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Prepared by Michael Kumhof, Douglas Laxton, and Daniel Leigh

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Abstract

 We thank a large number of people both inside and outside the Fund for encouraging work in this area. This includes Ken Rogoff, Raghu Rajan, Simon Johnson and Olivier Blanchard. The model builds heavily on previous modeling research at the Fund and here we would like to single out enormous technical contributions in both theory and solution techniques by Steve Symansky, Paolo Pesenti, Michel Juillard, and Peter Hollinger.

For thirty years prominent voices have advocated a policy of "starving the beast"—cutting taxes to force government spending cuts. This paper analyzes the macroeconomic and welfare consequences of this policy using a two-country general equilibrium model. Under several strong assumptions the policy, if fully implemented, produces domestic output and welfare gains accompanied by losses elsewhere. But negative effects can easily arise in the presence of longer policy implementation lags, utility-enhancing government spending, and productive government capital. Overall, the analysis finds no support for the idea that "starving the beast" is a foolproof way towards higher output and welfare.

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Keywords: Starve-the-beast, tax cuts, spending cuts, budget deficits, government debt, non-Ricardian behavior, welfare analysis.

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I. Introduction

For thirty years, prominent voices have endorsed a policy of "starving the beast"—cutting taxes to induce budget deficits in the hope that, over time, the deficits force reductions in government spending. Nobel Laureates Milton Friedman (2003) and Gary Becker have been among the proponents of this view. This philosophy has also been supported by a number of U.S. Presidents. For example, in 1981, President Reagan said:

> *There were always those who told us that taxes couldn't be cut until spending was reduced. Well, you know, we can lecture our children about extravagance until we run out of voice and breath. Or we can cure their extravagance by simply reducing their allowance.*

The 2001 tax cuts introduced by President Bush were also consistent with this approach.

Others, however, have suggested that this policy usually fails to restrain government spending. In particular, Romer and Romer (2007) find "no support for the hypothesis that tax cuts restrain government spending; indeed, [the findings] suggest that tax cuts may actually increase spending. The results also indicate that the main effect of tax cuts on the government budget is to induce subsequent legislated tax increases."[1]

Furthermore, even if it *did* restrain government spending, there is no consensus regarding the macroeconomic and welfare consequences of implementing a starve-the-beast approach, henceforth referred to as STB. On the one hand, it could be beneficial in the ideal case in which it results in cuts in entirely wasteful government spending. In particular, lower spending frees up resources for private consumption, and the associated lower tax rates reduce distortions in the economy. On the other hand, it could be costly if the spending cuts arrive with a considerable lag, implying a permanent increase in government debt and real interest rates. Also, lower government spending may itself entail welfare losses if agents attach a nonzero utility value to it, or if it augments the productivity of private factors of production.

A systematic analysis of these trade-offs is the main contribution of this paper. Our analysis is based on experiments conducted in a two-country New Keynesian model. Ricardian equivalence does not hold in the model because consumers have finite lifetimes, or finite planning horizons, as in Blanchard (1985), Weil (1989) and Yaari (1965).[2,3] This assumption is supported by recent empirical evidence, as discussed below. The assumption is important because one of the main concerns about STB centers on higher debt levels leading to higher real interest rates, which is an equilibrium feature of this type of overlapping generations model. We employ a simple open economy set-up to capture

[1] Similarly, Krugman (2003), Niskanen (2006) and Bayoumi and Goncalves (2007) find that, in the United States, tax cuts do not tend to be followed by government spending restraint. Auerbach, Gale, and Orzag (2006) argue that paying for the tax cuts implemented by the Bush Administration via expenditure restraint alone would be politically difficult.

[2] For recent examples of studies using this model class, see Farmer (2010) and Chadha and Nolan (2007).

[3] As pointed out by Weil (1989), the critical feature of the Blanchard (1985) model is not the finite planning horizon of existing households per se, but rather the fact that after a household's death new agents are born and inherit the liabilities of previous generations.

the fact that U.S. fiscal deficits are financed to a significant extent by foreign saving.[4] The model employs a set of nominal and real rigidities that are commonly used in the modern business cycle literature. These rigidities have the advantage of yielding plausible impulse responses at shorter horizons. The model also specifies a wide menu of fiscal policy tools, which allow us to study a number of different trade-offs involved in adopting the STB approach.

The effects of the STB approach are assessed in two ways. First, the paper examines whether the principal macroeconomic variables such as GDP and consumption, both in the United States and in the rest of the world, respond positively to this policy. Second, the paper assesses social welfare effects, summarized using a compensating consumption variation statistic. We investigate how the welfare assessment of STB depends on the rate at which the utility of future generations is discounted. In addition, the paper assesses how the welfare effects depend on the degree to which government spending directly contributes to household welfare or to productivity.

We find that STB only yields welfare gains under ideal circumstances. These include cuts to particularly distortionary types of taxation, a successful and rapid implementation of spending cuts, and the successful identification of spending categories that reduce neither welfare nor productivity. If, one the other hand, the spending cuts are either aborted or come very late, as suggested by Romer and Romer (2007), the impact on output and welfare becomes negative and large. The same is true if, as suggested by a number of studies that we will discuss below, government spending directly raises either household welfare or aggregate productivity.

The remainder of the paper is organized as follows. Section 2 describes the model, and Section 3 its calibration. Section 4 explains our approach to evaluating welfare. Section 5 describes the design of the policy experiments and reports the results. Section 6 concludes.

II. The Model

The world consists of two countries, the United States and the rest of the world (RW). When discussing the behavior of agents in one country alone we will not identify the country by additional notation. When the interaction between two countries is discussed we identify the United States by an asterisk.

Each country is populated by overlapping generations households with finite planning horizons, who consume final retailed output and supply labor to unions. In each period, $N^*(1-\theta)$ and $N(1-\theta)$ of such individuals are born in the United States and RW, respectively. Each agent faces a constant probability of death $(1-\theta)$ in each period, which implies an average planning horizon of $1/(1-\theta)$.[5] This implies that the total number of agents in the United States and in RW is N^* and N. In addition to the

[4] See Kumhof and Laxton (2007).

[5] In general we allow for the possibility that agents may be more myopic than what would be suggested by a planning horizon based on a biological probability of death. This is similar to the new generation of models that combine infinitely lived and liquidity constrained agents, such as Gali, López-Salido and Vallés (2007), who suggest that one interpretation of liquidity constraints is extreme myopia.

probability of death households also experience labor productivity that declines at a constant rate χ over their lifetimes[6], which adds another powerful channel through which fiscal policies can have non-Ricardian effects.

Firms are managed in accordance with the preferences of their owners, finitely-lived households, and they therefore also have finite planning horizons. Each country's primary production is carried out by a manufacturing sector that employs labor and accumulates capital, subject to investment adjustment costs. As is standard in open economy models, the economy's distribution sector technology then combines domestic and foreign goods subject to an import adjustment cost. It adds to this a publicly provided capital stock (infrastructure) as an essential further input. This capital stock is maintained through government investment that is financed by tax revenue. Price setting for final output is subject to nominal rigidities. It is sold to domestic consumers via a retail sector, to investors, and to the government. Retailers find it costly to rapidly adjust their sales volume, which generates inertial consumption dynamics over the short run.

Asset markets are incomplete. There is complete home bias in government debt, which takes the form of nominally non-contingent one-period bonds denominated in domestic currency. The only assets traded internationally are nominally non-contingent one-period bonds denominated in the currency of the United States There is also complete home bias in ownership of domestic firms. Equity is not traded in domestic financial markets, instead households receive lump-sum dividend payments.

The world economy grows at the constant rate $g = T_t/T_{t-1}$, where T_t is the level of labor augmenting world technology. The model's real variables, say x_t, therefore have to be rescaled by T_t, where we will use the notation $\check{x}_t = x_t/T_t$. The steady state of $\check{x}_t$ is denoted by $\bar{x}$. All aggregate variables represent normalized absolute rather than per capita quantities. This paper presents results for the perfect foresight case. Extensions to log-linear approximations are trivial.[7]

A. Households

A representative household of age a derives utility at time t from consumption $C_{a,t}$ and leisure $(1 - L_{a,t})$ (where 1 is the time endowment). The lifetime expected utility of a representative household has the form

$$\sum_{s=0}^{\infty} (\beta\theta)^s \left[\frac{1}{1-\gamma} \left((C_{a+s,t+s})^{\eta} \left(1 - L_{a+s,t+s}\right)^{1-\eta} \right)^{1-\gamma} \right] , \tag{1}$$

where β is the discount factor, $\theta < 1$ determines the length of the planning horizon, $\gamma > 0$ is the coefficient of relative risk aversion, and $0 < \eta < 1$. For money demand, we assume the cashless limit advocated by Woodford (2003). Consumption $C_{a,t}$ is given by a CES aggregate over retailed varieties $C_{a,t}(i)$, with elasticity of substitution σ_R.

[6]Declining income profiles eliminate excessive sensitivity of human wealth to changes in the real interest rate. In models with exogenous labor supply and stationary population shares it can be shown that declining productivity profiles can be calibrated to produce identical macroeconomic behavior as more plausible hump-shaped life-cycle productivity profiles. See Faruqee and Laxton (2000).

[7]A Technical Appendix (available upon request) provides a more comprehensive description of the model than is possible in the paper.

A household can hold domestic government bonds $B_{a,t}$ denominated in domestic currency, and foreign bonds $F_{a,t}$ denominated in the currency of the United States The nominal exchange rate vis-a-vis the United States is denoted by $\mathcal{E}_t$. In each case the time subscript t denotes financial claims held from period t to period $t+1$. Gross nominal interest rates on United States and RW currency denominated assets held from t to $t+1$ are i_t^* and i_t. Participation by households in financial markets requires that they enter into an insurance contract with companies that pay a premium of $\frac{(1-\theta)}{\theta}$ on a household's financial wealth for each period in which that household is alive, and that encash the household's entire financial wealth in the event of his death.[8]

The productivity of a household's labor declines throughout his lifetime, with productivity $\Phi_{a,t} = \Phi_a$ of age group a given by $\Phi_a = \kappa\chi^a$, where $\chi < 1$. The overall population's average productivity is assumed without loss of generality to be equal to one. Household pre-tax nominal labor income is therefore $W_t\Phi_{a,t}L_{a,t}$. Dividends are received in a lump-sum fashion from all firms in the manufacturing (M), distribution (D) and retail (R) sectors, with after-tax nominal dividends received from firm i denoted by $D^j_{a,t}(i)$, $j = M, D, R$. Households' labor income is taxed at the rate $\tau_{L,t}$, their consumption is taxed at the rate $\tau_{C,t}$,[9] and they are subject to a lump-sum tax $\tau^{ls}_{a,t}$. The consumption tax $\tau_{C,t}$ is assumed to be payable on the sales price P_t of distributors. We choose P_t as our numeraire. The relative prices and gross inflation rates of any good x are denoted by $p^x_t = P^x_t/P_t$ and $\pi^x_t = P^x_t/P^x_{t-1}$, gross final goods inflation by $\pi_t = P_t/P_{t-1}$, gross nominal exchange rate depreciation by $\varepsilon_t = \mathcal{E}_t/\mathcal{E}_{t-1}$, and the real interest rate by $r_t = i_t/\pi_{t+1}$. The real wage is denoted by $w_t = W_t/P_t$, and the real exchange rate vis-a-vis the United States by $e_t = (\mathcal{E}_t P^*_t)/P_t$. We let $b_t = B_t/P_t$ and $f_t = F_t/P^*_t$. The household's budget constraint in nominal terms is

$$P^R_t C_{a,t} + P_t C_{a,t}\tau_{C,t} + B_{a,t} + \mathcal{E}_t F_{a,t} = \frac{1}{\theta}\left[i_{t-1}B_{a-1,t-1} + i^*_{t-1}\mathcal{E}_t F_{a-1,t-1}\right] \tag{2}$$

$$+W_t\Phi_a L_{a,t}(1-\tau_{L,t}) + \int_0^1 D^M_{a,t}(i)di + \int_0^1 D^D_{a,t}(i)di + \int_0^1 D^R_{a,t}(i)di - P_t\tau^{ls}_{a,t} \; .$$

The household maximizes (1) subject to (2). The derivation of the first-order conditions for each generation, and aggregation across generations, is discussed in the Technical Appendix. Aggregation takes account of the size of each age cohort at the time of birth, and of the remaining size of each generation. The first-order condition for the consumption/leisure choice is, after rescaling by technology, given by

$$\frac{\check{C}_t}{N - L_t} = \frac{\eta}{1-\eta}\check{w}_t\frac{(1-\tau_{L,t})}{(p^R_t + \tau_{C,t})} \; . \tag{3}$$

The arbitrage condition for foreign currency bonds (the uncovered interest parity relation) is

$$i_t = i^*_t\varepsilon_{t+1} \; . \tag{4}$$

[8] The turnover in the population is assumed to be large enough that the income receipts of the insurance companies exactly equal their payouts.

[9] To facilitate simple closed-form solutions, both of these taxes as well as capital income taxes are assumed to be proportional.

We now discuss a key set of optimality conditions of the model. They express current aggregate household consumption as a function of their real aggregate financial wealth fw_t and human wealth hw_t, with the marginal propensity to consume of out of wealth given by $1/\Theta_t$. Human wealth is in turn composed of hw_t^L, the expected present discounted value of households' time endowments evaluated at the after-tax real wage, and hw_t^K, the expected present discounted value of dividend income plus net lump-sum transfers to or from the government. After rescaling by technology we have

$$\check{C}_t \Theta_t = \check{f}w_t + \check{h}w_t^L + \check{h}w_t^K \ , \tag{5}$$

where

$$\Theta_t = \frac{p_t^R + \tau_{C,t}}{\eta} + \frac{\theta j_t}{r_t} \Theta_{t+1} \ , \tag{6}$$

$$\check{f}w_t = \frac{1}{\pi_t g} \left[i_{t-1} \check{b}_{t-1} + i_{t-1}^* \varepsilon_t \check{f}_{t-1} e_{t-1} \right] \ , \tag{7}$$

$$\check{h}w_t^L = N \check{w}_t (1 - \tau_{L,t}) + \frac{\theta \chi g}{r_t} \check{h}w_{t+1}^L \ , \tag{8}$$

$$\check{h}w_t^K = \left(\check{d}_t^M + \check{d}_t^D + \check{d}_t^R - \check{\tau}_t^{ls} \right) + \frac{\theta g}{r_t} \check{h}w_{t+1}^K \ , \tag{9}$$

$$j_t = \left(\beta \frac{i_t}{\pi_{t+1}} \right)^{\frac{1}{\gamma}} \left(\frac{p_t^R + \tau_{C,t}}{p_{t+1}^R + \tau_{C,t+1}} \right)^{\frac{1}{\gamma}} \left(\chi g \frac{\check{w}_{t+1}(1 - \tau_{L,t+1})(p_t^R + \tau_{C,t})}{\check{w}_t (1 - \tau_{L,t})(p_{t+1}^R + \tau_{C,t+1})} \right)^{(1-\eta)(1-\frac{1}{\gamma})} \ . \tag{10}$$

The intuition of (5) - (10) is as follows. Financial wealth (7) is equal to the domestic government's and foreign households' *current* financial liabilities. For the government debt portion, the government services these liabilities through different forms of taxation, and these *future* taxes are reflected in the different components of human wealth as well as in the marginal propensity to consume. But unlike the government, which is infinitely lived, an individual household factors in that he might not be alive by the time higher future tax payments fall due. Hence *a household discounts future tax liabilities by a rate of* r_t/θ *or* $r_t/(\theta\chi)$*, which are higher than the market rate* r_t, as reflected in the discount factors in (8), (9) and (6). The discount rate for the labor income component of human wealth is higher due to the decline of labor incomes over individuals' lifetimes. The implication is that government debt is net wealth to the extent that households do not expect to become responsible for the taxes necessary to service that debt. The more myopic households are, the greater the portion of outstanding government debt that they consider to be net wealth.

A fiscal expansion through temporarily lower taxes represents a tilting of the tax payment profile from the near future to the more distant future, so as to effect an increase in the debt stock. The government has to respect its intertemporal budget constraint in effecting this tilting, and this means that the expected present discounted value of its future primary surpluses has to remain equal to the current debt $i_{t-1}b_{t-1}/\pi_t$ *when future surpluses are discounted at the market interest rate* r_t. But when individual households discount future taxes at a higher rate than the government, the same tilting of the tax profile represents an increase in human wealth because it decreases the value of future taxes for which the household expects to be responsible. For a given marginal propensity to consume, this increase in human wealth leads to an increase in consumption.

The marginal propensity to consume $mpc_t = 1/\Theta_t$ is, in the simplest case of logarithmic utility, exogenous labor supply and no consumption taxes, equal to $(1-\beta\theta)$. For the case of endogenous labor supply, household wealth can be used to either enjoy leisure or to generate purchasing power to buy goods. The main determinant of the split between consumption and leisure is the consumption share parameter η, which explains its presence in the marginal propensity to consume (6). While other forms of taxation affect the different components of wealth, the time profile of consumption taxes affects the marginal propensity to consume, increasing it with a balanced-budget shift of such taxes from the present to the future. By combining (6) with (10), we obtain the following steady state relationship between $\overline{mpc}$, $\bar{r}$ and θ:

$$\overline{mpc} = \frac{\eta}{\bar{p}^R}\left(1-\theta\beta^{\frac{1}{\gamma}}g^{(1-\eta)(1-\frac{1}{\gamma})}\bar{r}^{\left(\frac{1}{\gamma}-1\right)}\right) . \quad (11)$$

A higher real interest rate has a substitution and an income effect, the former reducing the marginal propensity to consume and the latter increasing it, with the two exactly offsetting each other for the log utility case of $\gamma = 1$. The conventional assumption is that $\gamma > 1$, and we will consider a benchmark of $\gamma = 4$. In that case the income effect is stronger, and the increase in the marginal propensity to consume due to a higher r partly offsets the contractionary consumption effect of a higher r on human wealth. The consequence is that for high γ real interest rates have to increase by more to clear markets following an increase in deficits. A shorter planning horizon, or lower θ, increases the level of the marginal propensity to consume. But it also decreases its sensitivity to the real interest rate, because agents with a short planning horizon care less about the future effects of real interest rate changes.

B. Firms

Firms maximize the present discounted value of dividends. Their discount rate includes θ so as to equate the discount factor of firms θ/r_t with the pricing kernel for nonfinancial income streams of their owners, which equals $\beta\theta\left(\lambda_{a+1,t+1}/\lambda_{a,t}\right)$. This equality follows directly from households' bond Euler equation $\lambda_{a,t} = \beta\left(\lambda_{a+1,t+1}r_t\right)$. To save space we only provide a brief outline of the optimization problems of firms. The Technical Appendix shows the complete derivations.

1. Manufacturers

The output of manufacturing firms equals Z_t^M, and is produced with a CES production function in capital K_t, labor L_t, and labor augmenting technology T_t. Capital accumulation takes place inside firms, subject to the usual accumulation equation with depreciation rate Δ_K, and subject to quadratic adjustment costs in gross investment I_t. Dividends D_t^M equal nominal revenue minus nominal cash outflows. The latter include the wage bill, investment, adjustment costs and capital income taxation, which is levied on the return to capital net of depreciation $(R_{k,t} - P_t \Delta_K q_t))\, K_t$.[10] The standard optimality conditions for labor, capital and investment are shown in the Technical Appendix.

2. Distributors

This sector represents the two-stage production and price setting technology for final output. Distributors are indexed by $i \in [0,1]$, are perfectly competitive in their input markets, and monopolistically competitive in their output market. In the first production stage a manufacturing output composite $Y_t^M(i)$ is produced by combining foreign and domestic manufactured goods, subject to an adjustment cost that makes rapid changes in the share of foreign goods costly.[11] In the second production stage this composite is combined with a publicly provided stock of capital K_t^G to produce final output $Z_t^D(i)$:

$$Z_t^D(i) = Y_t^M(i) \left(K_t^G / T_t \right)^{\alpha_G} \mathcal{S} \, . \tag{12}$$

The stock of public infrastructure K_t^G is identical for all firms and provided free of charge to the end user (but not of course to the taxpayer). It enters in a similar fashion to the level of technology, but with decreasing returns $\alpha_G < 1$. The term $\mathcal{S}$ is a normalization factor that is used to set $\bar{Z}^D = \bar{Y}^M$. The profit maximization problem of distributors consists of maximizing the present discounted value of nominal revenue minus nominal input costs, which include the cost of foreign and domestic manufactured goods, a fixed cost and inflation adjustment costs. The latter, following Ireland (2001) and Laxton and Pesenti (2003), is quadratic in changes in the rate of inflation rather than in price levels, which helps to generate realistic inflation dynamics. The fixed cost $P_t T_t \omega$ arises as long as the firm chooses to produce positive output. Net output is therefore equal to $\max(0, Z_t^D(i) - T_t \omega)$. The optimality conditions include input demands and a New Keynesian Phillips curve for final goods inflation.

3. Retailers

Households demand a CES aggregate of consumption goods varieties from retailers. Retailers face quantity adjustment costs that are quadratic in the rate of change of consumption. The optimization problem of retailers consists of maximizing the present discounted value of revenue, minus input costs and quantity adjustment costs. The first order condition for the retailer's problem features a steady state markup over the price of final goods and adjustment cost terms that depend on the rate of change of consumption.

[10] Here $R_{k,t}$ is the nominal rental rate of capital and q_t is the shadow price of capital (Tobin's q).

[11] This assumption has become widely used. It addresses a key concern in open economy DSGE models, namely the potential for an excessive short-term responsiveness of international trade to real exchange rate movements.

C. Government

1. Fiscal Policy

Fiscal policy consists of a specification of tax rates $\tau_{L,t}$, $\tau_{C,t}$ and $\tau_{K,t}$, lump-sum taxes/transfers τ_t^{ls}, and government spending for consumption and investment purposes G_t^{cons} and G_t^{inv}. G_t^{cons} is exogenous and unproductive, while G_t^{inv} augments the stock of publicly provided infrastructure capital K_t^G, the evolution of which is given by

$$\check{K}_{t+1}^G g = (1 - \Delta_G)\, \check{K}_t^G + \check{G}_t^{inv} \ . \tag{13}$$

The government issues nominally non-contingent one-period debt B_t at the gross nominal interest rate i_t. Letting $\check{b}_t = B_t / (P_t T_t)$, the government budget constraint is therefore

$$\check{b}_t = \frac{i_{t-1}}{\pi_t g} \check{b}_{t-1} - \check{s}_t \ , \tag{14}$$

$$\check{s}_t = \check{\tau}_t - \check{G}_t \ , \tag{15}$$

$$\check{\tau}_t = \tau_{L,t} \check{w}_t L_t + \tau_{C,t} \check{C}_t + \check{\tau}_t^{ls} + \tau_{K,t} \left(r_{k,t} - \Delta_K q_t \right) \right) \check{K}_t \ , \tag{16}$$

where $\check{s}_t$ is the primary surplus, $\check{G}_t = \check{G}_t^{cons} + \check{G}_t^{inv}$, $\check{\tau}_t$ is total tax revenue, and $r_{k,t}^J = R_{k,t}^J / P_t$. We denote the government debt to GDP ratio by $b_t^{rat} = \check{b}_t / g\check{d}p_t$.

2. Starving-the-Beast

In terms of the above model, STB is specified as an instantaneous cut in the tax revenue to GDP ratio $\tau_t^{rat} = \check{\tau}_t / g\check{d}p_t$, and a subsequent, more gradual cut in the government spending to GDP ratio $G_t^{rat} = \check{G}_t / g\check{d}p_t$.

Taxation

Tax policy is simply given by the assumption

$$\tau_t^{rat} = \tau^{rat} + \epsilon^\tau \quad , \tag{17}$$

where τ^{rat} is the original steady state tax revenue to GDP ratio and ϵ^τ is the (negative) shock to that ratio. This policy is implemented by an endogenous adjustment of one of the tax rates. In our baseline experiment this is the labor tax rate $\tau_{L,t}$, but we also consider one alternative where labor and capital income tax rates change by equal amounts. In that case we have a second assumption for the capital income tax rate

$$\tau_{K,t} - \bar{\tau}_K = \tau_{L,t} - \bar{\tau}_L \quad , \tag{18}$$

where $\bar{\tau}_L$ and $\bar{\tau}_K$ are the labor and capital income tax rates in the original steady state.

Spending

Spending policy according to STB is specified through a set of three assumptions. First, the fiscal authority allows for an increase in the debt to GDP ratio during the transition to a lower spending to GDP ratio. This is a stock adjustment and is therefore not instantaneous. Instead, the long-run level of the ratio is given by its original value b^{rat}

plus a shock ϵ^b. Second, by the long-run version of the government budget constraint, the long-run target $\tilde{G}_t^{rat}$ for the government spending to GDP ratio is therefore given by

$$\tilde{G}_t^{rat} = \left(\tau^{rat} + \epsilon^{\tau}\right) - \left(b^{rat} + \epsilon^b\right)\left(\frac{\tilde{r}_t}{g} - 1\right) \quad , \tag{19}$$

where $\tilde{r}_t$ is a term that converges to the long-run equilibrium real interest rate, which is endogenous in the model. Third, there is a gradual convergence of the spending to GDP ratio from the original steady state to $\tilde{G}_t^{rat}$, with autoregressive coefficient ρ^G. To ensure smooth and stable convergence to $\tilde{G}_t^{rat}$, it is necessary to also add a small correction term that depends on the deviation of the government debt to GDP ratio from its target $b^{rat} + \epsilon^b$. We have

$$G_t^{rat} = \left(1 - \rho^G\right)\tilde{G}_t^{rat} + \rho^G G_{t-1}^{rat} - \xi\left(b_t^{rat} - b^{rat} - \epsilon^b\right) \quad . \tag{20}$$

To obtain a smooth path of government spending it is of course necessary, given the shock to taxes ϵ^{τ}, to choose the convergence rate of government spending ρ^G and the shock to the debt level ϵ^b in a mutually consistent way. For example, when in our sensitivity analysis we roughly double the time it takes for government spending to reach its new lower level, we also allow the increase in the long-run government debt to GDP ratio to roughly double relative to the baseline. Also, the government spending to GDP ratio can be adjusted through either government consumption or government investment or a combination of the two, and we explore two possibilities in our sensitivity analysis.

3. Monetary Policy

Monetary policy uses an interest rate rule to stabilize inflation and output growth. The rule is similar to the class of rules discussed by Orphanides (2003), with one important exception. This is that, in an overlapping generations model that experiences permanent shocks to public (or private) saving rates, the steady state real interest rate also experiences permanent changes. The term proxying the steady state nominal interest rate $\widetilde{r}_t \pi_{t+1}$ therefore includes a moving average of past real interest rates that tracks the evolution of the equilibrium real interest rate over time:

$$i_t = \left(i_{t-1}\right)^{\mu_i}\left(\tilde{r}_t \pi_{t+1}\right)^{1-\mu_i}\left(\frac{\pi_{t+1}}{\bar{\pi}}\right)^{(1-\mu_i)\mu_\pi}\left(\frac{g\check{d}p_t}{g\check{d}p_{t-1}}\right)^{(1-\mu_i)\mu_y} \quad , \tag{21}$$

$$\tilde{r}_t = \left(r_t \tilde{r}_{t-1}^{\kappa_r}\right)^{\frac{1}{1+\kappa_r}} \quad . \tag{22}$$

III. Calibration

We work with an annual version of the model. The denomination of international bonds is in U.S. currency. The United States is calibrated to represent 25 percent of world GDP, and to have long-run or steady state government debt to GDP and net foreign liabilities to GDP ratios of 50 percent and 30 percent. RW also has a government debt to GDP ratio of 50 percent. We calibrate the U.S. imports to GDP ratio at 12 percent, which is in line with the historical average.

We fix the steady state world real growth rate at 2.5% per annum, and the steady state inflation rate in each country at 2% per annum. Given that there are no long-run trends in relative productivity and therefore in real exchange rates, the long-run real interest rate is equalized across countries, and we assume a value of 3% per annum. We find the values of the rates of time preference in each country that are consistent with the assumptions concerning real interest rates and net foreign asset positions.

The degree of non-Ricardian household saving behavior, and therefore the sensitivity of real interest rates to the level of government debt, is determined by the interaction of the intertemporal elasticity of substitution $1/\gamma$, the length of the planning horizon $1/(1-\theta)$, and the labor productivity decline rate χ. We assume an intertemporal elasticity of 0.25, or $\gamma = 5$,[12] a planning horizon of 10 years, implying $\theta = 0.9$,[13] and $\chi = 0.95$. The main criterion used in choosing these parameters is the empirical evidence for the effect of government debt on real interest rates. Our model is calibrated so that a one percentage point increase in the government debt to GDP ratio in the United States leads to an approximately two basis points increase in the U.S. (and world) real interest rate. This value is conservative because it is at the lower end of the range of the estimates of Laubach (2003), Engen and Hubbard (2004) and Gale and Orszag (2004), and thereby gives an advantage to STB policies in welfare evaluations. The reason is that a significant part of the cost of STB in our model is due to higher real interest rates caused by debt accumulated during the transitional period when spending is slow to decline.

The elasticity of labor supply depends on the steady state value of labor supply, which is in turn determined by the leisure share parameter η. We adjust η to obtain a labor supply elasticity of 0.5. Pencavel (1986) reports that most microeconomic estimates of this elasticity are between 0 and 0.45, and our calibration is at the upper end of that range, in line with much of the business cycle literature. A more recent reference supporting an elasticity of 0.5 is Domeij and Flodén (2006), who take into account the extensive margin.

The elasticity of substitution is assumed to equal 1 between capital and labor, and 1.5 between domestic and foreign manufactures as in Erceg, Guerrieri and Gust (2005b). Steady state price markups equal 20 percent in manufacturing and 5 percent in retailing. The manufacturing labor share parameters are set to ensure a labor income share of 60 percent, and the depreciation rate of capital equals 10 percent per annum. The steady state share of government spending in GDP is calibrated based on historical averages to equal 18 percent. The shares of different types of tax revenue in overall tax revenue are also based on historical averages.

Calibrating the steady state investment to GDP ratio, again based on historical averages, would ordinarily present a problem given that we have already fixed the capital income share parameter. But in our model capital income consists not only of the return to capital in manufacturing, but also of monopoly profits in distribution. We have introduced fixed costs in distribution that partly or wholly eliminate these profits. The fraction of steady state economic profits remaining after fixed costs can therefore be specified as an additional free parameter that allows us to fix the steady state investment to GDP ratio at 16 percent.

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[12] The choice of γ is highly model specific and cannot be directly compared to calibrations of the intertemporal elasticity of substitution in infinite-horizon models.

[13] Based on U.S. annual data starting in 1955 Bayoumi and Sgherri (2006) decisively reject the infinite horizon model and estimate a planning horizon that is significantly shorter than 10 years.

The most challenging aspect of the model calibration is the specification of public capital stock accumulation and of its productivity. First, the U.S. national accounts data allow us to decompose public spending into spending on infrastructure investment and spending on all other items. As a share of GDP, the former represents 3 percent and the latter 15 percent. We use this to determine the ratio between the steady state values of productive and unproductive government spending, but it should be clear that other decompositions would be very justifiable. Most troubling is that education and health spending are thereby classified as completely unproductive. Based on the evidence in Kamps (2004), we calibrate the depreciation rate of public capital at 4 percent per annum. The productivity of public capital is determined by the parameter α_G. Ligthart and Suárez (2005) present a meta analysis that evaluates a large number of studies on the elasticity of aggregate output with respect to public capital. We adopt their best estimate, which puts this elasticity at 0.14, by adjusting α_G accordingly. This is considerably below the highly controversial estimates of Aschauer (1989, 1998), but it is nevertheless very significant.

The investment, consumption and trade adjustment cost parameters and nominal rigidities are chosen to yield plausible short-run dynamics consistent with empirical evidence.[14] They are however of comparatively little significance for this paper's results given that our main concern is with medium- and long-run dynamics due to structural fiscal policies. The same is true for the monetary policy rules. Here we assume relatively little interest rate smoothing, $\delta_i = 0.25$, given that this is an annual model, an inflation coefficient of $\delta_\pi = 0.6$,[15] and an output growth coefficient of $\delta_y = 0.25$. We set $\kappa_r = 3$ in the expression for the moving average real interest rate $\tilde{r}_t$, which ensures that $\tilde{r}_t$ starts to reflect the major portion of a long-lived change in r_t within a period of 3 to 5 years.

IV. Welfare

To quantify welfare effects, the paper uses two approaches. The first is a benchmark metric in which government consumption does not contribute directly to household utility, a strong assumption which is nevertheless in line with many conventional models. The second is an alternative metric with government consumption in the utility function.

A. Benchmark Welfare: No Government Spending in Utility

In infinite horizon models it is natural to take the utility function of the representative agent as the welfare criterion for society. In overlapping generations models this is not as straightforward as the welfare effect of any policy will in general differ across generations alive today, as well as between current and future generations. We adopt the approach, following Ganelli (2005) and Velculescu (2004), of using the household utility function specified in the model, but replacing generation specific consumption and leisure with the corresponding average per capita values. We further allow for a range of different discount

[14] A fully satisfactory calibration of these parameters will require estimation. Given the wide application of this model to policy analysis inside the IMF this is an important part of our research agenda.

[15] Note that the overall coefficient on inflation is therefore equal to 1.6.

factors on the part of the policymaker, which determine the weights assigned to current versus future generations. We have

$$\sum_{s=0}^{\infty} (\mathfrak{D})^s \left[\frac{1}{1-\gamma} \left(\left(\bar{C}_{t+s}^{OLG}\right)^{\eta^{OLG}} \left(1-\bar{L}_{t+s}^{OLG}\right)^{1-\eta^{OLG}} \right)^{1-\gamma} \right] , \tag{23}$$

where $\mathfrak{D}$ denotes the discount factor, and per-capita consumption and labor are denoted by $\bar{C}_t^{OLG} = \check{C}_t^{OLG}/N$, and $\bar{L}_t^{OLG} = L_t^{OLG}/N$, with N equalling the size of the population.

The question of what weights to apply to different generations in assessing total welfare is of critical importance. There is no consensus on this issue.[16] On the one hand, Ramsey (1928) argued that current and future generations should be treated equally, a position that is consistent with $\mathfrak{D} = 1$. Following Ramsey (1928), studies such as Stern (2007) advocate a discount rate close to zero, specifically 0.1 percent per year. On the other hand, several studies emphasize reasons for not applying equal weights to current and future generations. For example, Marini and Scaramozzino (2000) find that, with positive technological change, not discounting the utility of future generations could result in present generations being treated unfairly. They derive an optimal discount rate equal to the sum of the rates of productivity and population growth, which suggests that 3 percent per year would be a reasonable value. Finally, Kaplow (2007) argues that different generations should be discounted at the "market rate of return to capital."

Given the lack of consensus, the welfare assessment is conducted based on a benchmark discount rate equal to the market rate of interest, following Kaplow (2007), as well as on a wide range of alternative discount rates. The real market interest rate used is 3 percent, the initial steady-state real interest rate in the model, and the alternative discount rates considered range from 0.1 percent to 10 percent per year.

The compensating consumption variation (ccv) provides an intuitive metric to express the results of the welfare analysis. It measures the percentage increase in original steady state consumption that, given the original amount of leisure, yields the same change in welfare as the policy change,

$$\sum_{s=0}^{\infty} (\mathfrak{D})^s \left[\frac{1}{1-\gamma} \left(\left(\bar{C}_{t+s}\right)^{\eta} \left(1-\bar{L}_{t+s}\right)^{1-\eta} \right)^{1-\gamma} \right] =$$

$$\sum_{s=0}^{\infty} (\mathfrak{D})^s \left[\frac{1}{1-\gamma} \left(\left(\bar{C}_{SS}(1+\frac{ccv}{100})\right)^{\eta} \left(1-\bar{L}_{SS}\right)^{1-\eta} \right)^{1-\gamma} \right] , \tag{24}$$

where the subscript SS denotes the initial steady state level. The calculation is repeated for the full range of discount rates, from 0.1 percent to 10 percent.

B. Alternative Welfare: With Government Spending in Utility

A number of studies emphasizes the direct contribution of government consumption to household welfare via the utility function. For example, Gali and Monacelli (2007) and

[16] As Calvo and Obstfeld (1988) emphasize, the social discount rate applied to future generations need not equal the pure time preference rate at which individuals discount their own future utilities.

Leith and Wren-Lewis (2005) include both private and government consumption in the household's utility function, based on the assumption that the government provides public goods enjoyed by households. In line with these studies, this paper adds government consumption per capita to the utility function as

$$\sum_{s=0}^{\infty}(\mathfrak{D})^s \left[\frac{1}{1-\gamma}\left(\left(\bar{C}_{t+s}\right)^{\eta}\left(1-\bar{L}_{t+s}\right)^{1-\eta}\right)^{1-\gamma}+\frac{\alpha}{1-\gamma}\left(\bar{G}^{cons}_{t+s}\right)^{1-\gamma}\right], \tag{25}$$

where $\bar{G}^{cons}_t = \check{G}^{cons}_t/N$ denotes domestic government consumption per capita, α denotes the weight on government consumption in the utility function, and government consumption enters separably with the same functional form (and parameter γ) as private consumption. Because of separability, the household first order conditions are unchanged.

Regarding the calibration of the weight on government consumption, this paper is consistent with previous studies. For the baseline calibration, as in Gali and Monacelli (2007) and Leith and Wren-Lewis (2005), the marginal rate of substitution (mrs) between private and government consumption is assumed to be -1. The mrs measures the steady-state change in private consumption required to keep utility constant following a unit increase in government consumption, holding labor effort constant. Formally, let $d\bar{C}_{SS}$, $d\bar{G}^{cons}_{SS}$, and $d\bar{L}_{SS}$ be the changes in per-capita private consumption, per-capita government consumption, and labor per capita in the steady state. The total derivative of utility conditional on a zero change in utility is given by

$$\frac{\partial U(x)}{\partial \bar{C}_{SS}}d\bar{C}_{SS}+\frac{\partial U(x)}{\partial \bar{G}^{cons}_{SS}}d\bar{G}^{cons}_{SS}+\frac{\partial U(x)}{\partial \bar{L}_{SS}}d\bar{L}_{SS}=0 \tag{26}$$

where x denotes the vector of variables that enter the utility function, $x=\left[\bar{C}_{SS}\;\bar{G}^{cons}_{SS}\;\bar{L}_{SS}\right]$. The marginal rate of substitution in steady state, mrs, is defined as

$$mrs=\frac{d\bar{C}_{SS}}{d\bar{G}^{cons}_{SS}}\mid_{dU=d\bar{L}_{SS}=0}=-\frac{\frac{\partial U(x)}{\partial \bar{G}^{cons}_{SS}}}{\frac{\partial U(x)}{\partial \bar{C}_{SS}}}=-\alpha\left[\frac{\left(\bar{G}^{cons}_{SS}\right)^{-\gamma}}{\eta\left(1-\bar{L}_{SS}\right)^{(1-\eta)(1-\gamma)}\left(\bar{C}_{SS}\right)^{(\eta(1-\gamma)-1)}}\right]. \tag{27}$$

As mrs approaches zero, the willingness of households to trade-offs government consumption for private consumption tends to zero, and the decline in government consumption associated with STB has a negligible effect on household welfare. On the other hand, as mrs rises in absolute size, government consumption becomes more valuable to households, and a decline in government consumption would, other things equal, reduce welfare. The parameter α is chosen to obtain a baseline calibration of $mrs=-1$.

To test the sensitivity of our results we will report the threshold value of mrs such that the policy change (STB) produces no change in welfare. For example, if STB yields a welfare gain equivalent to a 1 percent increase in steady state consumption when government consumption is assumed not to contribute directly to household utility (mrs = 0), the paper reports how large the mrs would have to be to eliminate that welfare gain. In particular, the threshold value of mrs is found by first searching for the value of α that equates the two sides of the equation

$$\sum_{s=0}^{\infty}(\mathfrak{D})^s\left[\frac{1}{1-\gamma}\left(\left(\bar{C}_{t+s}\right)^{\eta}\left(1-\bar{L}_{t+s}\right)^{1-\eta}\right)^{1-\gamma}+\frac{\alpha}{1-\gamma}\left(\bar{G}_{t+s}^{cons}\right)^{1-\gamma}\right]= \tag{28}$$

$$\sum_{s=0}^{\infty}(\mathfrak{D})^s\left[\frac{1}{1-\gamma}\left(\left(\bar{C}_{SS}\right)^{\eta}\left(1-\bar{L}_{SS}\right)^{1-\eta}\right)^{1-\gamma}+\frac{\alpha}{1-\gamma}\left(\bar{G}_{SS}^{cons}\right)^{1-\gamma}\right],$$

where the subscript SS denotes the initial steady state level, and then computing the corresponding threshold mrs using equation (27). The calculation is repeated for the full range of discount rates, from 0.1 percent to 10 percent, yielding a threshold mrs for each discount rate.

V. Results

The analysis is based on seven experiments, a baseline and six variations. In the baseline experiment, an immediate and permanent cut in the labor income tax-to-GDP ratio of 2 percentage points is followed by gradual cuts in government consumption that offsets the bulk of the tax cuts within about 6 years. The fiscal deficits induced during the transition eventually raise the government debt-to-GDP ratio by 5 percentage points. Since interest expenses rise, government consumption has to decline by somewhat more than 2 percent of GDP to balance the budget in the long run. The assumed 2 percentage point cut in the labor income tax to GDP ratio is broadly consistent with the estimated size of the 2001–03 tax cuts implemented by the Bush administration.[17]

The six variations on the baseline test the sensitivity of the results to key assumptions. First, we reduce the speed at which the government spending cuts arrive. Second, we replace the cut in government consumption with equal percentage cuts in government consumption and government investment. Third, we replace the cut in labor income taxes with equal percentage point cuts in labor and capital income taxes. Fourth, we increase households' planning horizon. Fifth, we reduce the elasticity of their labor supply. Sixth, we assume that spending cuts never materialize so that the tax cuts have to be reversed.

In each case, impulse responses are reported, in the top panels of Figures 1-7, in deviations from the original steady state, while welfare results are reported in the bottom panels. To facilitate comparison of magnitudes across experiments, the y-axes for each variable are identical in all figures. Tables 1-3 record the precise numerical values of GDP and consumption (Table 1), and of welfare without (Table 2) and with (Table 3) government spending in the utility function, corresponding to Figures 1-7. Table 1 also adds very long-run values of GDP and consumption at the 50-year horizon. This is informative because the stock-flow dynamics of the model implies that following shocks to government debt the model takes several decades to reach its final steady state, even though he bulk of the adjustments happens in the first 10 years.

[17] See, for example, Ahearn (2004), who estimates that the three principal tax cuts implemented during 2001–03, namely, the Economic Growth and Tax Reform Reconciliation Act of 2001, the Job Creation and Worker Assistance Act of 2002, and the Jobs and Growth Tax Relief and Reconciliation Act of 2003, totaled two percent of net national product. Note that the results reported in this paper do not depend on the exact magnitude of the tax cut, as the same tax cut size is applied across all the simulations conducted.

A. Baseline Experiment

The impulse responses for the baseline are reported in Figure 1a. In the short run the tax cut stimulates aggregate consumption, which rises gradually by about 3.5 percent over 6 years. Monetary policy responds to the inflationary pressure generated by higher private demand by raising nominal interest rates, and this increases real interest rates by up to 50 basis points on impact. This contracts investment by around 2 percent. It also contributes to a 1.7 percent real U.S. dollar appreciation, which in turn crowds in more imports and deteriorates the trade balance, except for an initial J-curve effect due to cheaper imports. This increases U.S. net foreign liabilities by eventually around 3 percent of GDP. After the first 4 years, the decline in investment and net exports combined with the reduction in real government consumption result in a modest, and temporary, decline in output below the initial steady state.

Over the longer run, U.S. aggregate saving decreases, not just due to lower government saving but also, given non-Ricardian household behavior, due to lower private saving. Because the United States represents 25 percent of world GDP, this has a significant impact on the world supply of savings, thereby raising global interest rates by around 8 basis points in the long run.[18] This effect crowds out private investment and reduces the aggregate capital stock, but the effect of this on output is more than offset by a significant increase in hours worked due to the tax cut, leaving long-run GDP around 0.2 percent higher. The U.S. real exchange rate depreciates over the long-run by just under 0.5 percent to allow an increase in exports sufficient to finance permanently higher imports and the larger interest obligations on the higher stock of net foreign liabilities.

Figure 1b and Table 2 show that STB produces a substantial welfare gain in the baseline. U.S. welfare improves by more than 3.0 percent of initial steady state consumption at all discount rates considered, and a 3.2 percent increase is obtained at the 3 percent discount rate. The increase in welfare is slightly stronger at smaller discount rates.

However, relaxing the assumption that government spending contributes nothing to household utility can easily turn substantial welfare gains into substantial welfare losses. In particular, with $mrs = -1$ the losses from lower government consumption and higher real interest rates more than offset the gains from higher private consumption and tax relief at all but the highest discount rates. At a discount rate of 3 percent the welfare loss equals 1.2 percent of initial steady state consumption. Only at discount rates of 20 percent or more (not reported here) would the overall welfare effect become positive, because this puts most weight on the extreme near-term before the welfare-reducing government spending cut is complete. The net welfare change in the baseline remains negative unless the mrs declines in absolute value to a threshold value of 0.72 or less.

Regarding the effects of STB for the rest of the world, both output and welfare decline unambiguously. The increase in global interest rates reduces RW output by eventually 0.2 percent, and household welfare declines by around 0.05 percent at all social discount rates considered.

[18] Notice therefore that real interest rates are mostly driven by monetary policy over the first five years, and almost exclusively by fiscal policy thereafter.

B. Sensitivity Analysis

1. Slower Expenditure Adjustment

The positive output and welfare effects observed in the baseline experiment decline if the government spending cuts arrive more slowly. As Figure 2 illustrates, if the bulk of the tax cuts is only offset after around 12 rather than 6 years, public debt eventually increases by 10 rather than 5 percentage points of GDP, accompanied by an increase in the U.S. net foreign liabilities to GDP ratio of between 5 and 6 percentage points. This causes a 15 basis-point long-run increase in U.S. and world real interest rates, leading to a long-run contraction in U.S. GDP of around 2.6 percent. RW, which also experiences higher real interest rates, experiences a GDP contraction of around 0.7 percent. We emphasize again that these computations favor STB because the assumed elasticity of real interest rates with respect to debt are at the lower end of the range of empirical estimates.

A comparison with the baseline case shows that the relative importance of lower tax distortions and of higher real interest rates is critical for the long-run output response. In the baseline, taxes drop sufficiently to raise long-run output despite higher real interest rates. Now, with slower expenditure adjustment and higher debt, real interest rates rise so much that output drops significantly in the long run.

Regarding welfare effects, Figure 2b shows that with slower expenditure adjustment, and under the assumption of wasteful government spending $mrs = 0$, we obtain a much smaller welfare improvement than in the baseline, due to stronger crowding out. At the 3 percent discount rate welfare in the United States improves by 1.4 percent of steady state consumption, compared with 3.2 percent in the baseline. Under the alternative assumption of $mrs = -1$ welfare declines by 2.7 percent of steady state consumption at the 3 percent discount rate, a decline that is almost two and a half times larger than in the baseline. In RW welfare deteriorates by 0.15 percent, which is also significantly worse than in the baseline.

2. Government Investment Cut

When the government replaces a share (in this case one sixth) of the cuts in unproductive government consumption with cuts in productive government investment, with an increase in public debt equal to the baseline, the macroeconomic and welfare effects of STB are much worse than in the baseline. As Figure 3a illustrates, the cut in productive public investment has negative effects on the economy's productive capacity, with real GDP eventually declining by 1.9 percent, and private investment declining by around 1 percent. Household consumption still increases despite the decline in GDP, but by only 1.2 percent in the long-run, compared with 3.5 percent in the baseline.

Regarding welfare effects, Figure 3b shows that under $mrs = 0$ we obtain a welfare improvement of only 1.7 percent of steady-state consumption at the 3 percent discount rate, half of the baseline. The reason is that a lot of productivity is lost with an erosion in public infrastructure. The spillover effects to RW remain negative as in the baseline.

Under $mrs = -1$ welfare falls by 2.3 percent of steady-state consumption at the 3 percent discount rate, a fall that is twice as large as in the baseline.

For computational reasons we have been unable to simulate a spending cut that falls entirely on government investment, given that the cut amounts to 2 percent of GDP while initial government investment is assumed to equal only 3 percent of GDP. But it should be clear from the above results that if enough of the cut falls on government investment then the welfare effects of STB will be highly negative at all discount rates, and potentially extremely damaging, even when government consumption does not yield utility.

3. Capital Income Tax Cut

The long-run output and welfare gains associated with tax cuts are particularly strong if the tax cuts fall more strongly on capital income taxation. In this experiment the tax cut is spread across labor income and capital income taxes so that both tax rates decline by the same amount in terms of percentage points. As shown in Figure 4a, with lower taxation of capital income, real private investment increases by around 2.5 percent in the long run, despite a higher real interest rate in response to lower U.S. saving. Consequently, the long-run expansion of U.S. output and consumption is larger than in the baseline that relies solely on labor income tax cuts. In the long run, the U.S. output gain is 0.7 percent, compared to 0.2 percent in the baseline.

Regarding welfare effects, Figure 4b shows that under $mrs = 0$, we obtain a welfare improvement of 3.4 percent of steady-state consumption at the 3 percent discount rate, compared to 3.2 percent in the baseline. The improvement in welfare over the baseline is larger at low discount rates that place a large weight on the long-run gains associated with greater U.S. private investment. A caveat related to this policy is that we have assumed that the tax authority is able to identify and tax only the pure return to capital. In the real world, however, corporate profits would be taxed, and in our model these would include pure economic profits due to market power, whose taxation is almost completely non-distortionary. Therefore, the larger the share of this latter category in overall corporate profits, the smaller would be the benefits of reducing corporate taxation. Under $mrs = -1$ welfare again declines at all but the highest discount rates, and by similar amounts to the baseline. RW losses are similar to the baseline, because the effect of this experiment on world real interest rates is similar.

4. Longer Planning Horizons

If agents have longer planning horizons, the negative effects of higher government debt are much less severe. The experiment involves lengthening households' planning horizons to 20 years ($\theta = 0.95$) from the baseline horizon of 10 years ($\theta = 0.90$), and reducing the life-cycle decline in productivity from the baseline 5 percent per year ($\chi = 0.95$) to 2 percent per year ($\chi = 0.98$). As shown in Figure 5a, with households acting in a more forward-looking manner, the tax cut has a smaller impact on aggregate demand and private saving, and causes a much smaller long-run increase in real interest rates. Due to the smaller crowding-out effects on private investment, the long-run gain in GDP is now

0.4 percent, compared with 0.2 percent in the baseline. Also, given the much smaller increase in global interest rates, the spillover effects to RW are negligible.

Regarding welfare effects, Figure 5b shows that under $mrs = 0$ we obtain a welfare improvement of 3.1 percent of steady-state consumption at the 3 percent discount rate, compared with 3.2 percent in the baseline. As in the baseline, assuming $mrs = -1$ again results in a negative welfare result at all discount rates. The main result of this experiment however is that the RW welfare effects are now virtually zero, due to smaller real interest rate effects.

5. Inelastic Labor Supply

As shown in Figure 6a, when labor supply is less elastic, labor income tax cuts have a less beneficial impact on long-run output, and welfare is slightly lower. In this experiment we reduce the labor supply elasticity from 0.5 to 0.25, and find that the long-run increase in GDP associated with STB declines to -0.1 percent from 0.2 percent in the baseline. The reason is that the increase in real interest rates is sufficient to offset the now much smaller labor supply response to lower tax rates.

Regarding welfare effects, Figure 6b shows that under $mrs = 0$ we obtain a welfare improvement by 3.0 percent of steady-state consumption at the 3 percent discount rate, compared with 3.2 percent in the baseline. As before, assuming $mrs = -1$ results in a fall in welfare of 1.8 percent of steady state consumption, substantially more than in the baseline, which exhibits a fall of 1.2 percent. Spillovers to RW are similar to the baseline.

6. Undoing the Tax Cut

The last experiment shows that if the tax cut does not succeed in inducing spending reductions and eventually has to be reversed, a plausible scenario, the effects on output and welfare are negative. The simulation assumes that the deficit created by the initial tax cut is closed over the same time horizon as it is in the baseline experiment, but by using labor income tax increases instead of government consumption cuts. As in the baseline, the accumulation of deficits results in a permanent increase in the public debt to GDP ratio of 5 percentage points.

As shown in Figure 7a, in the short run the economy still experiences an expansion as households respond to the initial tax cut. But over time the higher public debt and the higher taxes required to service the associated interest obligations crowd out output. The increase in global interest rates also implies substantial negative spillovers to RW at all discount rates.

Regarding welfare effects, Figure 7b shows that in this case, of course, there is no difference between the cases of $mrs = 0$ and $mrs = -1$. Substantial welfare losses occur at all but the highest discount rates, with a loss equal to 0.3 percent of initial steady state consumption at the 3 percent discount rate. RW welfare losses are also substantial, and very similar in magnitude because the main long-run effect of this policy is a higher world real interest rate.

C. The Relationship between Welfare and Discount Rates

The welfare results in Figures 1-7 reflect a combination of welfare-increasing and welfare-reducing effects of STB. On the positive side, lower government spending makes more resources available for private consumption and thereby, in the baseline case, increases welfare. Tax cuts do the same by lowering distortions, especially if taxes on capital income are cut. On the negative side, lower government spending can reduce either utility, if it enters into the utility function, or output available for private consumption, if it enters into the production function. Also on the negative side, higher debt raises real interest rates, which lowers investment, output and welfare. Slower or aborted spending adjustment reduces the gains and increases the losses.

In 10 out of the 14 cases illustrated in Figures 1-7, U.S. welfare gains increase with the discount factor, meaning they are larger if the welfare criterion cares mostly about the near future. These are the cases where the future costs of STB are relatively high. This includes all seven cases where government spending enters into utility, where given the fact that the reduction of government spending is gradual, higher discounting pays more attention to the short run when government spending is still high. Even when government spending does not enter utility, the same result applies, and is quantitatively even more important, for cuts in government investment. For delayed or aborted cuts to government spending that does not yield utility or increase productivity, higher discounting still raises welfare because it assigns less importance to the fact that consumers start to benefit much later (or never) from lower government spending that crowds in private consumption. Also, for delayed spending cuts, the larger increase in real interest rates in the long run becomes less important for welfare when the discount rate is high.

In the remaining four cases, including the baseline under the assumption that government spending does not enter utility, U.S. welfare is very slightly decreasing in the discount rate. Here a larger discount rate pays less attention to the future gains from crowding-in of private consumption due to lower government spending, which in this case are larger than the future losses due to higher world real interest rates.

VI. Conclusions

This paper has provided a systematic analysis of the macroeconomic and welfare effects of a policy popularly known as "starving the beast" (STB), which consists of cutting taxes with the intention of inducing budget deficits that, over time, force reductions in government spending. The analysis uses a carefully calibrated two-country model of the United States and the rest of the world, motivated by the fact that foreigners have recently played an important role in financing U.S. deficits. To deal with the obvious concern that our results depend on various aspects of the model's calibration, we conduct an extensive sensitivity analysis.

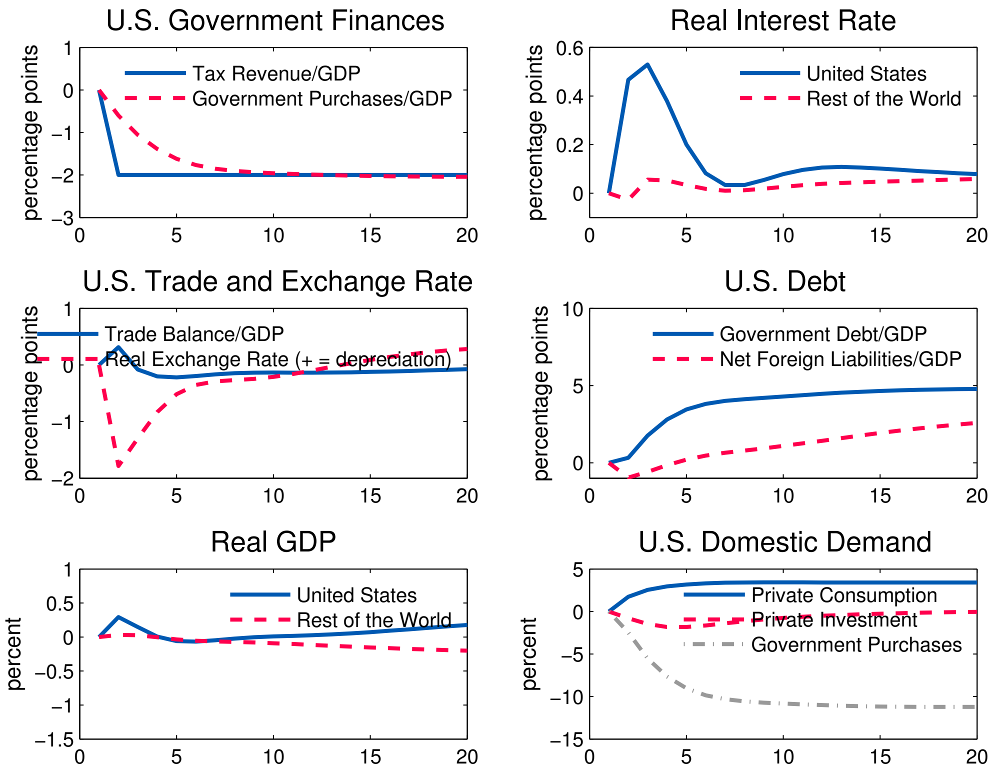
We find that the welfare results of STB are uncertain for the United States, and clearly negative for the rest of the world. Obtaining welfare gains in the United States requires, first of all, that STB actually succeeds in reducing spending, an optimistic assumption. It also requires that the government finds and eliminates spending that is completely unproductive for both household welfare and aggregate technology. On the other hand, if the eliminated government spending enters utility under a calibration that has been used in the recent literature, STB is detrimental. If part of it also enhances aggregate productivity under a calibration suggested by the empirical literature, the effects are even worse. The negative effects on the rest of the world arise because higher U.S. debt raises world real interest rates.

Another caveat to our analysis is that the rest of the world is assumed to not respond to the U.S. debt-financed tax cut with a debt-financed tax cut of its own. Such a response would offset some of the negative effects for the rest of the world, but would harm the United States by further raising world debt levels and, therefore, world real interest rates.

The results also illustrate how welfare assessments depend crucially on the rate at which the utility of future generations is discounted by policymakers. In particular, at very high discount rates that put a large weight on the short run, the gains associated with the near-term U.S. demand boom start to dominate the losses experienced at longer horizons.

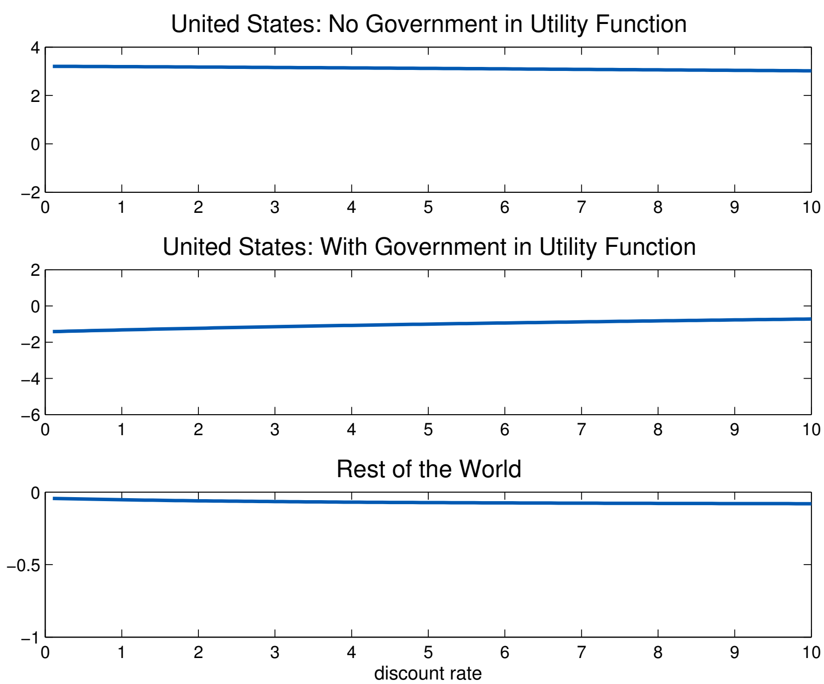
In sum, our study finds no support for the idea that "starving the beast" is a foolproof way towards higher output and welfare. In fact, under many plausible circumstances, it could lead to precisely the opposite outcome.

Figure 1. Base Case



Macroeconomic Effects

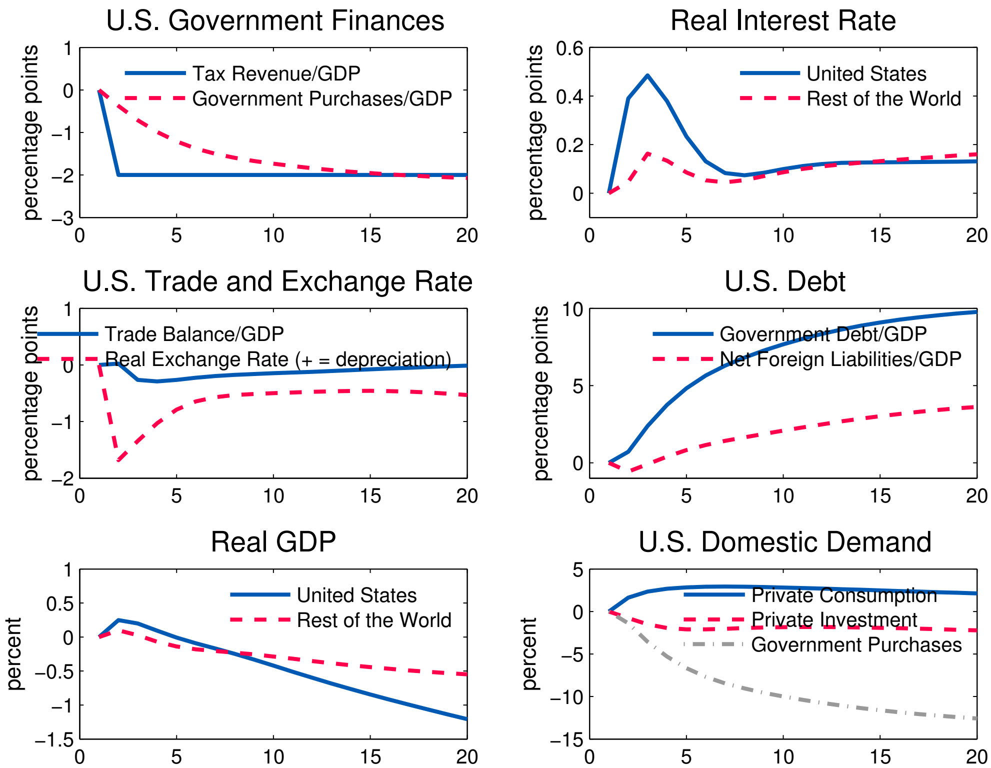
(deviation from initial steady state)



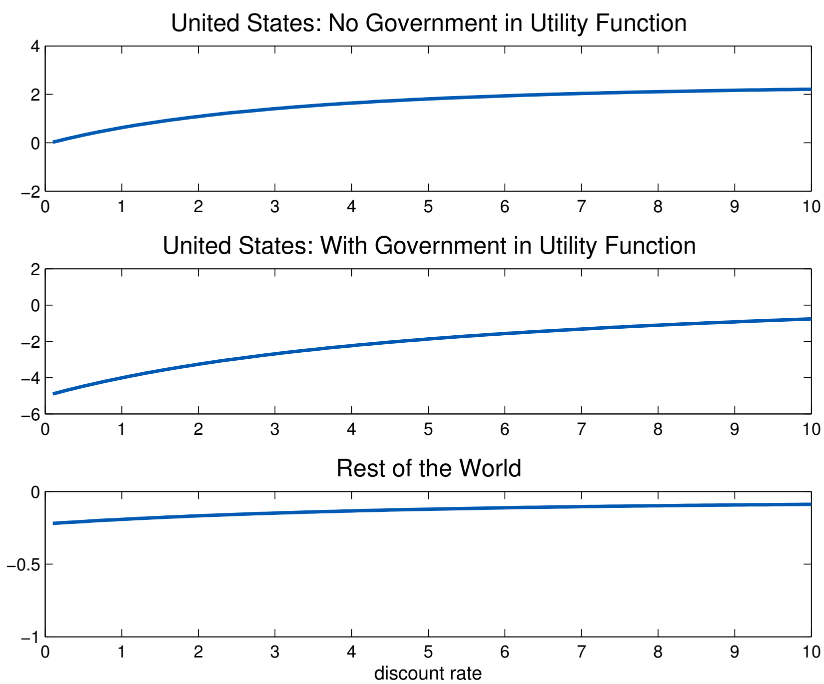
Welfare Effects

(percent of initial steady state consumption)

Figure 2. Slower Expenditure Adjustment

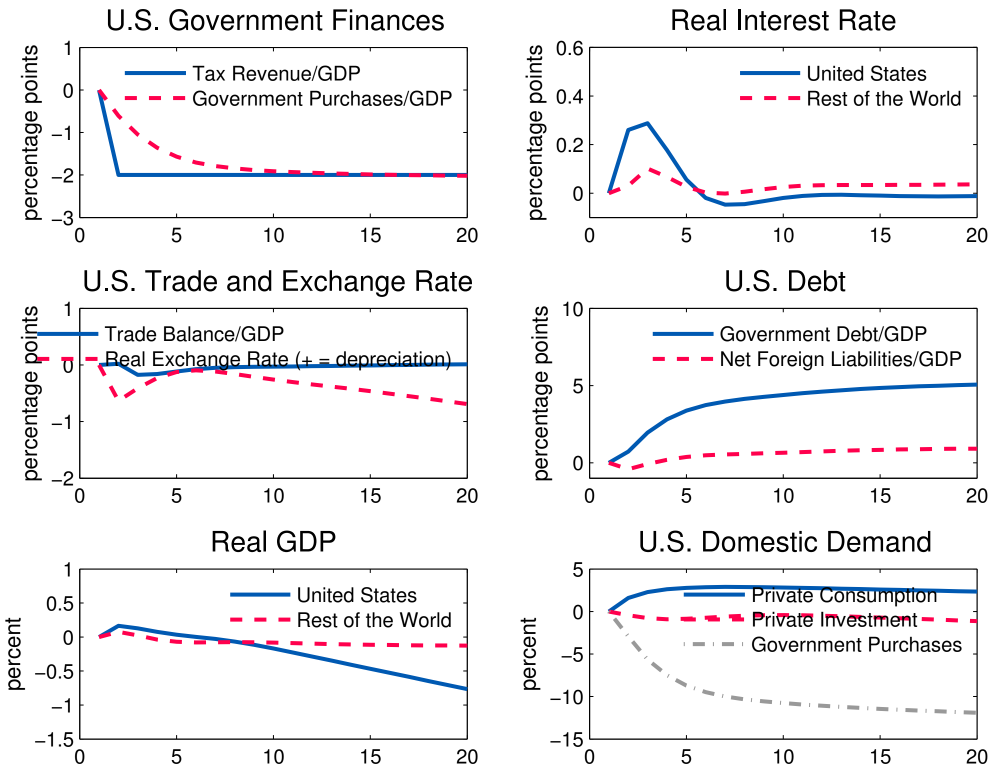


Macroeconomic Effects
(deviation from initial steady state)

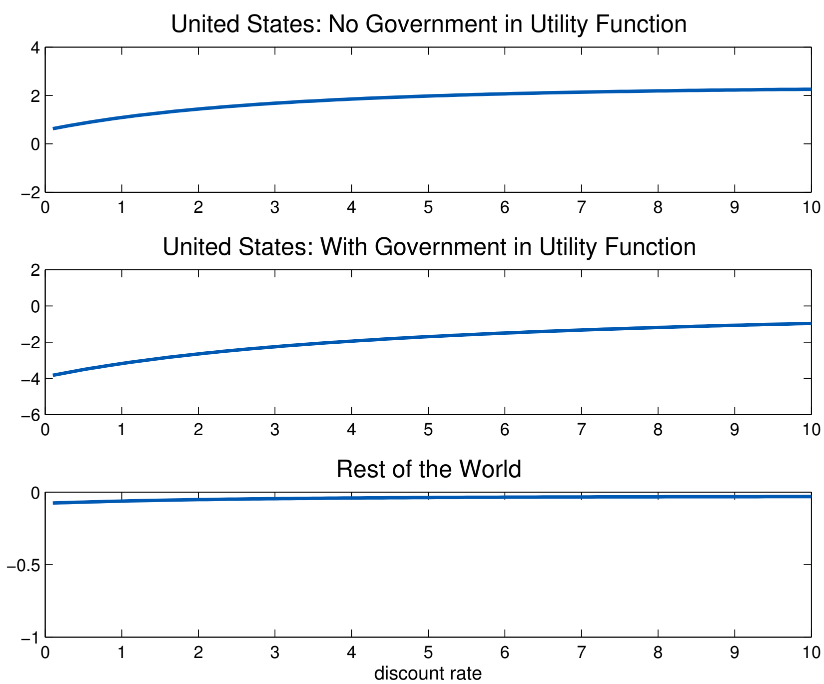


Welfare Effects
(percent of initial steady state consumption)

Figure 3. Government Investment Cut

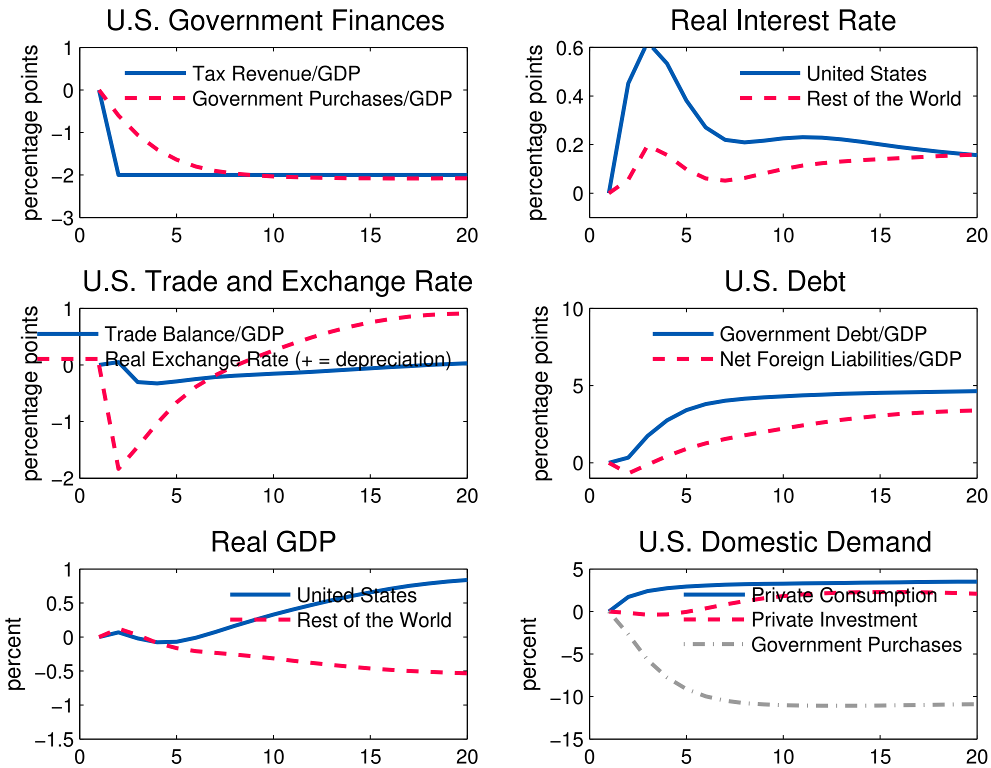


Macroeconomic Effects
(deviation from initial steady state)

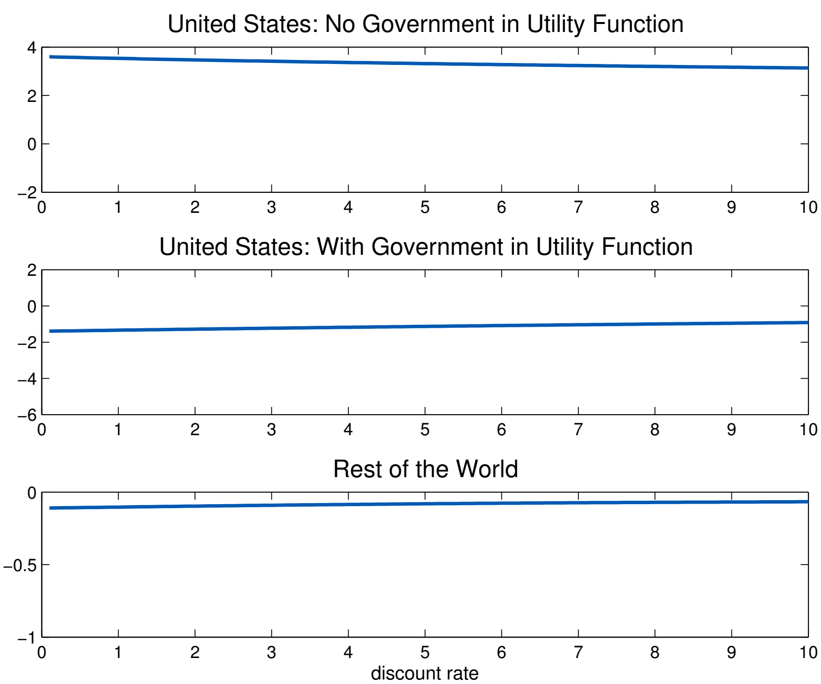


Welfare Effects
(percent of initial steady state consumption)

Figure 4. Capital Income Tax Cut

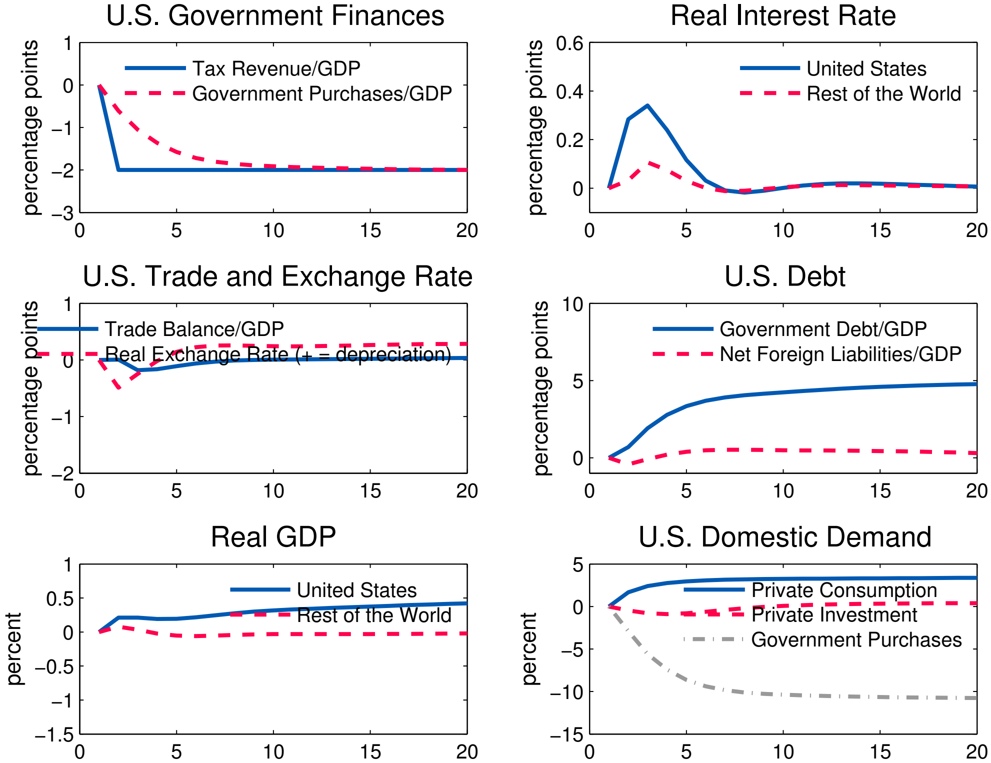


Macroeconomic Effects
(deviation from initial steady state)

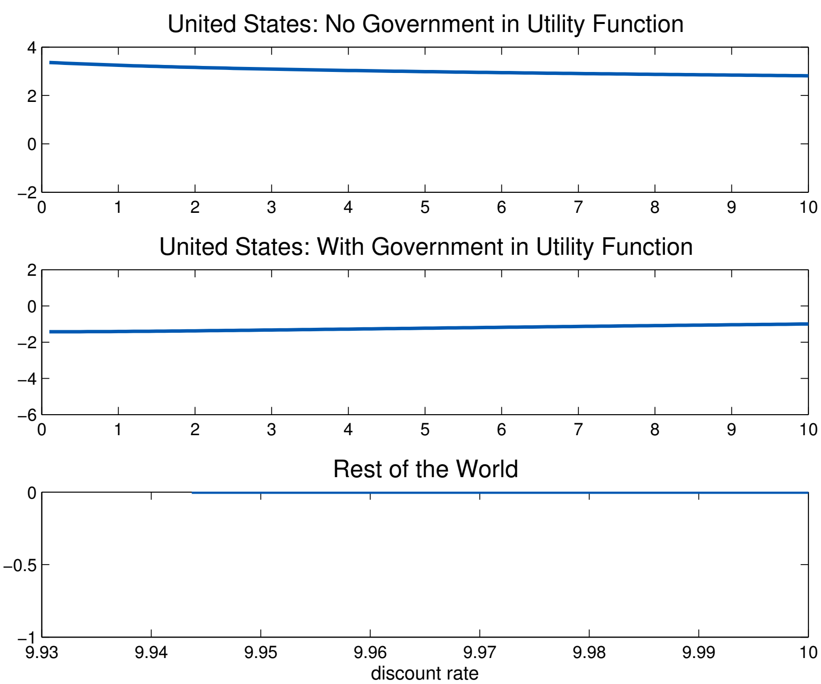


Welfare Effects
(percent of initial steady state consumption)

Figure 5. Longer Planning Horizons

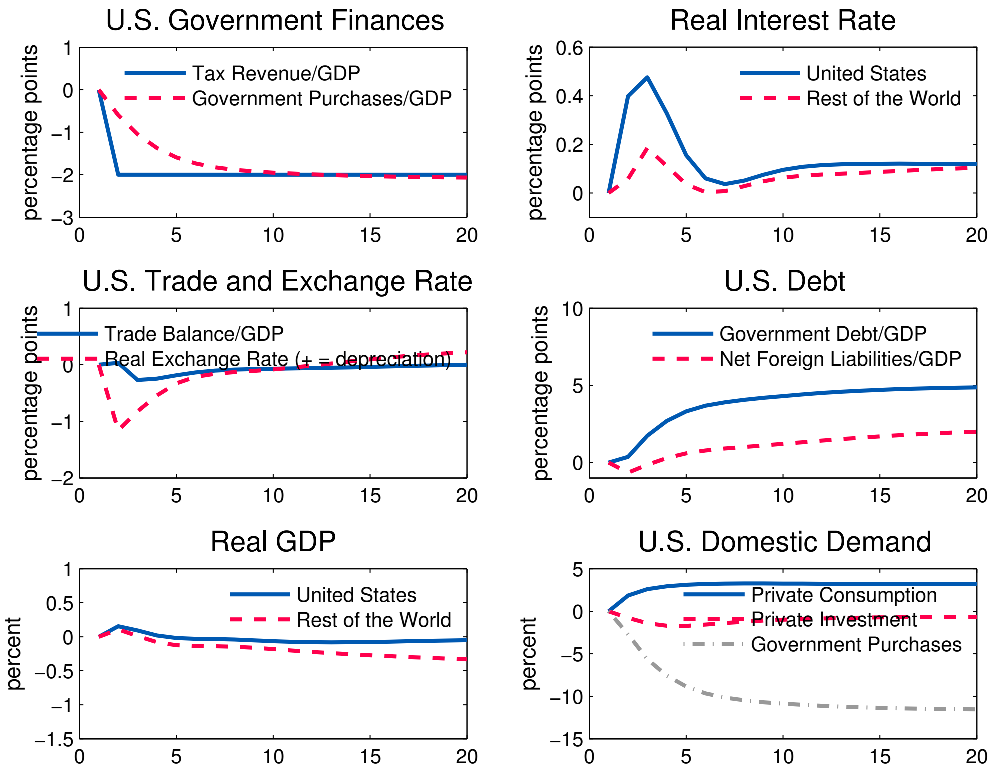


Macroeconomic Effects
(deviation from initial steady state)

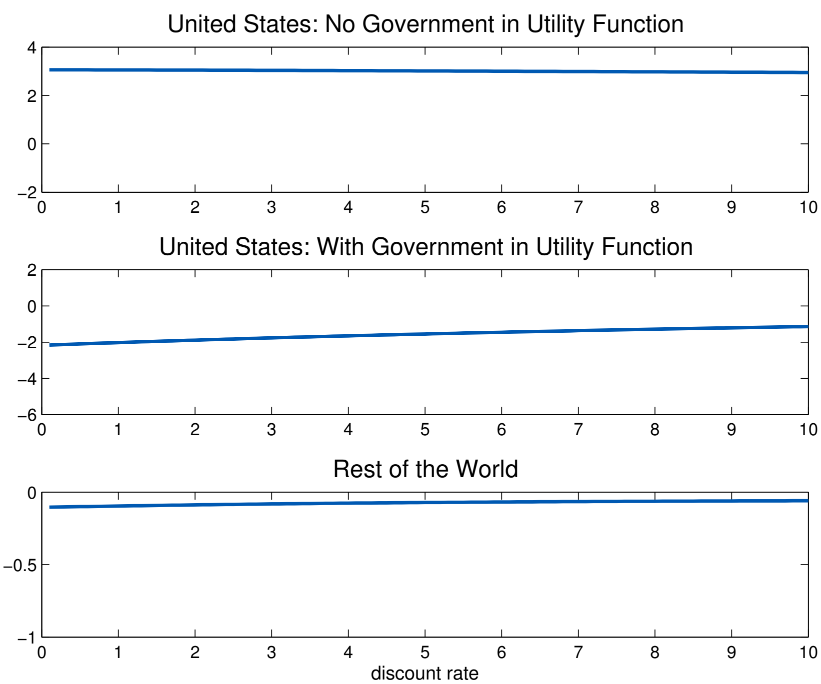


Welfare Effects
(percent of initial steady state consumption)

Figure 6. Inelastic Labor Supply

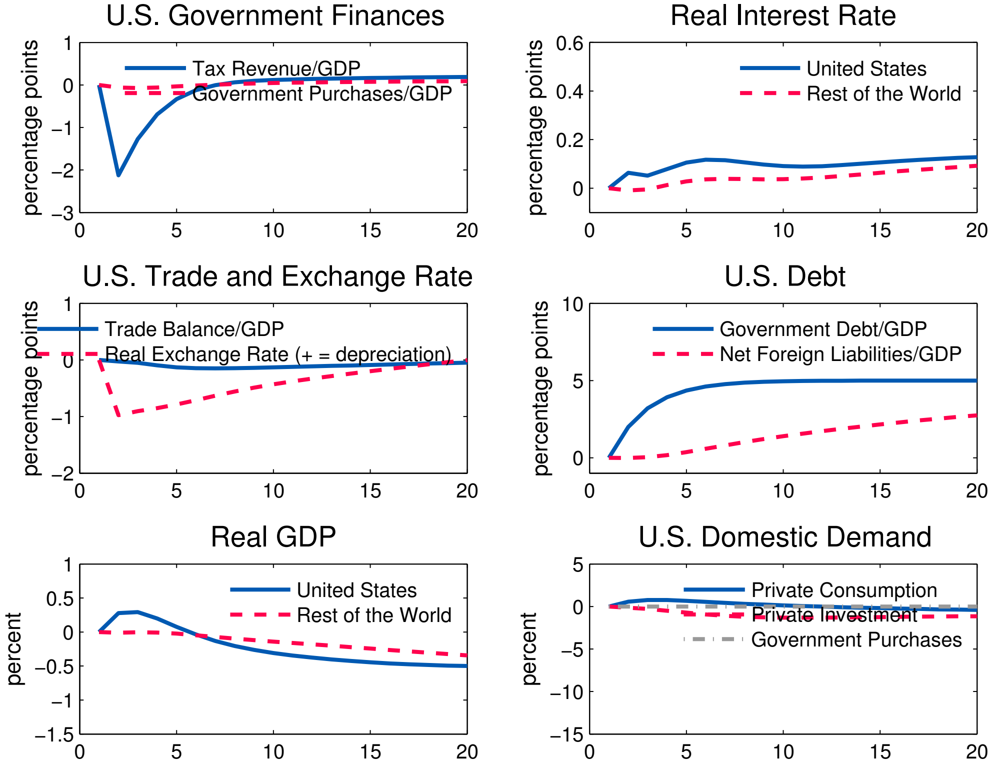


Macroeconomic Effects
(deviation from initial steady state)

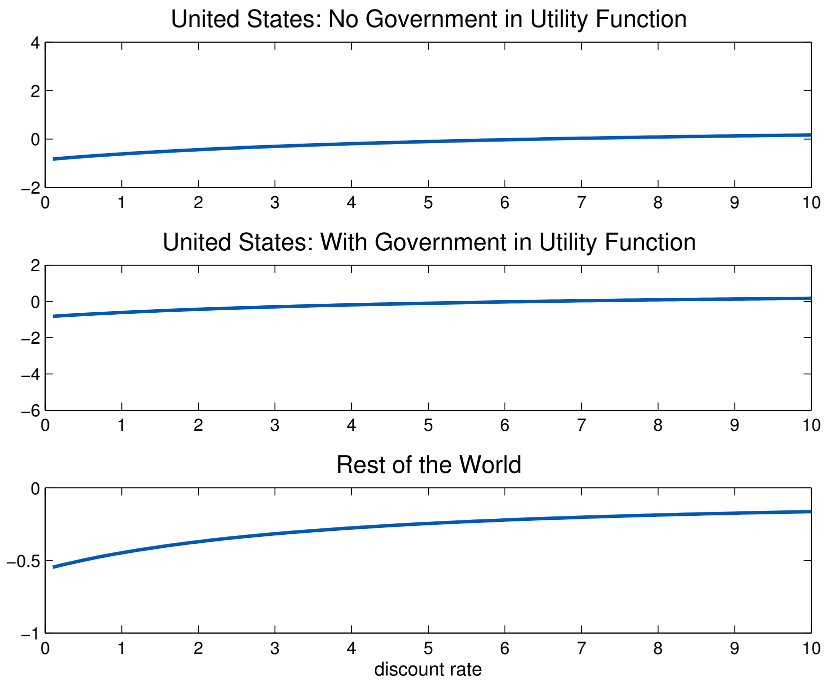


Welfare Effects
(percent of initial steady state consumption)

Figure 7. Undoing the Tax Cut



Macroeconomic Effects
(deviation from initial steady state)



Welfare Effects
(percent of initial steady state consumption)

Table 1. Macroeconomic Effects (in percent deviation from initial steady state)

Experiment	(1) Baseline	(2) Slower Expenditure Adjustment	(3) Government Investment Cut	(4) Capital Income Tax Cut	(5) Longer Planning Horizons	(6) Inelastic Labor Supply	(7) Undoing the Tax Cut
GDP							
United States							
1 year	0.29	0.25	0.16	0.07	0.21	0.15	0.28
10 years	0.02	-0.51	-0.23	0.40	0.33	-0.07	-0.35
50 years	0.21	-2.60	-1.88	0.71	0.44	-0.08	-0.64
RW							
1 year	0.03	0.10	0.08	0.12	0.08	0.11	-0.01
10 years	-0.10	-0.32	-0.09	-0.35	-0.03	-0.20	-0.16
50 years	-0.20	-0.70	-0.19	-0.50	0.02	-0.38	-0.62
Consumption							
United States							
1 year	1.74	1.64	1.59	1.70	1.67	1.86	0.58
10 years	3.42	2.76	2.78	3.31	3.27	3.25	0.06
50 years	3.39	0.71	1.24	3.55	3.50	3.17	-0.79
RW							
1 year	-0.03	0.01	0.01	0.02	0.02	0.02	-0.04
10 years	-0.08	-0.10	-0.03	-0.09	0.00	-0.06	-0.17
50 years	-0.07	-0.28	-0.08	-0.16	0.02	-0.13	-0.55

Table 2. Benchmark Welfare - No Government Spending in Utility Function

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Experiment	Baseline	Slower Expenditure Adjustment	Government Investment Cut	Capital Income Tax Cut	Longer Planning Horizons	Inelastic Labor Supply	Undoing the Tax Cut
United States	3.16	1.41	1.68	3.41	3.09	3.04	-0.30
	(3.20,3.00)	(0.02,2.21)	(0.62,2.25)	(3.59,3.13)	(3.36,2.81)	(3.06,2.95)	(-0.82,0.16)
RW	-0.07	-0.15	-0.05	-0.09	0.01	-0.08	-0.32
	(-0.04,-0.08)	(-0.21,-0.08)	(-0.07,-0.03)	(-0.10,-0.06)	(0.004,-0.00)	(-0.10,-0.05)	(-0.54,-0.16)
Discount rate	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	(0.1, 10)	(0.1, 10)	(0.1, 10)	(0.1, 10)	(0.1, 10)	(0.1, 10)	(0.1, 10)

Note: Table reports compensating variation (CV) based on assumption that government consumption does not contribute to household utility,i.e., an assumed marginal rate of substitution between private and government consumption of zero (mrs=0). Results at the 0.1 percent and 10 percent discount rates in parentheses.

Table 3. Alternative Welfare - With Government Spending in Utility Function

	(1)	(2)	(3)	(4)	(5)	(6)
Experiment	Baseline	Slower Expenditure Adjustment	Government Investment Cut	Capital Income Tax Cut	Longer Planning Horizons	Inelastic Labor Supply
CV with mrs=-1	-1.15	-2.69	-2.25	-1.23	-1.33	-1.77
	(-1.41,-0.72)	(-4.89,-0.76)	(-3.83,-0.96)	(-1.39,-0.91)	(-1.42,-0.99)	(-2.15,-1.13)
Threshold mrs (CV=0)	-0.72	-0.33	-0.41	-0.72	-0.68	-0.61
	(-0.68,-0.79)	(-0.00,-0.73)	(-0.13,-0.68)	(-0.70,-0.75)	(-0.68,-0.72)	(-0.56,-0.70)
Discount rate	3.0	3.0	3.0	3.0	3.0	3.0
	(0.1, 10)	(0.1, 10)	(0.1, 10)	(0.1, 10)	(0.1, 10)	(0.1, 10)

Note: Table reports the compensating variation (CV) in percent of initial steady state consumption based on an assumed marginal rate of substitution between private and government consumption of -1 (mrs = -1). The table also reports the threshold value of the mrs such that there is no change in welfare (CV=0).

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