \theta\Delta_t\Psi_t\left(\frac{P_t(j)}{P_t}\right)^{-\theta-1}\left(\frac{Y_t}{P_t}\right) - \\
& \varphi\Delta_t\left(\frac{P_t(j)}{\pi^* P_{t-1}(j)} - 1\right)\left(\frac{Y_t}{\pi^* P_{t-1}(j)}\right) + \beta E_t\left[\varphi\Delta_{t+1}\left(\frac{P_{t+1}(j)}{\pi^* P_t(j)} - 1\right)\left(\frac{P_{t+1}(j) Y_{t+1}}{\pi^* P_t(j)^2}\right)\right].
\end{aligned} \tag{10}$$

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 $P_t(j) = P_t$. Steady-state marginal costs are given by

$$\Psi = \frac{\theta - 1}{\theta}, \tag{11}$$

and $\Psi^{-1} = \mu$, where μ is the steady-state markup of price over marginal cost.

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

$$C_t + K_t - (1-\delta)K_{t-1} + G_t - \frac{\varphi}{2}\left(\frac{P_t(j)}{\pi P_{t-1}(j)} - 1\right)^2 Y_t = Y_t \tag{12}$$
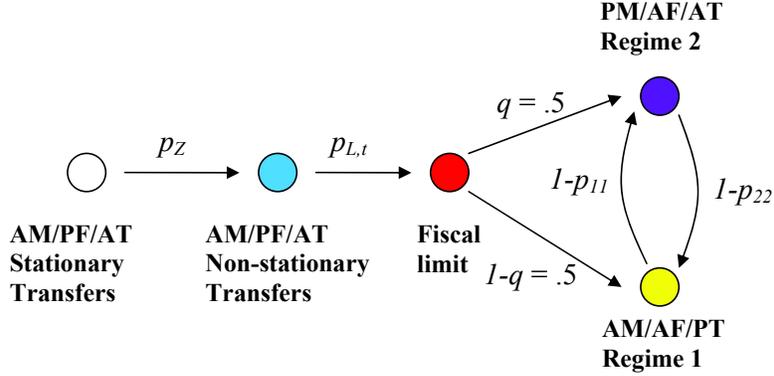
Figure 3: The unfolding of uncertainty about policy.

3.3 Fiscal Policy, Monetary Policy, and the Fiscal Limit

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

$$\frac{B_t}{P_t} + \frac{M_t}{P_t} + \tau_t \left(\frac{W_t}{P_t} N_t + R_t^k K_{t-1} \right) = g_t + \lambda_t z_t + \frac{R_{t-1} B_{t-1}}{P_t} + \frac{M_{t-1}}{P_t}. \tag{13}$$

We now describe the various layers of uncertainty surrounding tax, transfers, and monetary policies. Figure 3 describes schematically how the uncertainty unfolds. The fiscal authority sets promised transfers exogenously according to a Markov chain that starts with a stationary process for transfers, while monetary policy actively targets inflation, and tax policy raises tax rates passively when debt rises. The transfers process then switches, with probability $1 - p_z$, to a non-stationary process that is an absorbing state. The non-stationary process appears in figure 1 as the expotentially growing line labeled "Model." The transfers process, which operates for $t \geq 0$, is

$$z_t = \begin{cases} (1 - \rho_z) \overline{z} + \rho_z z_{t-1} + \varepsilon_t & \text{for } S_{z,t} = 1 \\ \mu z_{t-1} + \varepsilon_t & \text{for } S_{z,t} = 2 \end{cases} \tag{14}$$

where $z_t = Z_t / P_t$, $|\rho_z| < 1$, $\mu > 1$, $\mu\beta < 1$, $\varepsilon_t \sim N(0, \sigma_z^2)$. S_{zt} follows a Markov chain that evolves according to

$$\Pi_z = \begin{bmatrix} 1 - p_z & p_z \\ 0 & 1 \end{bmatrix}, \tag{15}$$

where the regime with exploding promised transfers is an absorbing state. The expected number of years until the switch from the stationary to nonstationary regime is $(1 - p_z)^{-1}$. In figure 3 the switch from the stationary to the non-stationary transfers policy occurs with probability p_z and is marked by the move from the clear circle to the lightly shaded (blue) circle.

When transfers grow exponentially and are financed by new debt issuances, for some time taxes can rise to support the expanding debt. At some point, however, for economic reasons—reaching the peak of the Laffer curve—or political reasons—the electorate's intolerance of

10

the distortions associated with high tax rates—tax policy will reach the fiscal limit. We model that limit as setting the tax rate to be a constant, $\tau_t = \tau^{\max}$ for $t \geq T$, where T is the date at which the economy hits the fiscal limit. The setting of $\tau^{\max}$ is important for the long-run performance of the economy and, *a priori*, there is no obvious value for $\tau^{\max}$. One possibility is that tax rates settle at a relatively high value; but another equally plausible scenario is that taxpayers will revolt against high rates and $\tau^{\max}$ will be relatively low.

Tax policy sets rates according to

$$\tau_t = \begin{cases} \bar{\tau} + \gamma\left(\frac{B_{t-1}/P_{t-1}}{Y_{t-1}} - b^*\right) & \text{for } S_{\tau,t} = 1, t < T \text{ (Below Fiscal Limit)} \\ \tau^{\max} & \text{for } S_{\tau,t} = 2, t \geq T \text{ (Fiscal Limit)} \end{cases} \tag{16}$$

where b^* is the target debt-output ratio and $\bar{\tau}$ is the steady-state tax rate.

The fiscal limit itself, and by implication the date at which the fiscal limit is hit, T, are stochastic. We posit that the probability at time t, p_{Lt}, of hitting the fiscal limit is an increasing function of the tax rate at time $t - 1$, implying that the probability rises with the level of government debt. We assume a logistic function governs the evolution of the probability

$$p_{L,t} = \frac{\exp(\eta_0 + \eta_1 (\tau_{t-1} - \bar{\tau}))}{1 + \exp(\eta_0 + \eta_1 (\tau_{t-1} - \bar{\tau}))}, \tag{17}$$

where $\eta_1 < 0$. Households know the maximum tax rate, $\tau^{\max}$, but the precise timing of when that rate takes effect is uncertain.

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

$$R_t = \bar{R} + \alpha(\pi_t - \pi^*) \tag{18}$$

where π^* is the target inflation rate. Monetary policy is active when $\alpha > 1/\beta$, so policy satisfies the Taylor principle. Policy is passive when $0 \leq \alpha < 1/\beta$.

Once the economy reaches the fiscal limit, tax policy is active, as it is no longer feasible to raise tax rates to finance further debt expansions. Because we take outright debt default off the table, some other policy adjustments must occur. Given active tax policy, we restrict attention to two possible policy regimes. One regime—denoted AM/AF/PT, Regime 1 in table 1—has monetary policy actively targeting inflation, while transfers policy is passive, with the government (partially) reneging on its promised transfers by the fraction $\lambda_t \in [0,1]$. The other regime—denoted PM/AF/AT, Regime 2—has monetary policy abandoning the targeting of inflation, with a pegging of the nominal interest rate at $\bar{R}$, and an "active" transfers policy that sets actual transfers equal to promised transfers.

At the fiscal limit, the dark shaded (red) ball in figure 3, households put equal probability on going to the two regimes in table 1, $q = 1 - q = 0.5$. Then policy bounces randomly between those two regimes, labeled in the figure Regimes 1 and 2, governed by the transition matrix

$$\Pi_T = \begin{bmatrix} p_{11} & 1 - p_{11} \\ 1 - p_{22} & p_{22} \end{bmatrix}, \tag{19}$$

where p_{ii} is the probability of remaining in regime i and $1 - p_{ii}$ is the probability of moving from regime i to regime j.

	AM/AF/PT		PM/AF/AT
	Regime 1		Regime 2
AM:	$R_t = \bar{R} + \alpha(\pi_t - \pi^*)$	PM:	$R_t = \bar{R}$
AF:	$\tau_t = \tau^{\max}$	AF:	$\tau_t = \tau^{\max}$
PT:	$\lambda_t z_t$	AT:	z_t

Table 1: AM: active monetary policy; PM: passive monetary policy; AF: active tax policy; AT: active transfers policy; PT: passive transfers policy.

3.4 CALIBRATION   The parameters describing preferences, technology and price adjustment are set to be consistent with Rotemberg and Woodford (1997) and Woodford (2003). To study the impact of fiscal policy over a relatively long horizon, we calibrate the model at an annual frequency. Intermediate-goods producing firms set the price of their good 15 percent over marginal cost, implying $\mu = \theta(1 - \theta)^{-1} = 1.15$. For the price adjustment parameter, we set $\varphi = 10$. If 66 percent of firms cannot reset their price each period, then a calibration at a quarterly frequency would suggest φ would be around 70. Prices are certainly more flexible at an annual frequency, so the choice of $\varphi = 10$ is made to capture a modest price of cost adjustment. The annual real interest rate is set to 2 percent ($\beta = .98$). Preferences over consumption and lesiure are logarithmic, so $\sigma = 1$ and $\eta = 0$. χ is set 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 is set to 0.4.

For real balances, δ is set so velocity in the deterministic steady state, defined as cP/M, matches average U.S. monetary base velocity at 2.4. We take this value from Davig and Leeper (2006), where we used data from 1959-2004 on the average real level of expenditures on non-durable consumption plus services. The parameter governing the interest elasticity of real money balances, κ, is set to 2.6 [Mankiw and Summers (1986), Lucas (1988), Chari, Kehoe, and McGrattan (2000)].

Mean federal government purchases are set to a constant 8 percent share of output throughout all the simulations. In the stationary transfer regime, μ is set so steady state transfers are 9 percent of output and the process for transfers is persistent, so we set $\rho_Z = .9$. Monetary policy is active in the stationary regime, where $\alpha = 1.5$, and fiscal policy is passive, where $\gamma = .15$. The inflation target is $\pi^* = 2.0$. Steady state debt to output in this regime is set to .4, which determines b^*. This implies that $\bar{\tau} = .1980$, a value for the average tax rate in line with figure 1. The expected duration of the stationary regime is five years ($p_Z = .8$), which is roughly about the time until the CBO projects transfers to begin their upward trajectory. Transfers then grow at 1 percent per year once the switch from the stationary to non-stationary regime occurs.

Once the economy switches to the regime with rising transfers, the same monetary and fiscal rules stay in place until the economy hits the fiscal limit. The probability of hitting the fiscal limit is rising according to the logistic function (17), where η_0 and η_1 are set so that initially, the probability of hitting the fiscal limit is 2 percent. The probability then rises as debt and taxes rise, reaching roughly 20 percent by 2075, after which it begins rapidly rising.

At the fiscal limit, we require taxes to be constant, $\tau^{\max} = .2425$. In the original station-

ary transfer state, this tax rate would support a steady state debt-output ratio of 2.3, an unprecedented level for the United States. However, with rising transfers, the level at which debt stabilizes is well below this. We will comment on the implications of altering τ^{max} when discussing the simulations. At the fiscal limit, higher tax rates are no longer available to the government to stabilize debt, so we allow two potential resolutions, both with a 50 percent chance of being realized. The first is a switch to passive monetary policy, where the monetary authority pegs the nominal interest rate $\alpha = 0$ and the fiscal authority continues to make good on the level of its promised transfers. The second resolution involves reneging on promised transfers payments. Under this scenario, monetary policy remains active.

After the fiscal limit has been hit, passive monetary policy alone is unable to completely stabilize debt as transfers continue on their explosive path. To stabilize debt, we allow recurring regime change between the passive monetary regime that provides the full amount of promised transfers and the active monetary regime with reneging. Each regime is calibrated to be persistent, where the expected duration of the passive monetary regime is 10 years and the expected duration of the reneging regime is 100 years.

We solve the model numerically using the monotone map method described in Davig and Leeper (2006). Details are provided in the appendix B.

4 Some Analytical Intuition

Before launching into the numerical solution of the complicated model that section 3 describes, it is instructive to examine simpler setups that admit analytical solutions and highlight some of the mechanisms at work in the numerical solution. The first simple setup is quite stark. It eliminates virtually all the uncertainty about future policies by assuming that the government's promised transfers always follow a non-stationary process and by positing that at some known future date, T, fiscal policy hits the fiscal limit and switches from passively adjusting lump-sum taxes to stabilize debt, to fixing tax revenues at their limit, τ^{max}. At date T, one of two possible policy combinations are pursued: either the government reneges on promised transfers or monetary policy becomes passive and pegs the nominal interest rate. Starkness comes from assuming that agents know which policy combination will be realized at T. A second simple setup adds a layer of uncertainty by positing that agents place probability $1-q$ on switching to the reneging regime and probability q on switching to the pegged nominal interest rate. The assumption that agents know the date when the economy reaches the fiscal limit is maintained throughout, as is the assumption that whatever policy regime is realized at T is an absorbing state.

We consider a constant endowment economy that is at the cashless limit. A representative household pays lump-sum taxes τ_t, receives lump-sum transfers z_t, and chooses sequences of consumption and nominal bonds, $\{c_t, B_t\}$, to maximize $E_0 \sum_{t=0}^{\infty} \beta^t u(c_t)$ subject to the budget constraint $c_t + B_t/P_t + \tau_t = y_t + z_t + R_{t-1}B_{t-1}/P_t$, with $R_{-1}B_{-1} > 0$ given. Set government purchases to zero in each period so that in equilibrium $c_t = y_t = y$. Then in equilibrium the consumption Euler equation reduces to the simple Fisher relation

$$\frac{1}{R_t} = \beta E_t \left(\frac{P_t}{P_{t+1}} \right) \tag{20}$$

where $\beta \in (0,1)$ is the household's discount factor. With a constant endowment, the equilibrium real interest rate is also constant at $1/\beta$.

We imagine that the government's *promised* transfers follow the non-stationary process given by (14), $z_t = \mu z_{t-1} + \varepsilon_t$, where $\mu > 1$, $E_t \varepsilon_{t+1} = 0$, and $z_{-1} > 0$ is given. The process for promised transfers holds for all $t \geq 0$. The growth rate of transfers is permitted to be positive, but it must be bounded to ensure that $\mu\beta < 1$. This restriction implies that transfers cannot grow faster than the steady state real interest rate. The government pays for transfers by levying lump-sum taxes and selling new one-period risk-free nominal debt, B_t.

Explosive growth in transfers implies that at some date T in the future, the economy will reach the fiscal limit, beyond which households will be unwilling to hold additional debt and the government has reached its maximum capacity to levy taxes. This is not strictly true in this endowment economy with lump-sum taxes, but it would be true in a production economy with distorting taxation, such as the model in section 3. Date T is the period at which the tax rate reaches its fiscal limit, so that $\tau_t = \tau^{\max}$ for $t \geq T$, as in (16).[9]

In the period before the economy reaches the fiscal limit, monetary policy is active and fiscal policy is passive. The rules are similar to those described in section 3,

$$R_t^{-1} = R^{-1} + \alpha \left(\frac{P_{t-1}}{P_t} - \frac{1}{\pi^*} \right), \qquad \alpha > 1/\beta \tag{21}$$

for monetary policy, where π^* is the inflation target. Fiscal policy adjusts taxes passively to the state of government debt

$$\tau_t = \tau + \gamma \left(\frac{B_{t-1}}{P_{t-1}} - b^* \right), \qquad \gamma > r = 1/\beta - 1 \tag{22}$$

where b^* is the debt target.

The government's flow budget constraint is

$$\frac{B_t}{P_t} + \tau_t = z_t + \frac{R_{t-1} B_{t-1}}{P_t} \tag{23}$$

If policy rules (21) and (22) were to remain in effect forever, the promised transfers process were stationary, and there were no fiscal limit, this economy would exhibit Ricardian equivalence, with inflation determined only by parameters describing monetary policy behavior. In particular, the solution for inflation would come from solving (20) and (21) to yield $\pi_t = \pi^*$, for all t. $R = \pi^*/\beta$ would be the steady state nominal interest rate and steady state inflation would be obtained from (20) and (21) as $\bar{\pi} = \pi^*$ But, with a non-stationary transfers process and a fiscal limit, such policy behavior, if agents believed it would remain in effect permanently, would produce an explosive path for government debt that, in finite time, would hit the fiscal limit and no equilibrium would exist. At that point, a rational expectations equilibrium requires that *some* policies adjust.

At the fiscal limit, monetary or transfers policies will adjust, with private agents *ex-ante* uncertain of which policy will do the adjusting. Agents place probability q on monetary policy switching to being passive and probability $(1-q)$ on the government reneging on the promised transfers. In particular, with probability q monetary policy switches to a pegged nominal interest rate $R_t^{-1} = R^{-1}$, $t \geq T$. With probability $(1-q)$ actual transfers are $\lambda_t z_t$, $\lambda_t \in [0, 1]$, $t \geq T$ and $(1 - \lambda_t)$ determines the extent to which the government reneges on its promised transfers.

---

[9] In expectation, setting $\tau^{\max}$ or the date T is equivalent, but specifying T is more convenient analytically.

4.1 Two Limiting Cases   Before examining the more general case where there is uncertainty about how policies will adjust in the future, we consider the two limiting cases in which $q = 0$, so government reneges on its promised transfers and monetary policy continues to be active with $\alpha\beta^{-1} > 1$, and $q = 1$, where actual transfers equal promised transfers and monetary policy converts to being passive with $\alpha = 0$ in (21).

Iterating forward on the government budget constraint and imposing both the household's transversality condition for debt accumulation and the household's Euler equation, we obtain the intertemporal equilibrium condition

$$\frac{B_0}{P_0} = E_0 \sum_{j=1}^{\infty} \beta^j s_j \tag{24}$$

where $s_t \equiv \tau_t - z_t$ is the primary surplus.

4.1.1 A Reneging Equilibrium   We begin with the case where $q = 0$, so agents expect the government eventually to renege on its promised transfers. It is convenient to derive the intertemporal equilibrium condition implied by the model and to decompose it into two expressions, one operating for $t < T$ and one for $t \geq T$. Then condition (24) is equivalent to

$$\frac{B_0}{P_0} = E_0 \sum_{j=1}^{T-1} \beta^j s_j + E_0 \beta^T \sum_{j=1}^{\infty} \beta^j s_{T+j} \tag{25}$$

For $t = 0, 1, \ldots, T-1$, tax policy obeys (22) and the government delivers on its promised transfers, so $s_t = \tau + \gamma \left(B_{t-1}/P_{t-1} - b^* \right) - z_t$, but in periods $t \geq T$, when taxes are at their limit and the government is expected to renege on its promised transfers, $s_{T+j} = \tau^{\max} - \lambda_{T+j} z_{T+j}$, $j \geq 0$. Using these surplus processes in (25) yields

$$
\begin{aligned}
\frac{B_0}{P_0} &= \sum_{j=1}^{T-1} (\beta^{-1} - \gamma)^{-j} \left(\tau - \gamma b^* - \mu^j z_0 \right) + (\beta^{-1} - \gamma)^{-(T-1)} E_0 \frac{B_{T-1}}{P_{T-1}} \\
&= \underbrace{(\tau - \gamma b^*) \sum_{j=1}^{T-1} (\beta^{-1} - \gamma)^j - \sum_{j=1}^{T-1} \left(\frac{\mu}{\beta^{-1} - \gamma} \right)^j z_0}_{\text{PV net surpluses from } t=0 \text{ to } t=T-1} \tag{26a}
\end{aligned}
$$

$$\underbrace{+ \frac{\beta}{(\beta^{-1} - \gamma)^{-(T-1)}(1 - \beta)} \tau^{\max} - (\beta^{-1} - \gamma)^{-(T-1)} E_0 \sum_{j=0}^{\infty} \beta^{j+1} \lambda_{T+j} z_{t+j}}_{\text{PV net surpluses at the fiscal limit}} \tag{26b}$$

Expression (26) decomposes the value of government debt at the initial date into the expected present value of surpluses leading up to the fiscal limit, (26a), and the expected present value of surpluses after the limit has been hit, (26b). At time 0, P_0 and $E_0 \sum_{j=1}^{\infty} \beta^j \lambda_{T+j-1} z_{t+j-1}$ are endogenous. This equilibrium condition displays what Woodford (2001) calls "Ricardian" characteristics: for any given P_0 there exists an expected present value of *actual* transfers that is consistent with equilibrium.

In the case where the probability is zero that monetary policy will switch to being passive, inflation is constant and uniquely determined in the usual way by the Taylor principle: $P_t/P_{t-1} = \pi^*$ for $t \geq 0$.

Economic behavior underlying this equilibrium is trivial. Because both taxes and transfers are lump sum, the model exhibits Ricardian equivalence. Before T, lump-sum taxes finance the actual (and promised) transfers, while from T on, the government reneges on promised transfers at just the right rate to make the fiscal policy sustainable and completely neutral. Inflation and the price level are determined entirely by monetary policy.

4.1.2 A Passive Monetary Policy Equilibrium

More interesting economic adjustments are induced in the case where $q = 1$, so that with certainty monetary policy will switch to a pegged nominal interest rate at the fiscal limit. In this case we have the usual mix of active monetary policy and passive fiscal policy—governed by rules (21) and (22)—through date $T - 1$, the period before the economy hits the fiscal limit. It is tempting to infer that during this episode the equilibrium will exhibit the characteristics that the usual mix of monetary and fiscal policies produce: inflation is entirely a monetary phenomenon and fiscal policy exhibits Ricardian equivalence. That inference is wrong, however, because it ignores the impacts on expectations in the periods leading up to T of the switch to passive monetary policy ($\alpha = 0$) and active fiscal policy ($\tau_t = \tau^{\max}$) at T.

The first part of (26), expression (26a), is unchanged, but the solution for $E_0(B_{T-1}/P_{T-1})$ now is modified in important ways. We impose that $\lambda_t \equiv 1$, so $E_0 z_{T-1} = \mu^{T-1} z_0$ and use the fact that for $t \geq T$, $s_t = \tau^{\max} - z_t$, so

$$
\begin{aligned}
\frac{B_{T-1}}{P_{T-1}} &= E_{T-1} \sum_{j=1}^{\infty} \beta^j s_{T+j-1} = E_{T-1} \sum_{j=1}^{\infty} \beta^j \left(\tau^{\max} - z_{T+j-1}\right) \\
&= \frac{\beta}{1-\beta}\tau^{\max} - \beta\mu \sum_{i=0}^{\infty} (\beta\mu)^i z_{T-1}
\end{aligned}
\tag{27}
$$

and therefore

$$
E_0 \frac{B_{T-1}}{P_{T-1}} = \frac{\beta}{1-\beta}\tau^{\max} - \beta\mu^T \sum_{i=0}^{\infty} (\beta\mu)^i z_0
\tag{28}
$$

Combining (26) and (28) yields

$$
\begin{aligned}
\frac{B_0}{P_0} &= (\beta^{-1} - \gamma)^{-(T-1)} \left[\frac{\beta}{1-\beta}\tau^{\max} - \beta\mu^T \sum_{i=0}^{\infty} (\beta\mu)^i z_0 \right] \\
&\quad + \sum_{j=1}^{T-1} (\beta^{-1} - \gamma)^{-j} (\tau - \gamma b^*) - \sum_{j=1}^{T-1} \left(\frac{\mu}{\beta^{-1} - \gamma} \right)^j z_0
\end{aligned}
\tag{29}
$$

This equilibrium condition has important implications for price level determination. The value of debt at $t = 0$ is uniquely determined by parameters describing preferences and fiscal behavior and by the exogenously realized level of transfers at that date.

Given B_0/P_0 from (29) and calling the right side of (29) b_0, use the government's flow budget constraint at $t = 0$ and the fact that $s_0 = \tau + \gamma(b_0 - b^*) - z_0$ to solve for P_0:

$$
P_0 = \frac{R_{-1} B_{-1}}{(1+\gamma)b_0 + (\tau - \gamma b^*) - z_0}
\tag{30}
$$

16

Given $R_{-1}B_{-1} > 0$, (30) yields a unique $P_0 > 0$ if $(1 + \gamma)b_0 + (\tau - \gamma b^*) - z_0 > 0$. Then the entire sequence of equilibrium $\{P_t\}$ is solved recursively: use (29) redated at $t = 1$ to obtain equilibrium b_1 and the government budget constraint at $t = 1$ to solve for P_1 using (30) redated at $t = 1$, and so forth.

In this environment where the equilibrium price level is determined entirely by fiscal considerations through its interest rate policy, monetary policy determines the expected inflation rate. Combining (20) with (21) we obtain an expression in inflation

$$E_t\left(\frac{P_t}{P_{t+1}}\right) = \alpha\beta^{-1}\left(\frac{P_{t-1}}{P_t}\right) + (\beta R)^{-1} - \alpha\beta^{-1}\frac{1}{\pi^*} \tag{31}$$

where

$$\alpha \begin{cases} > \beta^{-1}, & t = 0, 1, \ldots, T-1 \\ = 0, & t = T, T+1, \ldots \end{cases} \tag{32}$$

As argued above, the equilibrium price level sequence, $\{P_t\}_{t=0}^{\infty}$ is determined by versions of (29) and (30) for each date t, so (31) describes the evolution of expected inflation. Given equilibrium P_0 from (30) and an arbitrary P_{-1}—arbitrary because the economy starts at $t = 0$ and cannot possibly determine P_{-1}, regardless of policy behavior—(31) shows that $E_0(P_0/P_1)$ grows relative to the initial inflation rate. In fact, throughout the active monetary policy/passive fiscal policy phase, for $t = 0, 1, \ldots, T-1$, expected inflation grows at the rate $\alpha\beta^{-1} > 1$.[10] In periods $t \geq T$ monetary policy pegs the nominal interest rate at R, and expected inflation is constant: $E_t(P_t/P_{t+1}) = (R\beta)^{-1}$.

4.2 Policy Uncertainty and the Fiscal Limit As demonstrated by figure 3, there are two additional layers of uncertainty in the model described in section 3. We can introduce uncertainty in policy once the fiscal limit has been reached (red ball) by examining a simple three-period model. The timing is as follows: In the initial period ($t = 1$), the fiscal limit has not been reached, transfers follow the non-stationary process (14), monetary policy is active and fiscal policy passive. This is equivalent to the time period $t = 0, \ldots T-1$ in the previous setup. At the beginning of period two ($t = 2$), the fiscal limit is reached but agents remain uncertain about which policy will adjust. This uncertainty is resolved at the end of period 2. In period 3, there is no uncertainty about policy and therefore, period 3 is completely analogous to the previous setup for $t = T \ldots, \infty$.

At $t = 1$, we have

$$R^{-1} - \alpha\pi^{*-1} = \beta E_1\left(\frac{P_1}{P_2}\right) - \alpha\left(\frac{P_0}{P_1}\right) \tag{33}$$

$$\frac{B_1}{P_1} + \tau + \gamma\left(\frac{B_0}{P_0} - b^*\right) = z_1 + \frac{R_0 B_0}{P_1} \tag{34}$$

where (33) comes from the Euler equation (20) and monetary policy rule (21), while (34) comes from the government's budget constraint and fiscal policy rule.

---

[10]This result is reminiscent of Loyo's (1999) analysis of Brazilian monetary-fiscal interactions in the 1980s.

Agents know that in the next period ($t = 2$) the fiscal limit will be reached and policy will switch to either a passive monetary/active transfers regime with probability q, or an active monetary/passive transfers regime with probability $(1 - q)$. The conditional probability distribution of these policies is given by

$$\begin{cases} q & R_2^{-1} = R^{-1}, & z_2 = \mu z_1 + \varepsilon_2 \\ (1 - q) & R_2^{-1} = R^{-1} + \alpha(\pi_2^{-1} - \pi^{*-1}), & \lambda_2 z_2 = \lambda_2 \mu z_1 + \lambda_2 \varepsilon_2 \end{cases}$$

The equivalent of (33) and (34) are now

$$qR^{-1} + (1 - q)[R^{-1} - \alpha\pi^{*-1}] = \beta E_2\left(\frac{P_2}{P_3}\right) - (1 - q)\alpha\left(\frac{P_1}{P_2}\right) \tag{35}$$

$$\frac{B_2}{P_2} + \tau^{\max} = z_2[q + (1 - q)\lambda_2] + \frac{R_1 B_1}{P_2} \tag{36}$$

In period 3, we assume that $\tau^{\max}$ is set such that debt is completely retired ($B_3 = 0$) no matter which policy regime is realized in period 2. This corresponds to $\tau^{\max} = \delta z_3 + (R_2 B_2)/P_3$, where $\delta = 1$ if the economy is in the passive monetary/active transfers regime and $\delta = \lambda_3$ if active monetary/passive transfer regime is realized. This assumption implies that agents know one period in advance which policy will be in place in the final period.

Substituting (35) into (33), and (36) into (34), and imposing the Euler equation gives

$$E_1(P_2/P_3) = \frac{\alpha^2(1 - q)}{\beta^2}(P_0/P_1) + \frac{1}{\beta}\left(R^{-1} - \alpha(1 - q)\pi^{*-1}\right) + \frac{\alpha(1 - q)}{\beta^2}\left(R^{-1} - \pi^{*-1}\right) \tag{37}$$

$$\frac{B_0}{P_0} = (\beta^{-1} - \gamma)^{-1}E_0\{\tau - \gamma b^* - z_1 + \beta(\tau^{\max} - z_2[q + (1 - q)\lambda_2])$$
$$+ \beta^2(\tau^{\max} - z_3[q + (1 - q)\lambda_3])\} \tag{38}$$

The expectational effects associated with switching policies can be seen in (37) and (38). Equation (38) shows that the value of debt is still determined by the discounted expected value of net surpluses. The difference here is that the actual surplus is conditional on the realized policy regime. Conditional on time $t = 0$ information, the expected transfers process in period 2 and 3 is unknown (even though the uncertainty is resolved at the end of period 2). If $q \in (0, 1)$ and at the end of period two monetary policy is set to the passive regime, then agents will be "surprised" by amount $z_2(1 - q)(1 - \lambda_2)$ in period 2 and by amount $z_3(1 - q)(1 - \lambda_3)$ in period 3, and debt will be revalued accordingly. This surprise acts as an innovation to the agent's information set due to policy uncertainty. Naturally, as the agent puts high probability on this regime occurring ($q \approx 1$) or assumes the amount of reneging is small ($\lambda_2, \lambda_3 \approx 1$), the surprise is also small, and vice versa.

Comparing (37) with (31), notice that expected inflation in period 1 now depends upon q. This is true even though the monetary policy regime is active in period 1. The previous model demonstrated that monetary policy alone cannot uniquely determine the price level. With policy uncertainty, monetary policy cannot uniquely determine *expected* inflation. If agents put high probability on the passive monetary policy, active transfers policy regime ($q \approx 1$), then expected inflation at the beginning of period 2 will be primarily pinned down by the nominal peg. This result is irrespective of the actual policy regime announced at the

end of period 2. It is in this sense that expectational effects about policy uncertainty can dramatically alter equilibrium outcomes.

In this simple setup, these expectational effects are limited in magnitude because agents know precisely when the fiscal limit is reached. The additional level of uncertainty not examined in these simple models but present in the main model, is the randomness in hitting the fiscal limit as given by (17). In this environment, the conditional probability of switching policies outlined above would contain an additional term specifying the conditional probability of hitting the fiscal limit in that period. This implies that, because there is positive probability of hitting the fiscal limit in *every* period up to T, these expectational effects will be present from $t = 0, ..., T$ and will gradually become more important as the probability of hitting the fiscal limit increases. In effect, the endogenous probability of hitting the fiscal limit makes the probability q time varying.

5 Numerical Solution and Results

We solve the model laid out and calibrated in section 3 using a nonlinear algorithm called the monotone path method. That method discretizes the state space and finds a fixed point in decision-rules for each point in the state space.

This section reports results from the numerical solution in three forms. First, we show the transitional dynamics of the model for a particular realization of monetary-tax-transfers regimes. These dynamics highlight the critical role that expectations of future policies play in determining equilibrium. Second, we display the decision rules that underlie those transitional dynamics. Non-linearities are very important for the solution, and the decision rules highlight where the important non-linearities appear. Finally, we perform a Monte Carlo exercise, taking draws from policy regimes according to the Markov processes described in section 3. This exercise yields the stationary distribution of the economy.

5.1 Transition Paths   To understand the economic mechanisms at work, it is useful to condition on a particular realization of policy regimes and trace out how the equilibrium evolves following each type of regime change. Although in this counterfactual exercise we treat regimes as absorbing states, in the equilibria we study, agents form expectations based on the true probability distributions for policy regimes, as described in sections 3.3 and 3.4, and their decision rules embed those expectations. Expectations about policy regimes in the future can have strong effects on behavior in the prevailing regime. Because agents form expectations rationally, the counterfactual allows us to back out the expectational effects, which are reflected in sequences of forecast errors—policy surprises—that generate the dynamic adjustments along the transition paths. Realized policy regimes produce "shocks" to which agents in the model respond.[11] One cautionary note: because these counterfactuals impose regime changes at arbitrary dates, rather than at dates governed by the underlying Markov processes, the counterfactuals are most useful for understanding qualitative features of the equilibrium. Quantitative features are discussed in the Monte Carlo exercise in section 5.3.

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[11]These are *not* identical to impulse response functions used to study linear models. In linear models, impulse response functions show the response of the economy to a one-time *i.i.d.* shock, with the path following the shocks being deterministic. In contrast, our counterfactuals create a sequence of shocks arising from what agents perceive to be surprise realizations of policy regimes.
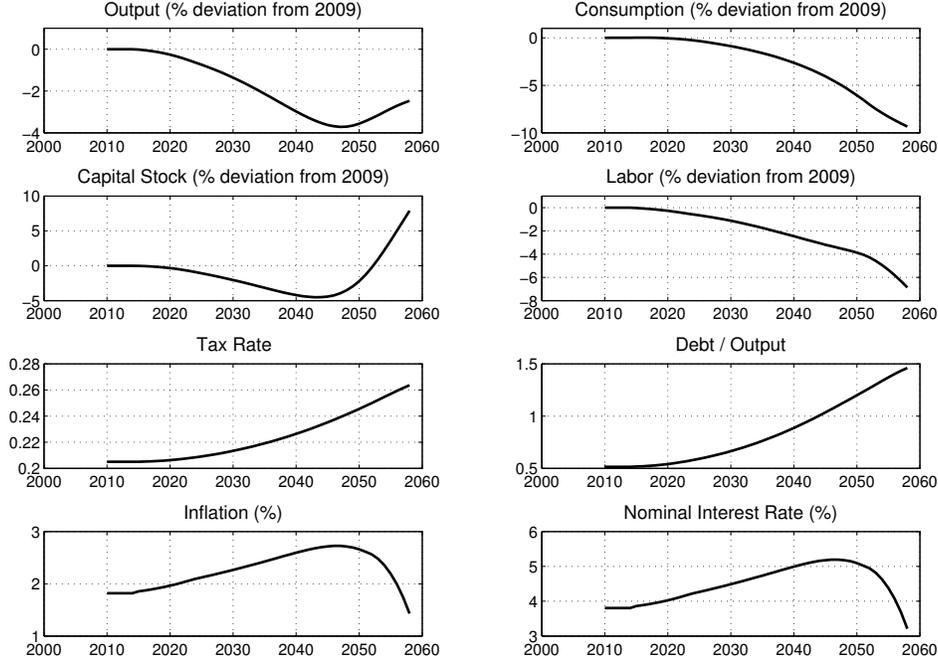
Figure 4: Transition paths conditional on remaining in the regime with active monetary, passive tax, and active transfers policies so the economy does not hit the fiscal limit.

5.1.1 Active Monetary, Passive Tax, and Active Transfers Policies

We imagine that the economy starts in 2010 in a regime characterized by active monetary policy, passive tax policy, and active (stationary) transfers policy and then randomly switches in 2015 to an identical regime, but where transfers follow the non-stationary process ($S_{z,t} = 2$ in expression (14)). When transfers policy is active, the government makes good on its promised path of transfer payments. The first set of transition paths, shown in figure 4, condition on staying in the latter regime throughout the simulation. Time paths for output, consumption, the capital stock, and labor are measured as percentage deviations from their 2009 levels.

Rising debt and the resulting rising tax rates are the dominant forces in this scenario. Steadily rising current and expected tax rates shift labor supply in, reducing hours worked, and discourage investment, reducing the capital stock below its 2009 steady-state level. Both consumption and output also decline. As the tax rate rises, however, the probability of hitting the fiscal limit and switching to other policies also rises, according to the logistic function in (17).

The likelihood of moving to other regimes creates two expectational effects. First, while the date at which the fiscal limit is hit is uncertain, agents know that at the limit the tax rate will be permanently fixed at $\tau_t = \tau^{\max}$, which in the simulation is 0.2425. When the current rate exceeds $\tau^{\max}$, agents expect *lower* rates in the future. Lower expected rates raise the expected return to capital, raising capital accumulation at the expense of consumption. This effect, however, does not kick in until about 2045 or later. Along the entire transition path, because tax policy is forced to remain passive while agents put probability on hitting the limit, agents are surprised at how high taxes are, which is why labor declines persistently.

20

The second expectational effect begins much sooner. Inflation rises in either of the two future regimes to which the economy moves after the fiscal limit. This creates higher expected inflation which has effects almost immediately, although they are small. Inflation in the model has two sources: higher expected inflation and higher real marginal costs.[12] Marginal cost in the model depends on the ratio of each factor price to its marginal product. Over the horizon that inflation is rising in figure 4, real marginal cost is falling very gradually, which would tend to lower inflation, implying that expected inflation drives the steady rise in actual inflation. Although some of the increase in inflation is expected, over the period when inflation rises, agents are continually surprised by inflation.

This expected inflation effect is a more sophisticated version of the phenomenon that section 4.2 highlights. In the analytical example, as the expressions (37) and (38) make clear, both expected and actual inflation are affects by q, the probability of switching to the passive monetary/active tax/active transfers regime. In figure 4 the steady rise in inflation is driven by the steady rise in the probability of hitting the fiscal limit and switching to one of the other two regimes. A time-varying probability of reaching the fiscal limit translates directly into time-varying expected inflation.

Despite the sequence of positive inflation surprises before 2045, nominal government debt does not get revalued and stabilized. Active monetary policy prevents revaluation by adjusting the nominal interest rate more than one-for-one with inflation. In periods of rising (surprise) inflation, monetary policy effectively raises nominal debt service by more than the inflation rate, ensuring continued growth in debt.

The upturn in the capital stock that begins in 2045 is also driven by two distinct expectational effects. As mentioned, one is the expectation of lower tax rates in the future. Another expectational effect derives from the possibility of switching to the regime in which the government does not fully honor its promised transfers. Lower expected transfers encourage savings in the form of capital accumulation. A higher capital stock reduces its marginal product sufficiently that real marginal costs begin to decline. Although expected inflation continues to rise, the falling marginal costs dominate, bring inflation down quickly.

From figure 4 emerges a central message of the paper: in an environment in which fiscal policy is unwilling or unable to stabilize debt, monetary policy cannot successfully target inflation.[13] The active monetary policy regime that prevails along the transition path responds aggressively to inflation with the aim of hitting a 2 percent inflation target. For over four decades it misses the target on the high side and then it misses the target on the low side. Both misses are due to expectational effects that are beyond control of the monetary authority in the current regime. Monetary policy loses control of inflation in an extreme form: it cannot control either actual or expected inflation, even though it is hawkishly targeting inflation.

5.1.2 Active Monetary, Active Tax, and Passive Transfers Policies

This scenario and the next arise after the economy hits the fiscal limit in year 2047 and tax rates are permanently set at $\tau^{\max}$. In terms of the analytical model of section 4, the random

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[12]This is a fundamental feature of the class of new Keynesian models produced with either Rotemberg (1982) or Calvo (1983) pricing.

[13]This is also the theme of much of the literature on the fiscal theory of the price level [for example, Woodford (2001), Sims (2005), and Cochrane (2009)].
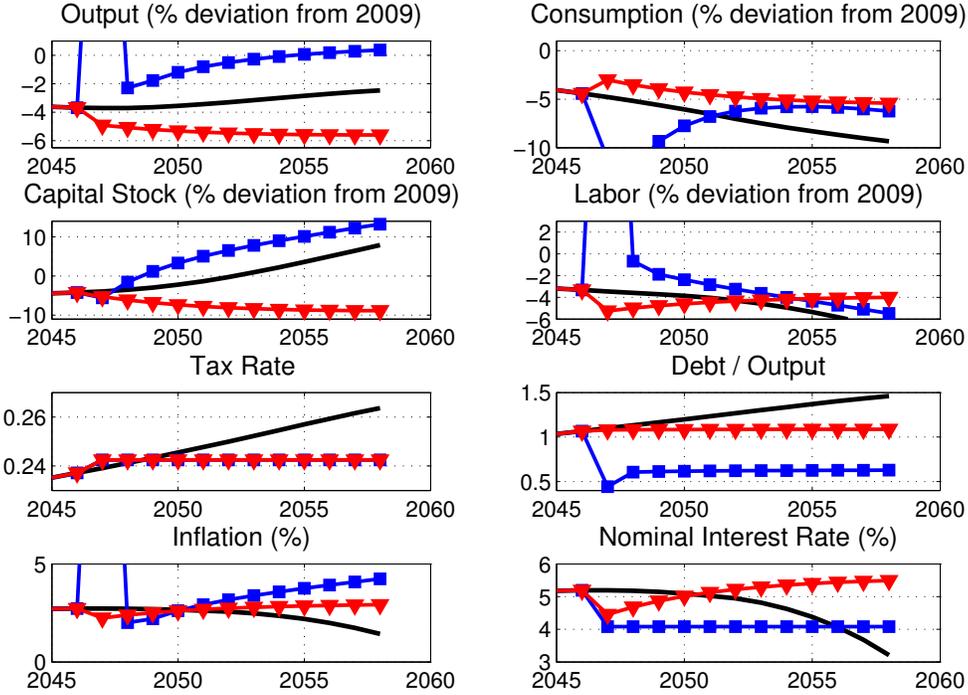
Figure 5: Transition paths for other two regimes superimposed on paths conditional on active monetary, passive tax, and active transfers policies. Active monetary/passive tax/active transfers policies are solid lines; passive monetary/active tax/active transfers policies outcomes are marked by squares; active monetary/active tax/passive transfers policies outcomes are marked by triangles. Large spikes in output, consumption, and inflation in the passive monetary/active tax/active transfers policies regime are truncated.

variable q has been realized as either 0 or 1, but in the numerical solution the economy does not then enter an absorbing state, as the two regimes recur randomly.

Leading up to 2047 the path of the economy is identical to that discussed in section 5.1.1. From 2047 on, tax policy is active—unresponsive to debt—and in the current scenario monetary policy continues to target inflation, while transfers policy passively adjusts to stabilize debt. Debt is stabilized when the government's delivered transfers are only a fraction, λ_t, of promised transfers, z_t.[14] Transition paths for this policy regime appear in figure 5. The figure shows paths from 2045 on and repeats the paths in figure 4, solid lines, for comparison. The active monetary/active tax/passive transfers regime outcomes appear as triangles.

When the passive transfers policy is realized, the tax rate is below the fiscal limit, so τ_t jumps immediately to $\tau^{\max}$, creating a surprise increase in the tax rate. This causes a sharp

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[14]Because transfers are lump-sum and λ_t is endogenous, there is a fundamental indeterminacy between the value of debt at the fiscal limit and the present value of $\lambda_t z_t$. Given the process for z_t, for each sequence of $\{\lambda_t \in [0,1]\}_{t=T}^{\infty}$, there is a corresponding value of debt at the limit, B_T/P_T. We resolve this indeterminacy by assuming that $B_t/P_t = b^{\max}$ for $t \geq T$ in the passive transfers regime.
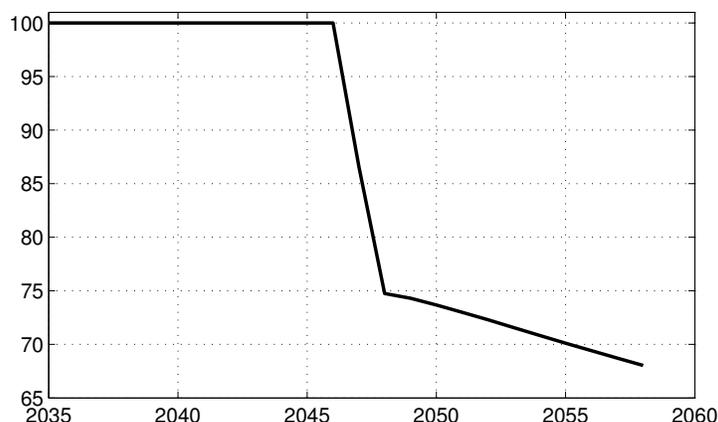
Figure 6: Realized path of λ_t, the percentage of promised transfers that is honored, associated with the counterfactual exercise in figure 5, which is conditional on active monetary, active tax, and passive transfers policies.

reduction in labor supply, hours worked, and output.[15] Passive transfers implies that the government does not fulfill its promises on transfer payments, as figure 6 shows. The shock of the regime change drives actual transfers to 75 percent of promised and then the fraction smoothly declines as the passive transfers regime continues to be in effect.

Regime change produces an unexpected drop in inflation, as agents had put a 50 percent chance on going to the passive monetary regime in which inflation is higher. Active monetary policy reacts to the drop in inflation by sharply lowering the nominal and the *ex-ante* real interest rates [figure 7]. Despite the decline in output, lower real rates raise consumption. As inflation gradually rises, the real interest rises, and consumption smoothly declines. Gradually rising inflation stems from agents' beliefs that a switch to passive monetary policy—and the jump in inflation that it engenders—remains a possibility. Even though the passive transfers regime is far more persistent (expected duration of 100 years) than is the passive monetary regime (expected duration of 10 years), as we see below, the jump in inflation that passive monetary policy produces is sufficiently large that its impacts spill into the regime with active monetary and passive transfers policies. Once again we see that the possibility that exploding promised transfers will be realized—coupled with active monetary policy—prevents the central bank from effectively targeting inflation.

5.1.3 Passive Monetary, Active Tax, and Active Transfers Policies   The final scenario has the government delivering on its promised transfers—active policy—while monetary policy abandons its effort to target inflation, reverting instead to pegging the nominal interest rate—passive monetary policy. In this regime, although promised transfers are currently being honored, agents place substantial probability on moving to the regime in which the government will renege. In anticipation of that reneging, agents increase savings dramatically, raising the capital stock well above even its initial 2009 level [marked by squares in figure 5]. The initial jump in the *ex-ante* real interest rate creates the incentive to increase investment [dashed line in figure 7].

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[15]The setting of τ^{max} is an obvious candidate for sensitivity analysis. If at the time of the regime change the tax rate were above τ^{max}, the opposite chain of reactions would occur.
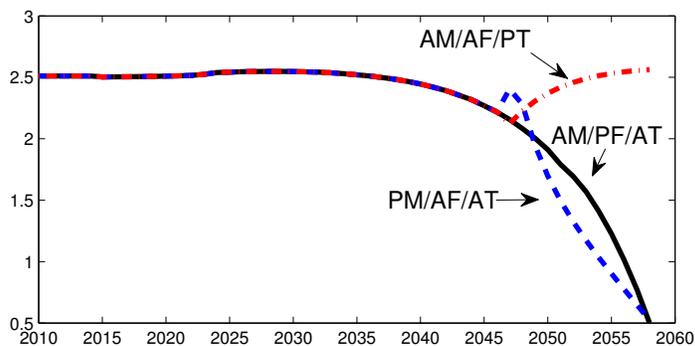
Figure 7: Ex-ante real interest rates in the three regimes. Active monetary/passive tax/active transfers policies are solid line; passive monetary/active tax/active transfers policies are dashed lines; active monetary/active tax/passive transfers policies are dotted-dashed lines.

At the time of the regime change there is a huge spike in inflation triggered by a sharp downward revision in the expected present value of primary surpluses. Agents had put 50 percent probability on the passive transfers regime, but the realization of active transfers causes them to revise downward their view of future surpluses. At the price level in place before the regime change, the real value of outstanding nominal debt is now too high to be supported by the new view of the surplus path. This creates a jump in aggregate demand—debt is initially overvalued so households seek to reduce their debt holdings—which raises labor demand, hours worked, output, and inflation. Costly price adjustment, however, more than absorbs the additional output, so both investment and consumption fall in the year of the regime change.[16]

Each period that policy remains in the passive monetary/active transfers regime, transfers are unexpectedly high, relative to the expectation of switching to the more persistent active monetary/passive transfers regime, another example of how expectations formation effects flow across regimes. These surprises create a sequence of positive forecast errors in inflation which steadily raise the inflation rate and, with monetary policy pegging the nominal interest rate, reduces *ex-post* real interest rates. Lower debt service helps to stabilize government debt.

Based on the analytical results in section 4.1, it might seem that this combination of passive monetary/active transfers policies, if it persisted indefinitely, could stabilize debt. That outcome, though, relies on the real interest rate being exogenous. In the more sophisticated model, capital accumulation drives down the real interest rate—see figure 7—which raises the expected present value of the already explosive transfers process. A higher expected present value of transfers, in turn, raises the expected rate of reneging in the active monetary/passive transfers regime to which agents are expecting to transit in the future. But lower expected future transfers encourages still more capital accumulation and the process repeats. The presence of expectations formation effects, stemming from the prospect of

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[16]Introduction of long-term nominal government bonds, along the lines of Cochrane (2001), would mitigate these extreme one-time jumps. Long-term bond prices would drop sharply instead, creating a higher path of expected inflation and smoothing out the discrete shifts appearing in 5.

the government possibly reneging on promised transfers, makes the passive monetary/active transfers regime unsustainable in the long run.[17]

In this regime, as in the past two, monetary policy continues to lose control of inflation. As figure 7 shows, the *ex-ante* real interest rate falls steadily after its initial jump at the time of the regime change. At the same time, though, monetary policy is pegging the nominal interest rate. Expected inflation must be rising. The combination of passive monetary policy with an explosive promised—and honored—transfers process implies that monetary policy not only cannot control *actual* inflation, but the interest rate peg also fails to control *expected* inflation.

5.2 Decision Rules   [to be written]

5.3 Stationary Distribution of the Economy   Figure 8 plots the 10 and 25 percentiles bands (dashed lines) and 75 and 90 percentiles bands (solid lines) of time paths of variables in the stationary distribution of the economy. The economy was simulated using 10,000 draws, assuming period 0 (2009) is the zero-shock steady state, stationary transfer regime. The draws represent percentage deviations from the steady state distribution over time. At each date, the figure depicts the cross-sectional distribution of the variables. Several findings emerge.

First, the dispersion in the distribution and the deviation from 2009 levels is very small for the first 10 years (from 2010–2020) for all variables. This result is not entirely inconsistent with CBO projections [Congressional Budget Office (2009a)] and figure 2. According to the CBO, the recovery of the economy and the corresponding increase in tax revenue, coupled with the reduction in non-interest government spending to pre-financial crisis levels (see figure 1), stabilizes debt over the short term. However, the mechanism operating in our model is quite different. While there is always a chance of hitting the fiscal limit, the probability of doing so is very small initially (2 percent) and increases only gradually. Agents know that while the process for transfers is unsustainable and a policy adjustment must occur in the future, the future is sufficiently far enough away that the expectational effects associated with policy uncertainty are heavily discounted. This result is, of course, very sensitive to the parameter values of the model. An increase in either the initial probability of hitting the fiscal limit or a steepening of the logistic function so that this probability increases at a faster rate over time, will change this result quantitatively. But qualitatively, the initial impact of "unfunded liabilities" will be small relative to the effects several decades out.

Related to this point, figure 8 shows that the debt/output ratio never reaches 150 percent at any point in time, even for the 90th percentile band. This result is in stark contrast to CBO projections in figure 2, where the debt-output ratio reaches a maximum of well over 700 percent. As emphasized in the introduction, the notion of "unfunded liabilities" is inconsistent with a rational expectations equilibrium. Debt, or, equivalently, primary surpluses, cannot grow exponentially *in expectation*. Assuming that policies adjust to ensure a stationary equilibrium places an upper bound on the debt-output ratio, but quantitatively the upper bound for our calibration only puts the debt-output ratio slightly above that after

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[17]If, however, passive monetary/active transfers were an absorbing state, then the expectations formation effects would disappear and the policy mix could be sustained with steadily rising inflation and the expected inflation rate being driven by the growth rate of expected transfers, μ.
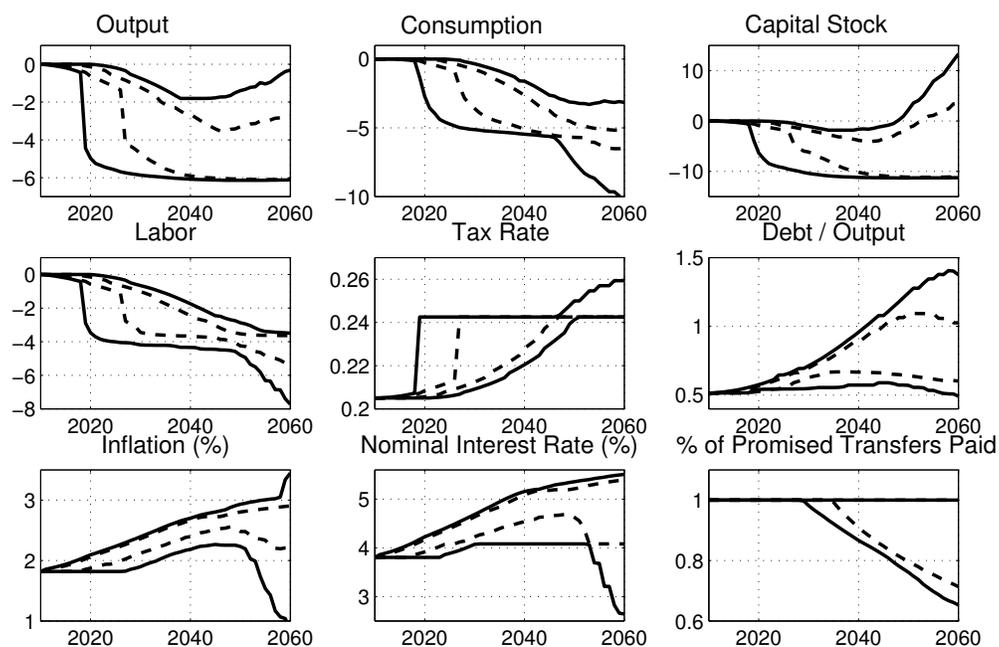
Figure 8: Stationary distribution of model variables from Monte Carlo simulation taking draws from policy regimes. Dashed lines are 25 and 75 percentile bands; solid lines are 10 and 90 percentile bands. Output, consumption, capital stock, and labor are percentage deviations from their 2009 levels. Draws represent percentage deviations from steady state. Based on 10,000 draws.

World War II. Moreover, and quite importantly, this ratio is achieved without a large amount of reneging on promised transfers. Figure 8 shows that most of the probability mass for the promised transfers paid out is greater than 0.8 for the entire time horizon, and there is no reneging at any percentile until 2030. As shown in figure 1, the calibrated distribution for non-stationary transfers roughly matches the projection of the CBO, and assumes real transfers per capita grow at 1 percent per year. Even after the fiscal limit is reached, our model allows for the possibility that promised transfers be paid in full for some time, assuming that monetary policy becomes passive. This mechanism adds an important dimension of reality to the model as policymakers may be reluctant to change popular entitlement programs and avoid the political "third rail." This mechanism explains why the percentage of promised transfers paid is so high.

Finally, the monte carlo exercise makes clear the time-varying uncertainty facing the economic agents and the wide range of possible equilibrium outcomes. For example, figure 8 shows that the capital stock may rise or fall over time. An increase in the capital stock is explained by a negative wealth effect operating through *expected* rengeing on transfers. As the probability of hitting the fiscal limit increases, there is an increase in the probability of the reneging regime becoming reality. A precautionary savings result ensues as agents save dramatically to offset the expected decline in transfers. The negative response of capital that shows up as early as 2020 is due to the distorting effects of taxes. Draws of the tax rate in the 90th percentile spike to $\tau^{\max}$ prior to 2020 because the economy has hit the fiscal limit. This "early" and persistent jump in the tax rate has the usual strong and negative impact on capital formation.

6 Concluding Remarks

A key element of our analysis, and of any reasonable analysis, of these looming fiscal issues is that future policy is marked by tremendous uncertainty. By taking a stand on the nature of that uncertainty, this paper shows that it is possible to use a rational expectations equilibrium to try to understand how these large fiscal issues will impact the macro economy. This is the paper's primary contribution.

To produce the numerical results we report, we have had to specify parameters describing private and policy behavior. Results are highly sensitive to those parameter settings. The framework the paper develops, however, is general and sufficiently flexible to accommodate alternative specifications on private behavior and the potential range and nature of policy adjustments in the future.

Despite the specificity of the stands we have taken, we are comfortable drawing some broad conclusions:

1. Although the looming fiscal issues are large, they may not produce the "end-of-the-world" scenarios that some commentators have suggested. For example, although in this environment monetary policy can no longer achieve its inflation target, there is no reason to expect a prolonged period of hyperinflation or even extremely high inflation. While it is true that private consumption falls over the coming decades, GDP may not be much lower, and the capital stock could even grow. In such an equilibrium, the degree to which the government reneges on its promised transfers could be quite moderate.

2. Uncertainty about future policies pushes many of the adjustments of the economy into the future, smoothing out adjustments that take place in the near term. Resolving that uncertainty is likely to bring effects forward in time.

3. When government spending policies push tax policy to the fiscal limit—whether that limit be economic or political—monetary policy loses control of inflation. Analyses of monetary policy going forward must come to terms with this reality.

We have considered only a small set of possible policy scenarios. Many other scenarios are possible. It is a worthwhile research program to examine other scenarios and trace out their likely consequences for the macro economy.

This paper has performed no welfare analysis, but the framework certainly points toward a research program that aims to design and evaluate monetary and fiscal rules that can both cope with the coming fiscal issues and reduce uncertainty about future policy. Of course, the political process—like research economists—must ultimately take a stand on how to resolve America's fiscal problems.

A Details About Figures 1 and 2

A.1 Congressional Budget Office Projections   Figure 2 plots the actual and projected debt-to-GDP ratio from 1790 through 2083. The dashed lines represent CBO projections [Congressional Budget Office (2009b)] under two scenarios—the Alternative Fiscal Financing (AF) and Extended-Baseline scenario (EB). The difference between the two forecasts is that the EB projection assumes current law does not change, while the AF allows for "policy changes that are widely expected to occur and that policymakers have regularly made in the past," [Congressional Budget Office (2009b)]. The prominent changes include: [i] assuming the expiring tax provisions in the Economic Growth and Tax Relief Reconciliation Act of 2001 and the Jobs and Growth Tax Relief Reconciliation Act of 2003 will be extended beyond 2010; [ii] assuming the Alternative Minimum Tax will be indexed to inflation;[18] [iii] assuming physician payment rates under Medicare will grow at the same rate as the Medicare economic index.[19] Federal interest payments, which already exceed 1 percent of GDP, would rise to 2.6 percent by 2020 and 12.9 percent by 2083 under the EB, and 3.9 percent by 2020 and 32.5 percent by 2083 under the AF.

The driving force behind the run-up in debt is a substantial increase in the three entitlement programs—Medicare, Medicaid and Social Security. Figure 1 decomposes federal spending into Social Security, Medicare and Medicaid, and other non-interest spending from 1962 through 2083 using CBO projections under the Extended-Baseline scenario.[20] Assuming no change in current law, the CBO predicts that federal spending on Medicare and Medicaid combined will grow from roughly 5 percent of GDP today to almost 10 percent by 2035 and to more than 17 percent by 2080 [Congressional Budget Office (2009b)]. As depicted in figure 1, the projected change in Social Security is roughly constant at 6 percent of GDP throughout the forecast horizon. The CBO predicts that the 2008 and 2009 stimulus spending to stabilize the economy is temporary and that other federal non-interest spending will level off at 10 percent of GDP. The CBO also predicts that under current law revenues will grow only slightly faster than the economy and will remain around historical levels of 18–20 percent of GDP. As is evident from figure 1, the majority of the growth in federal expenditures is due to increasing expenditures for Medicare and Medicaid. According to CBO estimates, the increase in spending for Medicare and Medicaid as a share of GDP will account for 80 percent of all of federal non-interest spending increases between now and 2040, and nearly 90 percent of spending growth between now and 2080.

B Numerical Solution Method

[to be written]

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[18]If the Alternative Minimum Tax (AMT) is not indexed to inflation, then by 2080, 75 percent of U.S. households will be subject to the AMT. Currently, this number is less than 3 percent.

[19]Current law stipulates that Medicare payment rates for physicians will fall by 21 percent in 2010 and continue to fall 4 percent annually for the next few years. However, Congress has acted to prevent similar reductions in pay rates since 2003.

[20]Federal spending on Medicare and Medicaid is net of premiums paid by Medicare beneficiaries and net of amounts paid by the states.

References

ABEL, A., AND O. BLANCHARD (1983): "An intertemporal equilibrium model of saving and investment," *Econometrica*, 51(3), 675–692.

AIZENMAN, J., AND N. MARION (1993): "Policy Uncertainty, Persistence and Growth," *Review of International Economics*, 1(2), 145–163.

ALTIG, D., A. AUERBACH, L. KOTLIKOFF, K. SMETTERS, AND J. WALLISER (2001): "Simulating fundamental tax reform in the United States," *American Economic Review*, 91(3), 574–595.

AUERBACH, A., AND K. HASSETT (2001): "Uncertainty and the design of long-run fiscal policy," *Demographic Change and Fiscal Policy*, pp. 73–92.

AUERBACH, A., AND K. HASSETT (2002a): "Fiscal policy and uncertainty," *International Finance*, 5(2), 229–249.

AUERBACH, A., AND K. HASSETT (2007): "Optimal long-run fiscal policy: Constraints, Preferences and the Resolution of Uncertainty," *Journal of Economic Dynamics and Control*, 31(5), 1451–1472.

AUERBACH, A., AND L. KOTLIKOFF (1987): *Dynamic fiscal policy*. Cambridge University Press.

AUERBACH, A. J., J. GOKHALE, AND L. J. KOTLIKOFF (1994): "Generational Accounting: A Meaningful Way to Evaluate Fiscal Policy," *Journal of Economic Perspectives*, 8(1), 73–94.

———— (1995): "Restoring Generational Balance in U.S. Fiscal Policy: What Will It Take?," *Federal Reserve Bank of Cleveland*, 31(1), 3–12.

AUERBACH, A. J., AND K. HASSETT (2002b): "Tax Policy and Business Fixed Investment in the United States," *Journal of Public Economics*, 47, 141–170.

AUERBACH, A. J., AND L. J. KOTILIKOFF (1987): *Dynamic Fiscal Policy*. Cambridge University Press, Cambridge, M.A.

BECKER, R. (1985): "Capital income taxation and perfect foresight," *Journal of Public Economics*, 26, 147–167.

BERNANKE, B. (1983): "Irreversibility, uncertainty, and cyclical investment," *The Quarterly Journal of Economics*, 98(1), 85–106.

BIZER, D., AND K. JUDD (1989): "Taxation and uncertainty," *The American Economic Review*, 79(2), 331–336.

BROCK, W., AND S. TURNOVSKY (1981): "The analysis of macroeconomic policies in perfect foresight equilibrium," *International Economic Review*, 22(1), 179–209.

Brunetti, A., and B. Weder (1998): "Investment and institutional uncertainty: a comparative study of different uncertainty measures," *Review of World Economics*, 134(3), 513–533.

Bryant, R. C. (2004): "Demographic Pressures on Public Pension Systems and Government Budget in Open Economies," Manuscript, The Brookings Institution.

Calvo, G. A. (1983): "Staggered Prices in a Utility Maximizing Model," *Journal of Monetary Economics*, 12(3), 383–398.

Chari, V. V., P. J. Kehoe, and E. R. McGrattan (2000): "Sticky Price Models of the Business Cycle: Can the Contract Multiplier Solve the Persistence Problem?," *Econometrica*, 68(5), 1151–1179.

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

———— (2009): "Understanding Fiscal and Monetary Policy in 2008-2009," Manuscript, University of Chicago.

Congressional Budget Office (2002): *A 125-Year Picture of the Federal Government's Share of the Economy, 1950 to 2075*. CBO, Washington, D.C.

———— (2009a): *An Analysis of the President's Budgetary Proposals for Fiscal Year 2010*. CBO, Washington, D.C., June.

———— (2009b): *The Long-Term Budget Outlook*. CBO, Washington, D.C., June.

Cooley, T., and J. Soares (1999): "A positive theory of social security based on reputation," *Journal of Political Economy*, 107(1), 135–160.

Davig, T., and E. M. Leeper (2006): "Fluctuating Macro Policies and the Fiscal Theory," in *NBER Macroeconomics Annual 2006*, ed. by D. Acemoglu, K. Rogoff, and M. Woodford, pp. 247–298. MIT Press, Cambridge.

———— (2007): "Generalizing the Taylor Principle," *American Economic Review*, 97(3), 607–635.

De Nardi, M., S. İmrohoroğlu, and T. Sargent (1999): "Projected US demographics and social security," *Review of Economic Dynamics*, 2(3), 575–615.

Dixit, A. (1989): "Entry and exit decisions under uncertainty," *Journal of Political Economy*, 97(3), 620.

Domar, E., and R. Musgrave (1944): "Proportional income taxation and risk-taking," *The Quarterly Journal of Economics*, 58(3), 388–422.

Dotsey, M. (1990): "The economic effects of production taxes in a stochastic growth model," *American Economic Review*, 80(5), 1168–1182.

Feldstein, M. (1969): "The effects of taxation on risk taking," *The Journal of Political Economy*, pp. 755–764.

Hall, R. (1971): "The dynamic effects of fiscal policy in an economy with foresight," *The Review of Economic Studies*, 38(2), 229–244.

Hassett, K., and G. Metcalf (1999): "Investment with uncertain tax policy: does random tax policy discourage investment?," *The Economic Journal*, 109(457), 372–393.

Hopenhayn, H. (1996): "Policy variability and economic growth," *The Review of Economic Studies*, 63(4), 611–625.

Huggett, M., and G. Ventura (1999): "On the distributional effects of social security reform," *Review of Economic Dynamics*, 2(3), 498–531.

İmrohoroğlu, A., S. İmrohoroğlu, and D. Joines (1995): "A life cycle analysis of social security," *Economic Theory*, 6(1), 83–114.

————— (1999): "Social security in an overlapping generations economy with land," *Review of Economic Dynamics*, 2(3), 638–665.

Kotlikoff, L., K. Smetters, and J. Walliser (1997): "The economic impact of privatizing social security," *Redesigning social security*, p. 327.

Kotlikoff, L., K. Smetters, and J. Walliser (1998): "Social security: privatization and progressivity," *The American Economic Review*, 88(2), 137–141.

Kotlikoff, L., K. Smetters, and J. Walliser (2001): "Distributional effects in a general equilibrium analysis of social security," *M. Feldstein and J. Liebman, The Distributional Effects of Social Security Reform, forthcoming*.

Kotlikoff, L., K. Smetters, and J. Walliser (2007): "Mitigating America's demographic dilemma by pre-funding social security," *Journal of Monetary Economics*, 54(2), 247–266.

Kotlikoff, L. J., and S. Burns (2004): *The Coming Generational Storm: What You Need to Know About America's Economic Future*. MIT Press, Cambridge, MA.

Kotlikoff, L. J., and J. Gokhale (1994): "Passing the Generational Buck," *The Public Interest*, 114(Winter), 73–81.

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

Loyo, E. (1999): "Tight Money Paradox on the Loose: A Fiscalist Hyperinflation," Manuscript, Harvard University.

Lucas, Jr., R. E. (1988): "Money Demand in the United States: A Quantitative Review," *Carneige-Rochester Conference Series on Public Policy*, pp. 137–168.

Mankiw, N. G., and L. H. Summers (1986): "Money Demand and the Effects of Fiscal Policies," *Journal of Money, Credit, and Banking*, 18(4), 415–429.

North, D. (1990): *Institutions, institutional change, and economic performance.* Cambridge: Cambridge University Press.

O'Neill, J. E. (1996): "CBO Testimony: The Long-Run Budgetary Impacts of an Aging Population," Statement before the Committee on the Budget, U.S. House of Representatives, Congressional Budget Office, March 13.

Pindyck, R. (1988): "Irreversible investment, capacity choice, and the value of the firm," *The American Economic Review*, 78(5), 969–985.

Ramey, G., and V. Ramey (1995): "Cross-country evidence on the link between volatility and growth," *The American Economic Review*, pp. 1138–1151.

Rotemberg, J. J. (1982): "Sticky Prices in the United States," *Journal of Political Economy*, 90(December), 1187–1211.

Rotemberg, J. J., and M. Woodford (1997): "An Optimization-Based Econometric Framework for the Evaluation of Monetary Policy," in *NBER Macroeconomics Annual 1997*, ed. by B. S. Bernanke, and J. J. Rotemberg, pp. 297–346. MIT Press, Cambridge, MA.

Sargent, T. (2006): "Ambiguity in American monetary and fiscal policy," *Japan & The World Economy*, 18(3), 324–330.

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

Sims, C. A. (2005): "Limits to Inflation Targeting," in *The Inflation-Targeting Debate*, ed. by B. S. Bernanke, and M. Woodford, pp. 283–299. The University of Chicago Press, Chicago.

Smetters, K., and J. Walliser (2004): "Opting out of social security," *Journal of Public Economics*, 88(7-8), 1295–1306.

Stiglitz, J. (1969): "The effects of income, wealth, and capital gains taxation on risk-taking," *The Quarterly Journal of Economics*, 83(2), 263–283.

Tobin, J. (1958): "Liquidity Preference as Behavior Towards Risk," *Review of Economic Studies*, 25(February), 65–86.

Woodford, M. (2001): "Fiscal Requirements for Price Stability," *Journal of Money, Credit, and Banking*, 33(3), 669–728.

——— (2003): *Interest and Prices: Foundations of a Theory of Monetary Policy.* Princeton University Press, Princeton, N.J.