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Debt in the U.S. Economy*

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Abstract

In 2011, the publicly held debt-to-GDP ratio in the United States reached 68% and is expected to continue rising. Many proposals to curb the government deficit and the resulting debt are being discussed. In this paper, we use the standard neoclassical growth model to examine the future path of output, budget deficits, and debt in the U.S. economy under different tax policies. While this framework is relatively simple, it incorporates the general equilibrium effects of tax policy, which are often missing from the Congressional Budget Office projections. Our results show that debt-to-GNP ratios above 100% are likely to continue into the future and that even small labor supply elasticities have a significant impact on these projections. We also find that labor income tax rates higher than 40% are needed for the deficit-to-GNP ratio to return to its historical level in the long run. Such high tax rates, however, result in about 10% lower per capita GNP and large welfare costs at the steady state compared to the historical tax rates.

JEL Classification: E27, E62, H68

Keywords: Tax distortion; Dynamic Laffer Curve; Debt-to-GNP Ratio.

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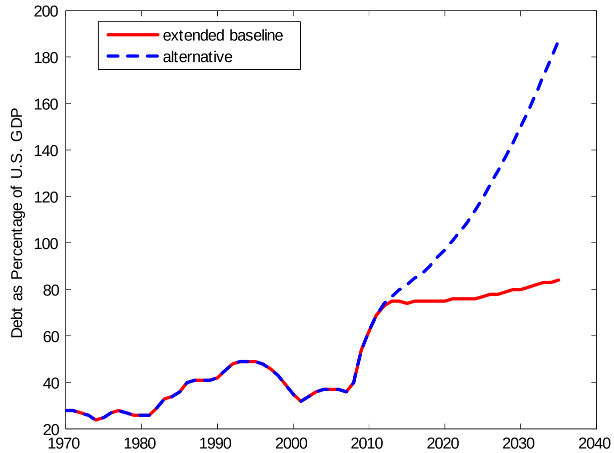

Figure 1: The U.S. Debt-to-GDP Ratio

1 Introduction

The publicly held debt-to-GDP ratio in the United States rose from 36% in 2007 to 68% in 2011, and this trend is not expected to be temporary. Figure 1 displays data on the U.S. debt-to-GDP ratio between 1970 and 2011 as well as two projections on the future debt-to-GDP ratio provided by the Congressional Budget Office (CBO, 2011). Both projections indicate future debt-to-GDP ratios that are significantly higher than the past levels. There are also significant differences between these two projections. The CBO's *extended baseline* scenario results in an 80% debt-to-GDP ratio in 2035, while the *alternative scenario* results in a 187% debt-to-GDP ratio. This fiscal outlook is generating significant academic, public, and political debate in the U.S.[1]

Currently, many proposals regarding how to reduce the government deficit and the resulting debt are being discussed. In this paper, we examine how different assumptions about future tax and spending policies might impact future output and the future debt-to-output ratio in the U.S.[2] We use a standard growth model with an infinite horizon, complete mar-

[1] See for example Cochrane (2012), Barro(2011), and Mankiw (2010).

[2] Throughout this paper, we use the term "debt-to-output" and "debt-to-GNP" interchangeably, since our measurement of output is GNP plus service flows from consumer durables and government capital.

kets framework that has been successful in addressing a variety of economic issues.[3] We calibrate the model economy to the U.S. data for the 1960–2011 period and show that it is able to capture the long-run movements in many of the key variables we are interested in. In particular, the model-generated ratios of deficit and debt to output mimic the actual data from this period reasonably well. We use this model to understand the impact of several potential fiscal policy actions on the future paths of employment, output, deficits, and debt, and then compare our results with the projections provided by the CBO.

Our main purpose is to examine how the reactions of labor and capital to changes in tax policy impact the projected output, and the debt-to-output ratio. To do so, we use a fully calibrated general equilibrium model to analyze the implications of different tax policies on the U.S. economy. The CBO's debt-to-GDP ratio projections shown in Figure 1 do not incorporate the effects of changes in tax policy on factor inputs and therefore on GDP, despite the fact that the marginal tax rates on labor income are assumed to increase from about 25% in 2011 to 35% in 2035 under the CBO's *extended benchmark* scenario.[4] We find that such changes in tax policy will have a significant impact on the future growth rate of output as well as the debt-to-output ratio. While the quantitative results are sensitive to the size of the elasticity of labor supply, the impact of behavioral responses is significant even with small labor supply elasticities.

In the literature there is considerable disagreement about the size of the labor elasticity. While the micro labor literature finds small labor supply elasticities, the macro literature argues for larger elasticities.[5] Chetty, Guren, Manoli, and Weber (2011) conclude that the existing micro evidence points to Frisch elasticities of 0.5 on the intensive margin and 0.25 on the extensive margin. We use a Frisch elasticity of 1.0 as our benchmark calibration to

[3] Our model is similar to the ones used in Cole and Ohanian (1999), Hayashi and Prescott (2002), Kehoe and Prescott (2002), and Chen, İmrohoroğlu, and İmrohoroğlu (2006 and 2009).

[4] For example, CBO (2011) reports that, "The budget projections in most of this report also omit the impact that different effective marginal tax rates would have on people's incentives to work and save. (Although the projections generally do not incorporate those economic effects, the effects are discussed in detail in Chapter 2.)"

[5] See, Blundell and MaCurdy (1999) or Saez, Slemrod and Giertz (2012) for the micro evidence, Rogerson and Wallenius (2009) or Ljungqvist and Sargent (2011) for the macro perspective and Chetty, Guren, Manoli, and Weber (2011) for the link between micro and macro elasticites. Keane (2011) provides an extensive survey of the existing literature. Reichling and Whalen (2012) summarize CBO's perspective on the existing literature.

capture the combined intensive and extensive margins, but also report results for a Frisch elasticity of 0.5.

Our results highlight the importance of incorporating behavioral responses into calculations regarding deficits and debt. Since our analysis is focused on the long-run behavior of the U.S. economy, even small behavioral changes add up to large long-run consequences. We find that the debt-to-output ratio in 2035 could easily be 40% to 70% higher for labor supply elasticities ranging from 0.5 to 1.0. For example, if we ignore the tax disincentives on factor inputs, our baseline tax experiment, which uses the increase in tax rates assumed in the CBO's extended baseline scenario, leads to a debt-to-output ratio of 63% in 2035 and this ratio is below 100% in the long run. However, in a general equilibrium model with a labor supply elasticity of 1.0, under the same tax policy the debt-to-output ratio jumps to 106% by 2035. Furthermore, the magnitude of the tax rate increases used in the CBO's extended benchmark scenario are no longer sufficient to stabilize the debt-to-output ratio below 100% in the long run. Higher debt-to-output ratios in the general equilibrium setting are due to the tax distortions on output growth: between 2011 and 2035, the average annual growth rate of output per capita declines from 1.54% in the economy with exogenous factor inputs to 0.92% once labor and capital are allowed to adjust.

To investigate the relationship between tax rates and the long-run deficit and debt-to-output ratios, we compute dynamic Laffer curves. We find that labor income tax rates in excess of 40% are needed to lower the deficit to output ratio to its historical level in the long run. Such high tax rates, however, result in about 10% lower per capita output and a 4.41% welfare cost compared to the historical tax rates. In addition, we find that an increase in the capital income tax rate alone is not effective in reducing the deficit and the debt-to-output ratios to their historical levels.

Our exercise is related to a large literature on dynamic scoring that discusses the possibility of incorporating the behavioral responses of labor and capital to changes in tax policy when estimating the budgetary effects of legislation. At the heart of the issue is the fact that the revenue projections used by the CBO do not incorporate the macroeconomic effects of changes in tax policy on factor inputs and therefore on GDP and total revenues.[6] Con-

[6]Revenue estimations often incorporate other behavioral responses, such as the impact of a change in the capital gains tax on the timing of the capital gains realizations. Auerbach (2005) provides a good summary.

sequently, the baseline calculations on debt provided by the CBO do not incorporate the responses of labor or capital to changes in tax rates. While many economists favor dynamic scoring, it continues to be a controversial issue. Opponents argue that the results are very sensitive to the choice of economic models, assumptions about parameters, and the methods employed to make this approach useful. Of course, not incorporating behavioral responses constitutes another assumption, the consequences of which can only be examined with the help of an economic model. The experiments we conduct in this paper shed some light on the quantitative implications of assuming no behavioral responses to tax policy changes versus incorporating behavioral responses with different elasticities. Our paper is similar to Mankiw and Weinzierl (2006), who show that the impact of a tax cut on revenues could be significantly different if behavioral responses are taken into account–that is, if dynamic scoring is used as opposed to static scoring. They also use the neoclassical growth model but focus more on measuring the steady-state differences across these approaches. We model and calibrate the transition as well as the past history of the U.S. responses to tax rate changes in more detail in order to understand the impact of behavioral responses on the economic variables in the near future. We argue that the neoclassical growth model can indeed be a useful tool to study the impact of tax policy on long-run projections for the U.S. economy.

There are many important issues regarding deficits and debt that we leave for future work. We do not have a theory of debt. In our model, high debt levels do not have any negative effects on interest rates or economic growth. We take the rate of return on government debt as exogenous and therefore cannot address potential changes in interest rates following extended deficits. Moreover, our model is silent on the potential impact of tax distortion on the trend growth rate of output via, for example, human capital accumulation. We also abstract from issues related to social security and demographics, a topic where, for example, Birkeland and Prescott (2007) argue that with changing demographics, large government debt, as high as five times the gross national income, may be optimal in order to finance the U.S. retirement system in the U.S. We leave the questions about the impact of debt on different generations for future work.[7]

[7] Chen, İmrohoroğlu, and İmrohoroğlu (2007) and Braun, Ikeda, and Joines (2009) develop overlapping generations models with incomplete markets to study the Japanese economy. By construction, these models deliver richer implications by disaggregating the economy into cohorts and different income and wealth groups. However, their aggregate predictions on the main macro variables seem to be consistent with those from the

In Section 2, we summarize the model economy. Calibration is presented in Section 3 and the results in Section 4. Section 5 concludes. The Appendix contains a definition of competitive equilibrium, a summary of equilibrium conditions, and a measurement of the welfare costs of tax distortions.

2 The Standard Neoclassical Growth Model

In this model, a representative household makes consumption and saving decisions by taking the factor prices and government policy as given. A stand-in firm maximizes its profits, setting each factor price equal to its marginal productivity. There is a government that finances exogenously given government purchases and transfer payments by taxing factor incomes and consumption, or by issuing new one-period bonds at an exogenously given interest rate. The engine of growth in the model is exogenously growing TFP. In this perfect foresight environment agents maximize their objective functions, taking into account future policy actions and prices.[8] Below, we present our model in detail.

2.1 The Household's Problem

Time is discrete, starting from period 0. There is a representative household with N_t working-age members at date t, facing the following problem in a complete markets environment:

$$\max \sum_{t=0}^{\infty} \beta^t N_t [\log c_t - \chi \frac{h_t^{1+\frac{1}{\gamma}}}{1+\frac{1}{\gamma}}] \tag{1}$$

subject to

$$C_t + K_{t+1} \leq [1 + (1 - \tau_{k,t})(r_t - \delta_t)]K_t + (1 - \tau_{h,t})w_t H_t + TR_t + \Pi_t^p,$$

where $c_t = C_t/N_t$ is consumption per household member, $h_t = H_t/N_t$ is the fraction of hours worked per member of the household, β is the subjective discount factor, χ is a parameter

standard model with an infinite horizon and complete markets.

[8] Chen, İmrohoroğlu, and İmrohoroğlu (2006) show that the impact of the perfect foresight assumption is fairly innocuous in this setting. However, it is possible that uncertainty about future fiscal policy may have important consequences on the business cycle properties of the U.S. economy such as in Fernandez-Villaverde, Kuester, Guerron, and Rubio-Ramirez (2012).

that indicates the relative weight of leisure in the utility function and γ determines the Frisch elasticity of labor supply. H_t is total hours worked by all working-age members of the household, $\tau_{h,t}$ and $\tau_{k,t}$ are the respective tax rates on labor and capital income, w_t is the real wage, TR_t is aggregate government transfers, and Π_t^p is a lump-sum subsidy, set equal to the government's primary budget balance. The rental rate of capital is denoted by r_t, and δ_t is the time-t depreciation rate.[9] The beginning-of-period t assets are denoted by K_t. Population growth is given by the change in the size of the household, which evolves over time exogenously at the rate $n_t = N_t/N_{t-1}$.

It is well known that the neoclassical growth model has difficulty accounting for the hours boom in the 1990s. To generate more reasonable results with the model, we feed in a labor wedge, as in Chari, Kehoe, and McGrattan (2007) or Ohanian, Raffo, and Rogerson (2008).[10]

The labor wedge, Δ_t^H, is defined to satisfy the following equation when consumption, c_t, hours worked, h_t, and output, y_t, are all taken from the data:

$$\frac{-u_{h_t}\left(c_t, 1-h_t\right)}{u_{c_t}\left(c_t, 1-h_t\right)} = \Delta_t^H \left(1-\tau_{h,t}\right) MPL_t,$$

where u_x ($x = c_t$ or h_t) is the partial derivative of period utility to x, and MPL_t denotes the marginal product of labor. After computing the labor wedge, we replace $(1-\tau_{h,t})$ in the first order condition for the consumption-leisure trade off with $(1-\tau_{h,t})\Delta_t^H$. Since taxes are already included in this model, the labor wedge is interpreted as a proxy for changes in labor distortions other than taxes. Other interpretations of the changes in the labor wedge may be related to factors that caused increases in the female labor force participation or the intangible capital explanation advanced by McGrattan and Prescott (2010), or the change in wage markups argued by Smets and Wouters (2007).

[9] Lower case letters refer to per-capita items and upper case letters denote economy-wide aggregate quantities.

[10] See McGrattan and Prescott (2010) for a discussion of this issue. Since we only feed in the labor wedge and not the other wedges, the model-generated hours per capita will not necessarily be the same as in the data.

2.2 The Firm's Problem

There is a representative firm with access to a constant returns to scale Cobb-Douglas production function given by:

$$Y_t = A_t K_t^{\theta} H_t{}^{1-\theta},$$

where Y_t is output at time t, A_t is total factor productivity, which grows exogenously at the rate $g_{A,t} = A_t/A_{t-1}$, and θ is the income share of capital. The aggregate capital stock, K_t, follows the law of motion:

$$K_{t+1} = (1-\delta_t)K_t + X_t, \tag{2}$$

where X_t is gross investment at period t.

The representative firm maximizes its profits by choosing capital and labor inputs, taking factor prices as given. This produces the usual equilibrium conditions that equate factor prices with their marginal productivity.

2.3 The Government Budget

The government faces exogenously given streams of government purchases G_t, government investment GI_t, transfer payments TR_t, and interest rate on debt i_t. These expenditures can be financed by taxing income from labor and capital or by raising new debt, B^g_{t+1}. In this paper, we do not explicitly model government debt, as this requires a way of introducing private capital's rate-of-return dominance over government debt, observed in the data, which is beyond the scope of this paper. Instead, we focus on the additions to existing debt by carefully modeling the government's flow budget constraint. We specify the government budgets as follows:

$$G_t + GI_t + TR_t + B^g_t\,(1+i_t) = \tau_{h,t} w_t H_t + \tau_{k,t}(r_t - \delta_t)K_t + B^g_{t+1}\frac{P_{t+1}}{P_t}, \tag{3}$$

where $\frac{P_{t+1}}{P_t}$ is the inflation rate. The primary budget balance is defined as:

$$\Pi^p_t \equiv \tau_{h,t} w_t H_t + \tau_{k,t}(r_t - \delta_t)K_t - (G_t + TR_t)\,. \tag{4}$$

The overall budget balance can be defined as $\Pi^b_t \equiv \Pi^p_t - I_t$, where $I_t \equiv B^g_t i_t$ is interest payment on government debt.

Plugging equation (4) into the household budget constraint, we get:

$$C_t + K_{t+1} \leq [1 + r_t - \delta_t]K_t + w_t H_t - G_t. \tag{5}$$

Equation (5) implies that given $\{G_t\}_{t=0}^{\infty}$, any tax sequence of $\{\tau_{h,t}, \tau_{k,t}\}_{t=0}^{\infty}$ influences the economy only through substitution effects. Stated differently, in our model government debt has no crowding-out effect on physical capital in our model. Equations (3) and (4) imply that $\Pi_t^p = GI_t + B_t^g(1+i_t) - B_{t+1}^g \frac{P_{t+1}}{P_t}$, which, combined with household's budget constraint, gives:

$$\begin{aligned} C_t + X_t - GI_t + B_{t+1}^g \frac{P_{t+1}}{P_t} \quad \leq \quad & [(1-\tau_{k,t})r_t + \tau_{k,t}\delta_t] K_t \\ & +(1-\tau_{h,t})w_t H_t + TR_t + B_t^g(1+i_t). \end{aligned} \tag{6}$$

Equation (6) shows that, implicitly, government debt is part of the household portfolio in our model. Note here that the variables $\{GI_t, B_t^g\}_{t=0}^{\infty}$ are exogenous to the household.

It should be emphasized that we do not have a theory as to household's holding of government debt. There is no consensus in the literature on the optimal size of government debt primarily because there is no agreement on a theory of debt. For this reason, we concentrate on the effects that financing government debts has on the economy as well as how fiscal policy affects the size of this debt. In this sense, government debt is endogenous in our model, as we determine its level by accumulating budget deficits that are endogenously determined by the interaction of demographics, fiscal policy, and private sector behavior. Note that the projected increases in TR_t incorporates the impact of the demographic transition on expenditures, and the U.S. government's fiscal policy is represented with the assumed paths of the expenditure items and the tax rates. Finally, the private sector optimally responds to changes in this environment by adjusting its consumption-saving behavior, and the general equilibrium effects show up as the wage rate and rate of return to capital adjust accordingly.

2.3.1 Constructing the Model's Debt-Output Ratio

We now derive the law of motion for the government debt and the debt-output ratio. To be consistent with the NIPA accounts, we first specify the law of motion of government debt in nominal terms. Equations (3) and (4), together with the definition of overall budget balance, imply that the evolution of debt in nominal terms is as follows:

$$\widehat{B}^g_{t+1} = \widehat{B}^g_t + \widehat{GB}_t, \tag{7}$$

where for every real variable x_t ($x_t = B^g_t$ or GB_t), $\widehat{x}_t$ denotes the corresponding nominal variable, given as $\widehat{x}_t = P_t x_t$. $\widehat{GB}_t$ denotes net borrowing, defined as $\widehat{GB}_t \equiv \widehat{GI}_t - \widehat{\Pi}^b_t$.

All the variables in our model are real and detrended, so we need to deflate and detrend the above law of motion for government debt. In real terms, equation (7) can be written as:

$$B^g_{t+1} = \left(B^g_t + GB_t\right) P_t/P_{t+1},$$

where P_t/P_{t+1} is the inverse of the inflation rate.

Accordingly, the law of motion of the debt-to-output ratio is as follows:

$$\frac{B^g_{t+1}}{Y_{t+1}} = \frac{\left(B^g_t + GB_t\right)}{Y_t} \frac{P_t}{P_{t+1}} \frac{Y_t}{Y_{t+1}}. \tag{8}$$

To compute interest payments on government debt as part of net government borrowing, we need to specify the interest rate on government debt. In this paper, we take the interest rate on government debt as exogenous. As equation (8) implies, the relevant interest rate to compute the debt is the nominal interest rate, once we explicitly take the inflation rate into account.

At the steady state, the debt-to-output ratio is given by:

$$\frac{B^g}{Y} = \frac{\left(GI - \Pi^p\right)/Y}{gn\frac{P_{t+1}}{P_t} - 1 - i}, \tag{9}$$

where $g \equiv g_A^{\frac{1}{1-\theta}}$ is the growth rate of output per capita at the steady state.

The debt-to-output ratio is the primary deficit (plus government investment) to output ratio, divided by some discount rate. The discount rate is positively related to the economy's nominal growth rate at the steady state, $gn\frac{P_{t+1}}{P_t} - 1$, and is negatively related to the nominal interest rate on government debt, i. At the steady state, since both the nominal growth rate of the economy and interest rate on government debt is determined by exogenous parameters that are independent of fiscal policies, there is a one to one mapping between the deficit to output ratio and the debt-to-output ratio.

2.4 The Role of Taxes

Our main purpose is to investigate the role of taxes in the projected debt-to-output ratios. The CBO's projections do not incorporate the distortionary impact of higher taxes on labor supply and tend to overestimate the impact of higher tax rates on curbing the debt-to-output ratio. We examine the quantitative impact of this assumption in the results section. Qualitatively, higher taxes have two effects. First, higher tax rates tend to reduce the debt-to-output ratio through their positive impact on tax revenues. Second, their negative impact on output mitigates some of the increase in tax revenues.

Equation (10) shows that an increase in $\tau_{h,t}$ or $\tau_{k,t}$ has a positive impact on the revenue-output ratio, given by $\tau_{h,t}(1-\theta)$ and $\tau_{k,t}\theta$, respectively:

$$\begin{aligned}\frac{\Pi_t^b}{Y_t} &= \frac{\tau_{h,t}w_tH_t + \tau_{k,t}(r_t-\delta_t)K_t}{Y_t} - \frac{(G_t+TR_t+I_t)}{Y_t} \\ &= \tau_{h,t}(1-\theta) + \tau_{k,t}\theta - \tau_{k,t}\frac{\delta_tK_t}{Y_t} - \frac{(G_t+TR_t+I_t)}{Y_t}. \qquad (10)\end{aligned}$$

However, a higher $\tau_{h,t}$ ($\tau_{k,t}$) reduces the level of Y_t via its distortionary impact on H_t (K_t). The reduction in Y_t increases the deficit-output ratio via the last two terms in equation (10).[11] The magnitude of the change in Y_t depends on the Frisch elasticity of labor supply.

3 Measurement and Calibration

This section summarizes the adjustments made to observed macroeconomic aggregates and government accounts so that the data accounts are aligned with our model accounts as well as with the calibration of the economy.

[11] These effects are also discussed in the dynamic Laffer curve literature, such as Ireland (1994) and Pecorino (1995), among others.

3.1 Adjustments to National Accounts

We use data from the 2012 revision of the National Income and Product Accounts (NIPA) and the Fixed Asset Tables (FAT) from Bureau of Economic Analysis (BEA) for the years 1960–2011. Our adjustments to measured macroeconomic aggregates follow Cooley and Prescott (1995). We define capital K as the sum of the fixed assets, stock of consumer durables, inventory stock, and net foreign assets. Incorporating net foreign assets into the measurement of K allows the model economy to capture the part of U.S. government debt that is held by foreigners. Consequently, output Y corresponds to GNP plus the service flows from government capital and consumer durables. To accurately compare our findings with the government reports, we convert the data that are reported as the ratios of GDP into the ratios of GNP whenever necessary. Capital depreciation is the sum of consumption of fixed capital and the depreciation of consumer durables.

3.2 Adjustments to the Government Debt

This subsection describes how the general government accounts are arranged so that the government accounts in the data are in line with those in the model. The aim is to have the primary and the overall budget balances in the data and model aligned conceptually. The paper's ultimate goal is to quantify how closely the standard growth theory comes to generating the historical budget balance and debt figures and to use the model to deliver both medium- and long-run predictions on both the government accounts and national accounts.

The budget balance, $\tau_{h,t}w_tH_t + \tau_{k,t}(r_t - \delta_t)K_t - (G_t + TR_t + I_t)$, corresponds to net government saving in the NIPA data. The government tax revenues, $\tau_{h,t}w_tH_t+\tau_{k,t}(r_t-\delta_t)K_t$, are measured as current receipts in the data. G_t is measured as government consumption. Transfer payments, TR_t, are calculated as the difference between current transfer payments and current transfer receipts. The interest payment on government debt, I_t, is calculated as the difference between interest payments and income receipts on asset.

Finally, net borrowing, GB_t, is calculated in the data as

Current Receipts − Transfer Payments − Interest Payments − Government Consumption −

Gross Government Investment + Consumption of Fixed Capital

Note that net borrowing, GB_t, includes both the budget deficit ($-\Pi_t^b$) and net government investment (GI_t). Since our model does not have government production, in our model we construct government investment as the product of model-generated output and the share of net government investment in total output from the data.[12] We then add GI_t back to the model's simulated budget deficit to generate net borrowing that comparable to the data.

After we compute the net borrowing in the data, we construct government debt in each year between 1961 and 2010 following equation (7), taking the 1959 value of the federal government debt held by the public as the initial debt level for 1960. The growth rate of our measured government debt between 1961 and 2011 closely tracks the growth rate of federal government debt held by the public.

3.3 Calibration

The starting year for the analysis is 1960, and 2011 is the last year for which we have data for all of the variables. The model takes the observations for the exogenous inputs as given for the 1960–2011 period and makes certain assumptions about their values for 2012 and beyond. It is assumed that a steady state will be reached far into the future, so we have a two-point boundary problem, starting with the given initial conditions in 1960, and ending at the steady state. Since the steady state is in the far future, the steady-state values do not affect our short-term predictions.

The following two subsections present the calibration choices in detail, summarizing the parameters that are constant throughout the analysis, the exogenous variables for which we have direct observations, and the assumptions made for the values of these exogenous variables for 2012 and beyond.

While there are many calibration issues, it may be useful to provide an overall summary for the growth rate of two of the variables that are critical for the evolution of the debt-to-output ratio that is given in equation (8). These are the growth rate of output and the inflation rate. After 2011, we assume the annual inflation rate will be 2%. The output growth rate, determined endogenously, turns out to be 2.1% at the steady state. The CBO's assumptions for the annual inflation rate and the growth rate of output in the long run are

[12] Our quantitative results below are robust to the exclusion of government investment, since, in reality, it is a tiny fraction of GDP.

2% and 2.2%, respectively.

3.3.1 Constant Parameters

Throughout our analysis, there are three parameters that are time invariant. The capital share parameter, θ, is set to 0.4. The subjective discount factor, β, is set to 0.969 so that the capital-output ratio is 3.2 at the final steady state. In our benchmark calibration we set the Frisch elasticity of labor supply equal to one but also provide results with a Frisch elasticity of 0.5. We set the parameter for the disutility of labor, χ, to 6.16 when $\gamma = 1$, and to 18.16 when $\gamma = 0.5$ so that both economies match an average U.S. workweek of 35 hours for the 1960–2011 period.

3.3.2 Inputs for 1960–2011 and Beyond

Calibration of the Initial Conditions: We use the initial capital-output ratio for the U.S. in 1960, 3.2, to pin down the initial capital stock. In addition, the initial debt level in 1960 is set to target an initial debt-to-output ratio of 39.8%, which is the ratio of federal government debt held by the public to output at the beginning of 1960. We also set the initial level of government expenditures and transfers to their 1960 levels.

Calibration of the 1960–2011 period: In our benchmark simulation, we use the actual U.S. time series data between 1960–2011 for TFP growth rates, $g_{A,t} - 1$; population growth rates, $n_t - 1$; the level of government purchases, G_t; the level of transfer payments, TR_t; the depreciation rate, δ_t; and capital and labor income tax rates, $\tau_{k,t}, \tau_{h,t}$.[13] The annual inflation rate, P_{t+1}/P_t, is taken as the growth rate of the GNP deflator. We take the nominal interest rate on government bonds as exogenously given. There are several possible choices to to use as a proxy for this interest rate. Given that U.S. government bonds are issued in many different maturities, we chose to compute the implicit interest rate as the ratio of government interest payments to the stock of the previous period's gross federal debt. Figure 2 displays this imputed interest rate against the three-month T-bill rate and the 10-year Treasury note rate between 1960 and 2010 as well as the projections used by the

[13] Specifically, the initial government consumption and transfer payment are calibrated to match the ratios $\frac{G_t}{K_t}$ and $\frac{TR_t}{K_t}$ at 1960. We then construct $\{G_t, TR_t\}_{1960}^{2011}$ using the corresponding growth rates from NIPA data.

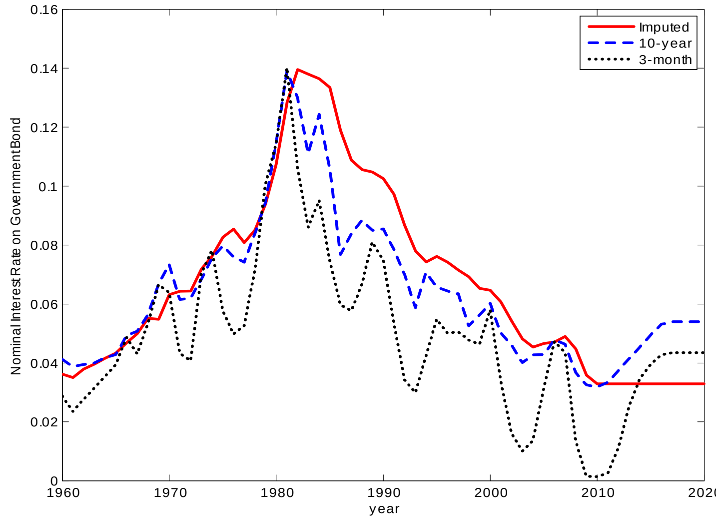

Figure 2: Nominal Rates

CBO for the T-bill and T-note rates until 2020.

We use data from Statistics of Income (SOI) on individual income tax returns (1960–2010), the Social Security Bulletin, and the National Incomes and Product Accounts (1960-2011), and the method used in Joines (1981) and McGrattan (1994) to construct the marginal tax rates. As Prescott (2004) shows, in an infinite horizon framework, the consumption tax rate and the labor income tax rate generate the same distortions on the labor–leisure choice. Thus, the effective marginal tax rate on labor income is calculated as the combination of the labor and consumption tax rates.

Calibration beyond 2012 and the steady state: We set the TFP growth rate after 2012 and at the steady state equal to its long run average of 1.1% per year (which implies an annual TFP factor growth rate of 1.36%). We set the depreciation rate, δ, and the population growth rate after 2011 and at the steady state equal to their values in 2011. We assume the inflation rate after 2011 to be 2% and the nominal interest rates on government bonds to be 3.3%; both are consistent with the CBO assumptions.

For the benchmark economy, we use the projections for tax rates given by the CBO's *extended benchmark* scenario. In this case, the CBO assumes that the tax cuts that were enacted since 2001 are allowed to expire as scheduled in 2012 and that the exemption amounts for the individual alternative minimum tax (AMT) revert to their 2001 levels in 2012. Both of these assumptions result in marginal tax rates on labor income to increase from about 25% in 2011 to 35% in 2035. In addition, the CBO assumes that the marginal tax rate on capital income increases by 8 percentage points (from 12% to 20%) between 2011 and 2013.[14] We use the CBO assumptions underlying its extended benchmark scenario, not because we think these tax paths are likely to be realized in the U.S. but more as examples of tax rates that lead to stable debt-to-output ratios in the future if behavioral responses are ignored. Since CBO projections omit the impact of different tax rates on people's incentives to work and save, tax revenues in this scenario rise significantly after 2010, which result in the projected debt-to-GNP ratio of 73% in 2035.[15] Specifically, we use the tax rates assumed in the CBO's *extended baseline* scenario until 2035 and set the tax rates after 2035 and at the steady state equal to their 2035 values, which are $\tau_k = 41.25\%$ and $\tau_h = 35.61\%$. Later, in our alternative experiments, where tax rates are assumed to continue at their historical rates, we set both τ_k and τ_h after 2011 and at the steady state equal to their values in 2011, $\tau_k = 33.25\%$ and $\tau_h = 25.61\%$.

Table 1 summarizes the constant parameters and the exogenous variables at the steady state. In addition, Figure 3 plots the data and the assumptions for the future path of the capital and labor income tax rates, the population growth rate, and the growth rate of the TFP factor. To compare these series, we plot both the projected tax series given by the extended benchmark scenario of the CBO and the series where tax rates after 2011 are constant at their 2011 levels.

In our benchmark calibration, we use data from the CBO's *extended benchmark* scenario for the projections on government expenditures and transfer payments. Later, we also conduct an experiment with government expenditure and transfer payment projections proposed by the Bowles-Simpson Commission.[16] Both the CBO and the Bowles-Simpson

[14] In particular, the labor income tax rate increases by 3 percentage points between 2011 and 2012, 1 percentage point between 2012 and 2013, and then steadily 6 percentage points until 2035. Similarly, the capital income tax rate increases by 2 percentage points between 2011 and 2012 and 6 percentage points between 2012 and 2013 and remains constant afterwards.

[15] The CBO makes projections on debt-to-GDP ratios. In order to make the numbers comparable, we have calculated the debt-to-GNP ratio that would have resulted in the CBO projections. The 73% debt-to-GNP ratio corresponds to the 80% debt-to-GDP ratio reported by the CBO. Specifically, we used our measured real GNP in 2010 and the projected growth rate of real GDP beyond 2010 by CBO to project the corresponding level of real GNP. The projected debt-to-GNP ratio is then obtained as the ratio of the CBO's projected level of real debt to the projected level of real GNP.

[16] The National Commission on Fiscal Responsibility and Reform was created by Pres-

Table 1: Parameter Values

Constant Parameters		
θ	Capital Income Share	0.40
α	Utility Parameter for Leisure	1.45
β	Subjective Discount Factor	0.969
Exogenous Variables at Steady State (%)		
$g_A - 1$	TFP Growth Rate	0.81
$n - 1$	Population Growth Rate	0.75
δ	Depreciation Rate	6.29
τ_k	Capital Income Tax Rate	41.25
τ_n	Labor Income Tax Rate	35.61

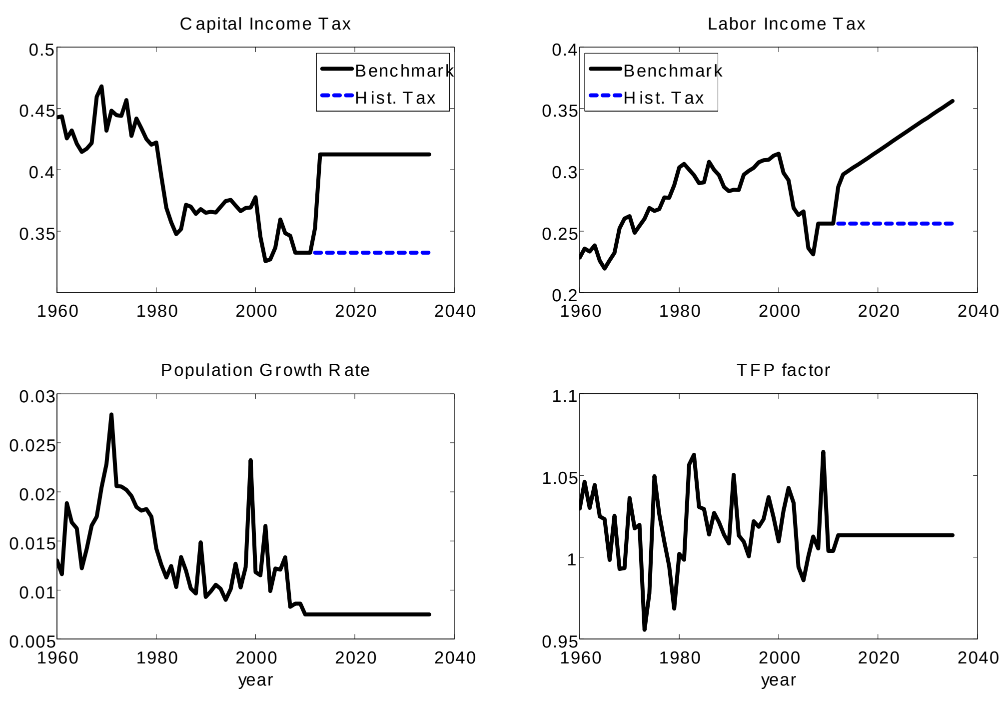

Figure 3: Data and Assumptions for the Future

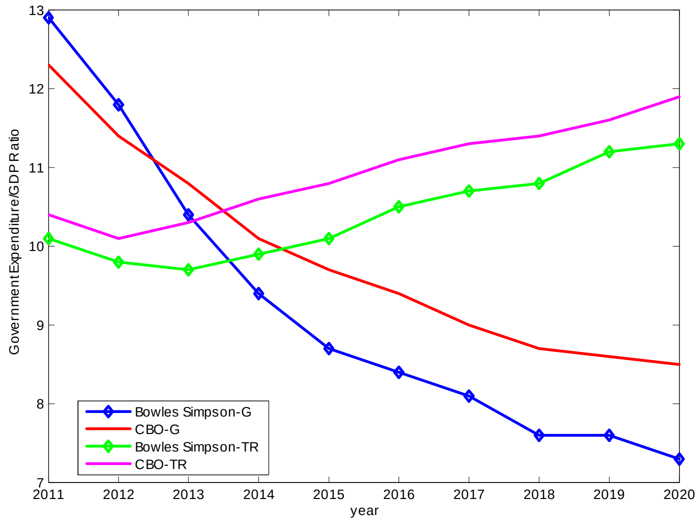

Figure 4: Expenditures as a Percent of GDP

Commission provide projections on different categories of federal government spending. In the CBO projection, TR_t is computed as the sum of Social Security, Medicare, Medicaid, CHIP, and Exchange Subsidies, while G_t, together with net government investment, constitutes the other non-interest payments. For the Bowles-Simpson projections, we combine their projections on Social Security and health care expenditures into TR_t and "other mandatory spending" and "discretionary spending" into G_t. Figure 4 summarizes the differences between the CBO and Bowles-Simpson projections.

Specifically, we use the growth rate of the level of expenditures and transfers implied by these projections in our simulations. This leads to endogenous ratios of expenditures to output in our model, since Y_t is endogenous. For the period after 2035 and at the steady state, we set the growth rate of expenditures and transfers equal to the growth rate of output at the steady state, given by gn, to be consistent with the balanced growth path. It is important to mention that the projections by the CBO and the Bowles-Simpson plan are for the federal government expenditures and revenues only. In our benchmark exercises, we assume that state and local government expenditures will decline at the same rate as federal

ident Obama in 2010 to identify policies to improve the U.S. fiscal situation. Erskine Bowles and Alan Simpson co-chaired the commission. Their report can be found at: http://www.fiscalcommission.gov/sites/fiscalcommission.gov/files/documents/TheMomentofTruth12_1_2010.pdf expenditures as projected by the CBO. Later, we examine the sensitivity of our results to this assumption, taking into account the fact that the federal government constitutes about 40% of total U.S. government consumption and 33% of government investment.

4 Main Results

We start this section by examining the model's performance for the 1960–2011 period. Next, we examine its projections on the debt-to-GNP ratio through 2080 under different assumptions on tax rates. The calibration of the economy remains constant between these cases except for the differences in the future path of tax rates. Consequently, differences in the resulting long-run debt-to-GNP ratios reflect only the differences in the future path of tax rates that are fed into the model and the model economy's endogenous response to various rates. Next, we report the steady state implications of different tax policies and calculate dynamic Laffer curves for the model economy. Finally, we conduct several experiments to assess the consequences of additional scenarios, such as an increase in the future inflation rate or the TFP growth , on the debt-to-GNP ratio in 2035.

4.1 1960–2011

In this section, we examine how the model economy behaves between 1960 and 2011. The benchmark calibration makes assumptions about the future path of exogenous variables that are summarized in the calibration section. However, the results between 1960 and 2011 are fairly insensitive to the assumptions about the exogenous variables assumed after 2011.

The top two panels in Figure 5 summarize GNP per capita and hours per capita generated by the benchmark model as well as their counterparts in the actual data. The lower two panels summarize the results on the capital-output ratio and the investment-output ratio. Notice that the model generated values for GNP per person, hours per capita, and the capital-output ratio are higher than their data counterparts after the 1990s. Also, the model-generated investment-output ratio fluctuates more than the data. Nevertheless, the model is able to capture the general trends in these variables reasonably well.

Figure 6 displays the overall government budget balance and the debt-to-GNP ratios generated by the model economy as well as their counterparts in the data. The simulated

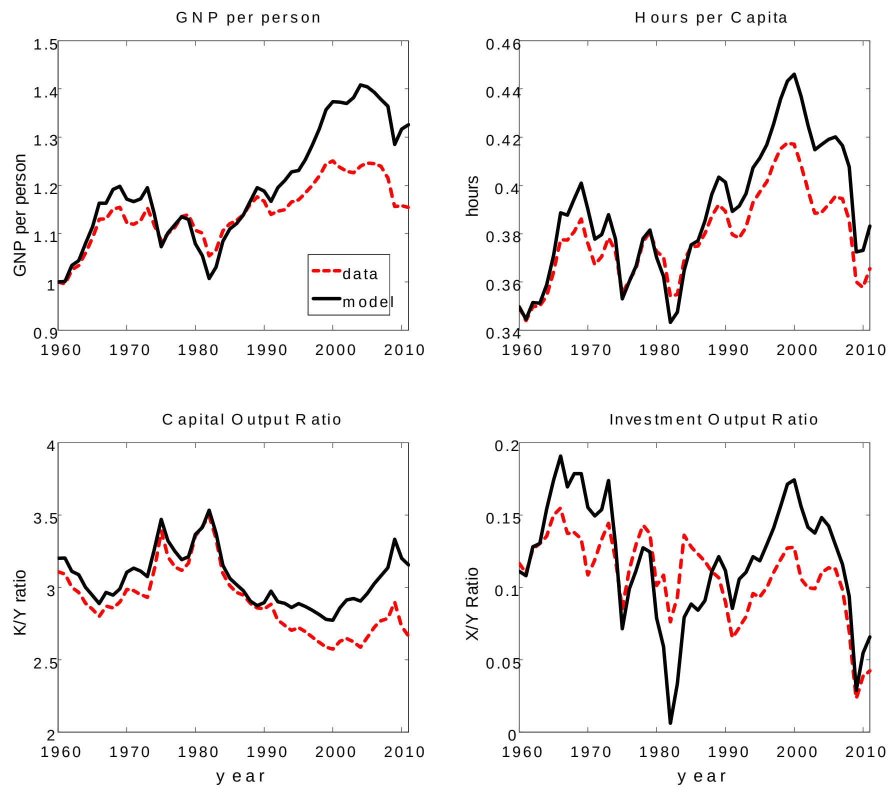

Figure 5: Benchmark Economy

Note: This figure displays GNP per person, hours per capita, capital-output ratio, and the investment output ratio for the U.S. economy between 1960 and 2011 and the simulation results from the benchmark economy.

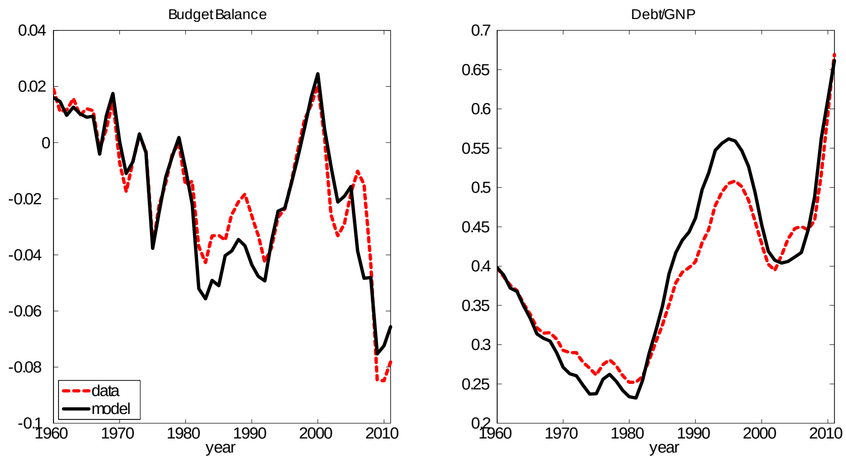

Figure 6: Deficit and Debt

Note: This figure displays the data for the budget balance, given in equation 4, and the debt-to-GNP ratio for the U.S. economy between 1960 and 2011 and the simulation results for these variables from the benchmark economy.

series are generated through a mix of exogenously fed series such as government purchases and transfer payments and endogenous variables such as GNP and tax revenues. Our model economy captures the time series behavior of the government deficit and the debt-to-GNP ratio reasonably well. The model-generated debt-to-GNP ratio in the 1990s is higher than the actual data due to higher deficits generated by the model in the 1990s. For all other periods, however, both the budget balance and the debt ratio are fairly close to their data counterparts.

While the model economy may not be able to capture all the aspects of the U.S. economy precisely, it seems to provide a reliable and transparent framework to help us evaluate the implications of different assumptions about future policies governing tax rates and spending.

4.2 Projections

We start this section by examining the disincentive effects that higher taxes have on the behavior of labor and capital and on the medium- and long-run projections of debt-to-GNP ratios. Next, we compare the consequences of higher versus historical tax rates on economic growth and debt-to-GNP ratios in 2035 and 2080. Lastly, we generate dynamic Laffer curves and find the tax rates on labor and capital that can generate a stable debt-to-GNP ratio in the long run.

4.2.1 Benchmark Results

In this section, we generate projections for the debt-to-output ratio using tax rates assumed in the CBO's *extended baseline* scenario of the CBO through 2035 and set the tax rates after 2035 equal to their 2035 values, which are $\tau_k = 41.25\%$ and $\tau_h = 35.61\%$. We also examine the sensitivity of the debt-to-GNP projections to the disincentive effects of taxes on labor and capital.

The best way to study this question is not immediately apparent. Simulating economies with different assumptions about the behavior of factor inputs, starting from 1960s, gives rise to many differences in 2011 that make comparisons across the various economies impossible. We need to set up a counterfactual experiment such that we can compare two economies that are identical to each other in 2011 and differ after 2011 only with respect to the assumed behavior of labor and capital. To accomplish this task, we first simulate the benchmark economy between 1960 and the steady state. We take the hours worked and the capital stock generated by this economy in 2011 and use them to simulate the properties of another economy where the values of labor and capital after 2011 are exogenously set to their 2011 values. This economy, where both labor and capital are exogenous, is referred to as the "Economy with Exogenous Factor Inputs." We compute output, tax revenues, the debt-to-GNP ratio, and several other statistics for both economies.

In the first two panels of Figure 7, we present the hours per capita and the capital-output ratio between 1960 and 2080 generated by both economies. With exogenous inputs, hours per capita remains constant at 0.38, its value in 2011, while in our benchmark economy hours per capita declines to 0.35 around 2028 and remains at that level. Accordingly, by 2035, both hours per capita and GNP per capita are 9% lower than their counterparts in the economy with exogenous factor inputs. Also in sharp contrast is the debt-to-GNP ratio, which by 2035 is 106% under the benchmark economy, almost twice as large as in the economy with exogenous inputs (63%). The long-run pattern of the debt-to-GNP ratio differs more dramatically between these two economies: by 2080, while the debt-to-GNP ratio is around 74 percent in the economy with exogenous inputs, it grows to more than

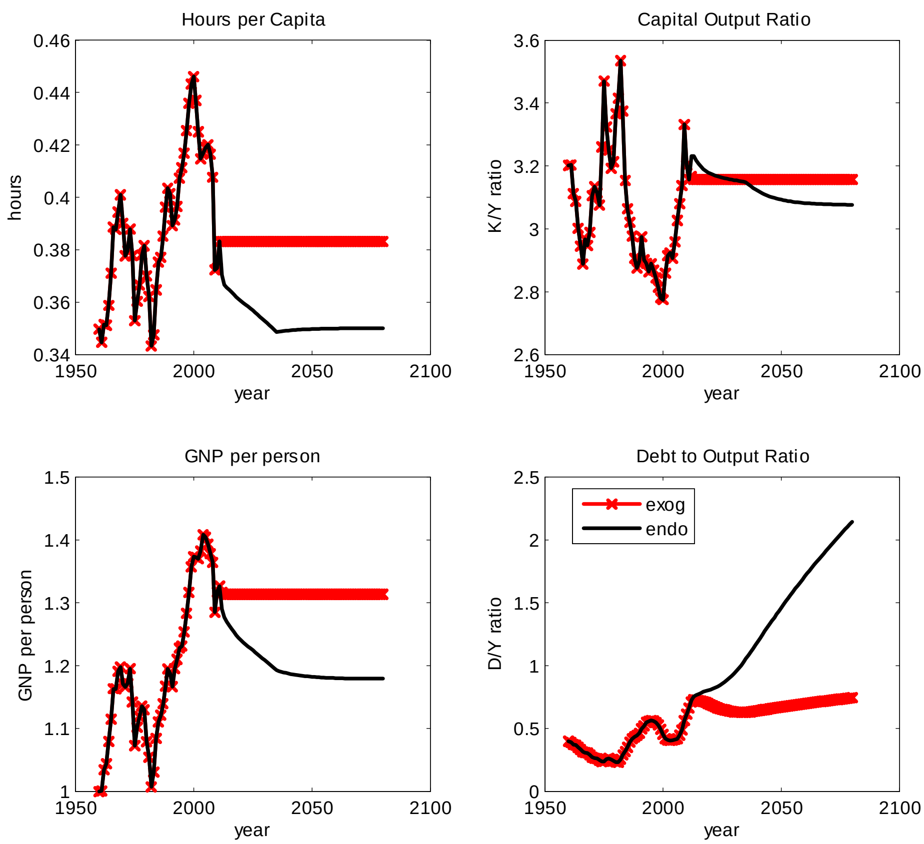

Figure 7: The Role of Behavioral Responses to Tax Increase

Note: This figure displays the properties of two economies, one with endogenous labor (with a Frisch elasticity of 1.0) and capital and another where labor and capital are assumed to be constant after 2011.

200% under the benchmark economy. This experiment shows that relatively small declines in labor and capital inputs lead to significantly higher debt-to-GNP ratios in the long run.

The disincentive effect of taxes on labor and the projected debt-to-output ratio remains significant even under a lower elasticity of labor supply. An economy with a Frisch elasticity of labor supply of 0.5 generates a debt-to-GNP ratio of 97% in 2035 which is 42% higher than its counterpart in the economy with exogenous inputs. The growth rate of per-capita GNP between 2011 and 2035 is 1.04%. Similar to the findings summarized above, the differences between the benchmark economy and the economy with exogenous factor inputs grow over time. By 2080, the debt-to-GNP ratio is 184% with a Frisch elasticity of 0.5, as opposed to 74% with exogenous factor inputs. We conclude that even though there is quite a bit of disagreement about the right elasticity of labor supply, abstracting from the likely behavioral responses of labor and capital may have important consequences for the long-run calculations of debt-to-GNP ratios.

To analyze the above results further, we examine the relative role of the disincentive effects of taxes on labor versus capital inputs separately. For this purpose, we construct an economy where labor is exogenous but capital is endogenous. The last case is labelled as "Exog. L only". Similar to the economy with exogenous inputs, in this economy the labor input from 2012 on is exogenously set to be the corresponding value in 2011 as generated by the benchmark economy.

Table 3 compares the debt-to-output ratio between the three economies: our benchmark economy, the economy with Exog. L only, and the economy with exogenous inputs. The comparison is for the case with a Frisch elasticity equal to one. The analysis associated with a Frisch elasticity equal to 0.5 delivers similar results. As previously mentioned, the economy with exogenous K and L leads to a debt-to-GNP ratio of 63% in 2035 and a growth rate of per-capita GNP of 1.54% per year between 2011 and 2035. If we assume labor stays constant but allow capital to respond to changes in the capital income tax rate, the annual growth rate of per capita GNP declines to 1.43% and the debt-to-GNP ratio increases to 84% by 2035. Allowing labor also to respond to the changes in taxes results in our benchmark case, where the debt-to-GNP ratio reaches 106% and the annual growth rate of per capita GNP is 0.92%. In other words, the ability of higher taxes to lower the debt-to-GNP ratio is significantly muted in our benchmark economy. These results also

Table 2: The Role of Labor versus Capital

	Benchmark	Exog. L only	Exog. K and L
D/Y in 2035 (%)	106	84	63
D/Y in 2080 (%)	215	127	74
Y/N growth (2011-2035)	0.92	1.43	1.54
Y/N growth (2011-2080)	1.19	2.13	2.20

show that tax disincentives on labor impact the annual growth rate of GNP per capita more significantly. Nevertheless, distortions on both capital and labor play an important role in the projections of the debt-to-GNP ratio.

4.2.2 The Effects of Higher Taxes

Our baseline experiment is conducted under the assumption that labor and capital income tax rates rise to 36% and 41% respectively, by 2035. We now examine the quantitative effects of this increase in taxes by comparing the baseline scenario to an alternative policy where labor and capital income tax rates after 2011 remains at their 2011 levels, with $\tau_h = 0.26$ and $\tau_k = 0.33$. We label this case as "Historical tax rates" and our baseline case as "High tax rates".

Table 3 reports the debt-to-GNP ratio (in 2035 and 2080) and the average annual growth rate of output between 2011 and 2035 and 2080 under different Frisch elasticities. Along the transition, all economies share the same TFP growth. However, the growth rate of capital and the level of labor differ across economies with different tax policies when behavioral responses are taken into account. As a result, differences in tax policies give rise to differences in the growth rate of per capita GNP during the transition. For a Frisch elasticity of 1.0, the debt-to-GNP ratio in 2035 is 106% with higher taxes, in contrast to 174% with the historical tax rates. However, higher taxes also reduces the growth rate of per capita GNP from 1.27% to 0.92% between 2011 and 2035. Similarly, with a Frisch elasticity of 0.5, an increase in the tax rate reduces the growth rate of per capita GNP from 1.30% to 1.04%. The effects of this distortion persist in the longer run, as can seen by an annual average growth rate of GNP per capita of 1.33% with historical tax rates as opposed to 1.19% with higher tax rates when Frisch elasticity is equal to 1.0.

In summary, we find that higher tax rates result in lower debt-to-GNP ratios in the

Table 3: Economic Consequences of Higher Taxes

	Elasticity 1.0		Elasticity 0.5	
	High tax	Hist. tax	High tax	Hist. tax
D/Y in 2035 (%)	106	174	97	174
D/Y in 2080 (%)	215	420	184	421
Y/N growth (2011–2035)	0.92	1.27	1.04	1.30
Y/N growth (2011–2080)	1.19	1.33	1.23	1.34
Welfare	4.47%		3.23%	

long run compared to what occurs with historical tax levels. Nevertheless, debt-to-GNP ratios continue to be high compared to historical standards. At the same time, higher taxes distort labor supply and capital accumulation decisions, which in turn result in slower growth in aggregate output. The distortionary effect of high taxes increases as the labor supply elasticity increases.

In Table 3 we also report the welfare consequences of these different tax rates by calculating the consumption compensation required to make welfare the same between economies with high versus historical taxes using equation (14). According to the results in the last row of Table 3, individuals born into a high tax economy (for example, with a Frisch elasticity of 1.0) would need a 4.47% higher consumption level each period to make their welfare the same as in the economy with historical taxes. Notice that the welfare differences are due to tax rate differences that materialize after 2011. Naturally, the welfare effects are smaller for a Frisch elasticity of 0.5 (a consumption compensation of 3.23% per year). Overall, however, these are large welfare costs and are reminiscent of the Lucas (1987) finding that a household would be willing to give up 20% of yearly consumption to increase the economy's growth rate by a mere 1 percent. While the model economy is silent on the potential adverse effects of high debt levels, the above calculations suggest that the welfare benefits of reducing the debt-to-output ratio–for example–from 174% to 106% would have to be more than 4.47% per year for debt reduction with increased taxes to be a worthwhile effort in an economy with a Frisch elasticity of 1.0.

4.2.3 Taxes and the Steady State

Our previous exercise suggests that once the behavioral responses of capital and labor are taken into account, increases in tax rates assumed in the CBO's extended baseline scenario are not sufficient to stabilize the debt-to-output ratio in the long run. The natural question is to find the tax rate at which deficits will be close to their historical levels and the debt-to-output ratio would stabilize, perhaps below 100% in the long run.

To address this issue, we examine the dynamic Laffer curves for capital and labor income tax rates at the steady state. We start with the case where the tax rates at the steady state are set at their 2011 levels, and then calculate the steady state tax revenues by changing one tax rate at a time. To make comparisons easier, we normalize the steady state tax revenue and GNP per capita associated with the case $\tau_h = 26\%$ and $\tau_k = 33\%$ to 100. The top two panels of figure 8 displays these dynamic Laffer curves for labor and capital income tax rates. In Panel (a), the Laffer curve is generated by varying the labor income tax rate from 0% to 95% while the capital income tax rate is kept constant at 33% (its level in 2011). In Panel (b), the capital income tax rate varies between 0% and 90% while the labor income tax rate is kept constant at 26%. The vertical line in each panel refers to the level of capital or labor income tax rate in 2011.

We find that the labor income tax rate that maximizes revenues is 67% for a Frisch elasticity of 1.0 and 77% for a Frisch elasticity of 0.5. The tax revenue increases by more than 40 percent even with a Frisch elasticity equal to 1.0, if the labor income tax rate increases from its 2011 level to 67%. These findings are similar to the results reported in Trabandt and Uhlig (2009).[17] The capital income tax rate that maximizes revenues is 61% for both levels of Frisch elasticities. However, tax revenues increase only by about 10 percent if the capital income tax rate increases from its 2011 level to 61%. In fact, varying capital income tax rates from 0 percent to the level that maximizes tax revenues would only increase tax revenues by 30 percent, suggesting that the role of capital income tax in raising tax revenues at the steady state is limited. The bottom two panels of figure 8 report the behavior of per capita GNP for these different tax rates. Panel (c) shows that GNP per capita declines by 31% as the labor income tax rate increases from its 2011 level to 67%, the level that maximizes tax revenues. In Panel (d), GNP per capita is reduced by 22% when the capital income tax rate increases from 33%, its 2011 level, to 61%, the level that maximizes tax revenues.

[17] Several papers examine different aspects of the relationship between tax rates and tax revenues such as Baxter and King (1993), Ireland (1994), Schmitt-Grohe and Uribe (1997) and Holter, Krueger, and Stepanchuk (2013). See also Cochrane (2011).

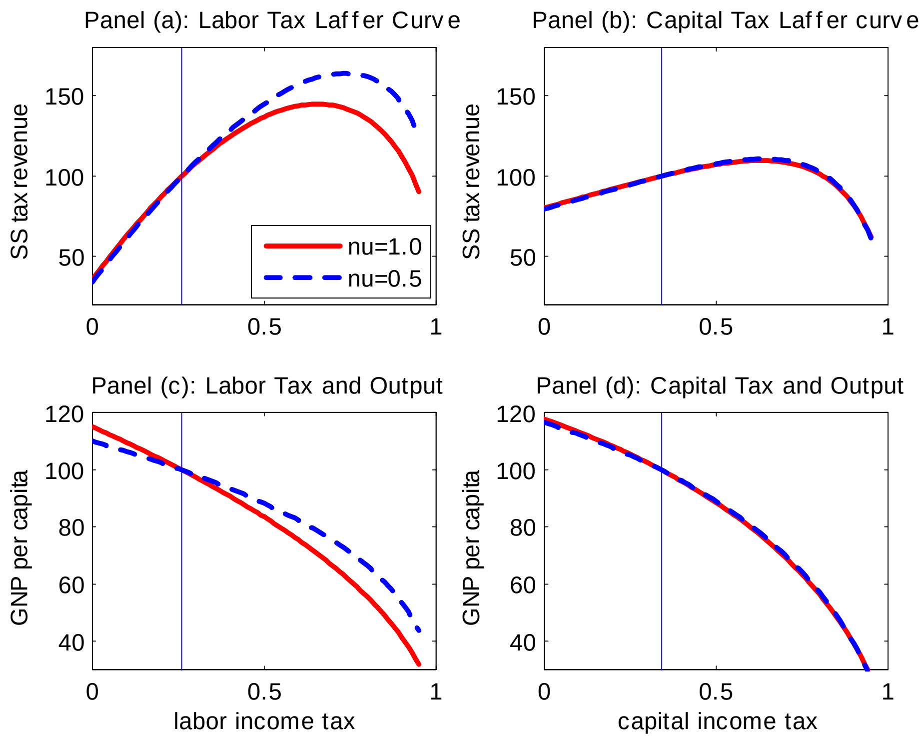

Figure 8: Tax revenues and Per Capita GNP

Note: The top two panels of this figure display dynamic Laffer curves for economies with Frisch elasticities of 1.0 and 0.5. The bottom two panels show the change in per capita GNP in those economies as the tax rates are increased. The vertical line in each panel refers to the level of capital or labor income tax rate in 2011.

A more potentially interesting example is to investigate the deficit and debt-to-GNP ratios that correspond to these different tax rates. After all, maximizing tax revenues while GNP per capita keeps declining may not be a particularly useful exercise. Notice that the debt-to-GNP ratio at the steady state, given in equation (9), is a function of the deficit-to-GNP ratio divided by a constant. This constant is equal to the economy's nominal growth rate, 4.1% under our calibration, minus the nominal interest rate, 3.29%. While our assumption about the future interest rates on debt is likely to be on the conservative side, small decreases in the nominal interest rate would result in significantly smaller debt-to-GNP ratios at the steady state. Therefore, it may be more instructive to focus on the deficit-to-GNP ratio for the steady state comparisons. The U.S. deficit was 1.89% of GNP during 1960–2011 and 1.51% during 1960–2008, excluding the recent recession.

Table 4 reports tax revenues, the debt-to-GNP ratio, the deficit-to-GNP ratio, and per capita GNP at the steady state, as we vary the labor income tax rate while the capital income tax rate stays constant at its 2011 level. As mentioned before, tax revenues are maximized at a labor income tax rate of 67%. However, the deficit is close to its historical levels at a labor income tax rate of 42%. At this rate, however, detrended GNP per capita is 10% lower than its level with a labor income tax rate of 26%, the 2011 tax rate. The budget deficit is almost zero at a labor income tax rate of 47%, where debt-to-GNP ratio stabilizes at 9%.[18] Beyond that point, the debt-to-GNP ratio becomes negative.

The last column in Table 4 reports the welfare cost of being born into economies with higher tax rates as opposed to historical tax rates. Specifically, we compare the lifetime utility at the steady state in an economy with $\tau_k = 0.33$ and $\tau_h = 0.26$ to its counterparts in economies with the same tax rate on capital income but higher tax rates on labor income. For example, the welfare cost of being born into an economy with $\tau_h = 0.42$ (the tax rate that lowers the deficit-to-GNP ratio to 1.7%) as opposed to $\tau_h = 0.26$ is 4.41%. In other words, individuals born into the economy with higher tax rates that bring the deficit close to its historical levels would need a 4.41% higher consumption level each period to to achieve the same level of welfare as in the economy with historical taxes.

Similar to the arguments made earlier, welfare cost measures are provided only to give an

[18] With a Frisch elasticity of 0.5, a labor income tax rate of 42% is sufficient to stabilize the debt to GNP rate around 14%.

Table 4: Labor Tax Rates and the Economy ($\tau_k = 0.33$)

τ_h	Revenue	D/GNP	$-\Pi^p$/GNP	GNP/N	Welfare
.26	100	891	7.83	100	0
.32	112	614	5.40	96	1.29
.37	121	396	3.48	94	2.68
.42	128	**194**	**1.70**	90	4.41
.47	135	9	0.08	86	6.56
.52	140	-154	-1.35	82	9.18
.57	144	-288	-2.53	78	12.40
.62	146	-387	-3.40	75	16.38
.67	**147**	-436	-3.83	69	20.31
.72	145	-418	-3.67	65	27.48

Note: We normalize the steady-state tax revenue and GNP per capita in the case τ_h= 0.26 to 100. All other numbers are expressed in percent.

idea about the extent of the costs of higher taxes only. In our model, government consumption is not valued by households. However, as long as the level of government consumption is constant across different tax regimes, we would obtain the same welfare results if government consumption enters separably into the utility function. Braun and Uhlig (2006) show that depending on the valuation of government consumption, higher taxes may increase welfare if government consumption adjusts endogenously with the level of revenues.[19] In our experiment, government consumption is set exogenously and does not increase with tax revenues. The only effect of higher revenues is in reducing the deficit and the resulting debt-to-GNP ratio.

To explore the effectiveness of capital income taxes on reducing debt and deficit in the long run, we also examine the deficit- and debt-to-GNP ratios as we vary the tax rate on capital while the labor income tax rate is set equal to 26%. Similar to the findings in Trabandt and Uhlig (2009) revenues are maximized around a capital income tax rate of 61% but are not very sensitive to the tax rate. In fact, it is evident from Figure 8 that tax revenues increase only by 10 percent when the Laffer curve is maximized. Consequently the deficit- and the debt-to-GNP ratio do not decline much beyond their starting values of 7.83% and 891%. These results are also not very sensitive to the Frisch elasticity of labor supply.

Overall, we find that the labor income tax rate would have to increase from a current

[19] Modeling the potential benefits of lowering debt-to-GNP ratios, however, would result in different welfare implications. Such an investigation is beyond the scope of this paper.

level of 26% to more than 40% in order for the debt-to-GNP ratio to stabilize below 100% in the long run. Such a drastic increase in the tax rates, however, is associated with a high welfare cost. In addition, we find that increasing capital income tax rates are not helpful in lowering the deficit at the steady state, due to its disincentives on capital and labor supply. This finding is consistent with the conventional wisdom that taxing capital income is a bad idea (see Atkeson, Chari, and Kehoe, 1999).

4.3 Alternative Experiments

Our analysis so far suggests that tax distortions impede the ability of higher taxes in reducing the debt-to-GNP ratio significantly. In this section we investigate how the debt-to-GNP ratio may change under different assumptions on some of the exogenous variables that are potentially important for either government revenue or GNP. We conduct several additional experiments by making changes in the economy one at a time. For these calculations, we use the economy with historical tax rates that resulted in a debt-to-GNP ratio of 174% in 2035 in our previous calculations.

4.3.1 Cutting Expenditures

Apart from increasing taxes, cutting government expenditures is a candidate policy choice for reducing the U.S. deficit and debt in the long run. In this section, we investigate the projections on the debt-to-GNP ratio under an alternative expenditure scenario given by the National Commission on Fiscal Responsibility and Reform headed by Erskine Bowles and Alan Simpson. Their proposal involves larger cuts in both discretionary and mandatory spending categories such as Social Security and Medicare through 2020. For example, total discretionary spending, which is the spending category G_t in the model economy, is set at about $9 trillion between 2012 and 2020 in the Bowles-Simpson plan as opposed to $11 trillion in the CBO baseline scenario. Expenditures on transfer payments (Social Security and health care) are also lower under the Bowles-Simpson plan. These differences are evident from Figure 4, which shows that the projected ratio of government expenditures to GDP under the Bowles-Simpson plan declines at a faster rate than its counterpart under the CBO projection.[20]

Specifically, we implement the path of expenditures in G_t and TR_t proposed by the Bowles-Simpson Commission and examine the path of the debt-to-GNP ratio after 2011. To facilitate the comparison, tax rates are assumed to continue at their 2011 levels and the model economy is solved for a Frisch elasticity of one. Under the Bowles-Simpson proposal, in 2035 the debt-to-GNP ratio is 120%, as opposed to the 174% obtained with the CBO projections. Therefore, this exercise shows that the path of expenditure cuts proposed by the Bowles-Simpson Commission can have an important impact on the future debt-to-output ratios.[21]

4.3.2 High Employment, High TFP

Besides fiscal policies, the projected debt-to-output ratio in the long run depends crucially on the projected output growth. In the results reported so far, we assumed that the labor wedge will stay at its 2011 level, which causes the average hours worked to be much lower than its peak in the 1990s. Consequently, GNP per person generated for the period after 2011 is also lower than its peak in the 1990s. These features of the simulated data contribute to the high debt-to-GNP ratios generated in our simulations. In this section, we examine what the projected debt-to-output ratio would be like if U.S. GNP per person grew significantly faster after 2011 compared to our benchmark estimate.

To address this question, in the following counterfactual experiment, we assume that the labor wedge between 2011 and 2020 gradually returns to its average level in the 1990s. The rest of the calibration is the same as in the economy where future projections on expenditures come from CBO's extended baseline scenario and tax rates stay at their historical levels. Unsurprisingly, this assumption results in a gradual increase in hours worked. Accordingly, after 2011 GNP per person gradually recovers to its level in late 1990s, as displayed by the

[20] Their proposal also includes various changes in tax exemptions that result in an increase in the tax base. Our model is not rich enough to evaluate the impact of changes in the tax code.

[21] We also experiment with the expenditure projections provided by the CBO under their *alternative scenario*. While spending for Social Security is identical under the two CBO scenarios, spending for Medicaid and especially for Medicare is higher under the *alternative scenario* where, for example, Medicare's payment rates for physicians are assumed to remain at current levels. Overall total primary spending is projected to increase to 25% of GDP under the alternative scenario as opposed to 23.3% of GDP under the extended benchmark scenario. Under this scenario, the model-generated debt-to-GNP ratio reaches 225% in 2035, as opposed to 174% under the extended benchmark scenario.

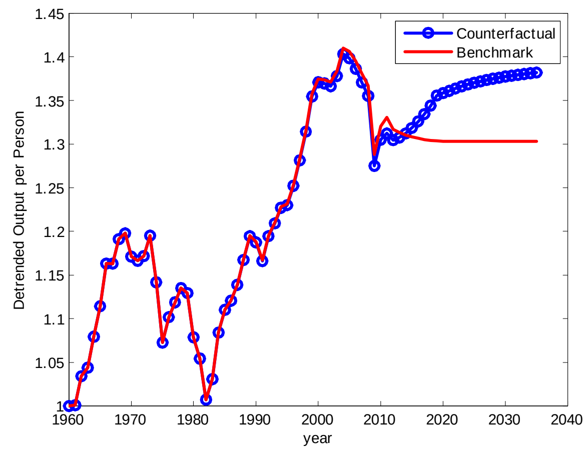

Figure 9: Output per Capita

Note: In this figure, the solid line denotes the (detrended) output per capita in the benchmark economy; the line with circles denotes the output per capita in the case where labor wedge between 2011 and 2020 gradually go back to its average level in the 1990s. In each case, output per capita is normalized so that the 1960 value is equal to 1.0.

"counterfactual" line in Figure 9. Under this fairly rosy scenario, the debt-to-GNP ratio is 142% in 2035 (instead of the 174% under the case with a constant labor wedge) and the deficit is 10%.

In addition to the higher labor wedge, if we assume a high growth rate for TFP (1.31%), as high as its average in the 1990s, for five years after 2011, then the debt-to-GNP ratio goes down to 123% in 2035.[22] Since expenditures on health care are expected to rise into the future, for the debt-to-GNP ratio to decline to lower levels, the TFP growth rate needs to continue to be high for the next 35 years. If we assume that high TFP growth continues between 2011 and 2045, for example, the debt-to-GNP ratio reaches 108% in 2035 and declines to 50% at the steady state. Overall, these exercises demonstrate that significant and persistent increases in the growth rate of the economy are needed to reduce the debt-to-output ratio to its historical levels.

[22] We assume that the TFP growth rate goes up to 1.31% (significantly higher than its historical average of 1.07%) for five years after 2011, and returns to its steady state level after that. If the 1.31% growth rate continues for 10 years, the debt-to-GNP ratio declines to 116% in 2035.

4.3.3 Inflation

Equation (9) implies that higher inflation helps to reduce the debt-to-output ratio by serving as a tax on the household who holds government debt. In our previous simulation, we assumed the inflation rate in 2011 and beyond would continue at 2%, its 2011 level. In addition, the nominal interest rate on government debt is assumed to be 3.3% into the future. In the next set of counterfactual experiments, we increase the inflation rate to 4% and 6% without making any changes in the assumed nominal interest rate. Consequently, real interest rates are -0.7%, and -2.7%.

Our findings indicate that by 2035, the debt-to-GNP ratio declines from 174% in the case with 2% inflation to 133% with 4% inflation and 104% with 6% inflation. These experiments can be thought of as an upper bound on the potential role of inflation in lowering the debt-to-GNP ratios in the future. In reality, higher inflation rates would most likely be associated with higher nominal interest rates, putting an upward pressure on future interest payments and the debt-to-GNP ratios.

4.3.4 Federal Versus State and Local Expenditures

In our previous simulations, we assumed that both federal and state and local government purchases will decline after 2011 as projected by the CBO. However, CBO projections are primarily for the federal government, which constitutes about 40% of government consumption and 33% of government investment.[23] In the next experiment, we assume that state and local government consumption grow at the balanced growth rate after 2011 and only federal government consumption grows at a rate projected by the CBO's *extended benchmark* scenario. In this case, with historical taxes, the debt-to-output ratio in 2035 is 210% instead of 174%.

4.4 Summary

Table 5 summarizes the findings of various experiments conducted above. A useful starting point is the comparison between the CBO's extended baseline scenario, with a 74% debt-to-

[23] In 2010, federal government's consumption expenditures were $1.05 trillion while total U.S. government consumption was $2.5 trillion. Gross investment by the federal government was $168 billion. The same year, state and local governments spent $336 billion on investment.

GNP ratio projected for 2035, and the model-generated predictions. Important assumptions in the CBO's baseline case include tax rates increasing from 25% in 2010 to 35% in 2035 and no labor supply response to this tax increase. Our experiment that is most similar to the CBO benchmark is the case with higher tax rates and exogenous inputs. This scenario results in a debt-to-GNP ratio of 63% in 2035. Incorporating labor and capital supply responses increases this ratio to 106% in a utility function with a Frisch elasticity of 1.0 (and to 97% with a Frisch elasticity of 0.5). Alternatively, if tax rates are assumed to continue at their historical averages, the debt-to-GNP ratio in 2035 is around 174% irrespective of the labor supply elasticity. If we assume that the labor wedge and the TFP growth rate are as high as they were in the 1990s, the debt-to-GNP ratio declines to 123%. With a 4% inflation instead of 2% as assumed earlier, the debt-to-GNP ratio declines from 174% to 132%. Using the larger cuts proposed by the Bowles-Simpson plan for the case with historical taxes result in a debt-to-GNP ratio of 120%.

Table 5: Summary Table

	Debt-to-GNP Ratio in 2035 (%)
CBO benchmark projections	74
High Tax Rates	
CBO exp.; exogenous inputs	63
CBO exp.; endogenous inputs	106
Historical Tax Rates (Endogenous Inputs)	
CBO expenditures	174
CBO exp.; high labor wedge and high TFP growth	123
CBO exp.; 4% inflation	132
Bowles-Simpson expenditures	120

5 Conclusions

In this paper, we investigate the consequences of different tax policies for the U.S. economy using a fully calibrated neoclassical growth model. While the framework is relatively simple, it matches the time series behavior of budget deficits and debt in the U.S. economy between 1960 and 2011 reasonably well. It also incorporates the general equilibrium effects of policy that are often missing from the CBO projections. Our findings stress the importance of incorporating behavioral responses into calculations regarding deficits and debt, especially when large changes in tax rates are being evaluated, as in the CBO calculations. We find that the debt-to-output ratio in 2035 can easily be 40% to 70% higher for labor supply elasticities ranging from 0.5 to 1.0. In addition, changes in tax rates imply large welfare costs due to changes in factor inputs and GNP. We also find that the tax rate on labor income would have to be higher than 40% for the deficit-to-GNP ratio to return to its long-run historical levels. Such a policy results in a 10% lower GNP per capita and large welfare costs at the steady state.

We leave many important and interesting issues for future work. Extending our model to an overlapping generations framework will allow us to investigate the impact of the projected debt levels on different generations, the crowding out of private capital due to government deficits, and the potential impact of the consumption versus the labor income tax rates to finance government debt.

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6 Appendix

In this appendix, we first define the competitive equilibrium. We then characterize the equilibrium condition and detrend the economy. Finally, we specify our measure of the welfare cost of raising taxes.

6.1 Competitive Equilibrium

For a government fiscal policy $\{G_t, GI_t, TR_t, i_t, \tau_{h,t}, \tau_{k,t}\}_{t=0}^{\infty}$, a competitive equilibrium consists of an allocation $\{C_t, X_t, H_t, K_{t+1}, Y_t\}_{t=0}^{\infty}$, a primary balance Π_t^p, and factor prices $\{w_t, r_t\}_{t=0}^{\infty}$ such that:

- the allocation solves household's problem,
- the allocation solves the firm's profit maximization problem with factor prices given by: $w_t = (1-\theta)A_t K_t^{\theta} {H_t}^{-\theta}$ and $r_t = \theta A_t K_t^{\theta-1} {H_t}^{1-\theta}$,
- the government budget constraint is satisfied,
- the goods market clears: $C_t + X_t + G_t = Y_t$.

6.2 Equilibrium Conditions

We can combine the equilibrium conditions of the model in three equations below:

$$\chi h_t^{\frac{1}{\gamma}} = (1-\tau_{h,t}) \frac{(1-\theta) A_t (K_t/H_t)^{-\theta}}{C_t/N_t} \tag{11}$$

$$\frac{C_{t+1}}{N_{t+1}} = \frac{C_t}{N_t} \beta \left\{ 1 + (1-\tau_{k,t+1}) \left[\theta A_{t+1} K_{t+1}^{\theta-1} {H_{t+1}}^{1-\theta} - \delta_{t+1} \right] \right\}, \tag{12}$$

$$K_{t+1} = (1-\delta_t)K_t + A_t K_t^{\theta} {H_t}^{1-\theta} - C_t - G_t. \tag{13}$$

Our approach is to start from given initial conditions and then compute an equilibrium transition path towards a balanced growth path at which per capita aggregate variables grow at the rate $g_t = \gamma_t^{1/(1-\theta)}$. For a variable z_t, detrending is done by applying $\widetilde{z}_t = z_t / \left[A_t^{\frac{1}{1-\theta}} N_t \right]$.

Using this change of variables to equations (11), (12), and (13), we obtain equations:

$$\begin{aligned}
\widetilde{c}_t \chi \widetilde{h}_t^{\frac{1}{\gamma}} &= (1-\tau_{h,t})(1-\theta)x_t^{\theta} \\
\widetilde{c}_{t+1} &= \frac{\widetilde{c}_t}{g_{t+1}} \beta \left\{ 1 + (1-\tau_{k,t+1}) \left[\theta x_{t+1}^{\theta-1} - \delta_{t+1} \right] \right\}, \\
\widetilde{k}_{t+1} &= \frac{1}{g_{t+1} n_{t+1}} [(1-\delta_t) + (1-\psi_t) x_t^{\theta-1}] \widetilde{k}_t - \widetilde{c}_t,
\end{aligned}$$

where ψ_t is the ratio of government purchases to output, G_t/Y_t, and x_t is detrended capital-labor ratio, $(K_t/H_t)/A_t^{\frac{1}{1-\theta}}$.

The steady-state conditions are obtained by setting $\widetilde{z}_t = \widetilde{z}$ for all t :

$$\begin{aligned}
\widetilde{c} \chi \widetilde{h}^{\frac{1}{\gamma}} &= (1-\tau_h)(1-\theta)x^{\theta} \\
1 &= \frac{1}{g} \beta \left\{ 1 + (1-\widetilde{\tau}_k) \left[\theta x^{\theta-1} - \widetilde{\delta} \right] \right\} \\
\widetilde{k} &= \frac{1}{gn} [(1-\widetilde{\delta}) + (1-\widetilde{\psi}) x^{\theta-1}] \widetilde{k} - \widetilde{c}.
\end{aligned}$$

These three equations deliver the steady-state values of detrended capital and consumption where $\widetilde{\delta}$, $\widetilde{\tau}_h$, and $\widetilde{\tau}_k$ are the steady-state depreciation rate, the labor income tax rate, and the capital income tax rate, respectively.

In addition, the labor wedge is computed as:

$$\Delta_t^H = \frac{c_t \chi h_t^{1+\frac{1}{\gamma}}}{(1-\tau_{h,t})(1-\theta) y_t}.$$

Finally, the detrended law of motion for the debt-to-output ratio is:

$$\frac{\widetilde{B}_{t+1}^g}{\widetilde{Y}_{t+1}} = \frac{\left(\widetilde{B}_t^g + \widetilde{GB}_t \right)}{\widetilde{Y}_t} \frac{\widetilde{Y}_t A_t^{\frac{1}{1-\theta}} N_t}{\widetilde{Y}_{t+1} A_{t+1}^{\frac{1}{1-\theta}} N_{t+1}} \frac{P_t}{P_{t+1}}.$$

6.3 Measurement of Welfare Costs

To put the quantitative results in perspective we also report welfare costs that are obtained in the following way:

Define the lifetime utility of the representative consumer in the high tax regime as:

$$V^h = \sum_{t=0}^{\infty} \beta^t N_t U \left(c_t^h, h_t^h \right),$$

where $U\left(c_t^h, h_t^h\right)$ follows equation (1). Similarly, for the low tax regime, we can define the representative consumer's lifetime utility as V^l. In each period, the percentage increase in consumption required to equate the welfare in the high-tax economy to the welfare in the low-tax economy can be found from:

$$\widehat{V}^h = \sum_{t=0}^{\infty} \beta^t N_t u \left(c_t^h (1+x), h_t^h \right) = \sum_{t=0}^{\infty} \beta^t N_t u \left(c_t^l, h_t^l \right),$$

where, x is the consumption compensation. This gives:

$$\begin{aligned} \sum_{t=0}^{\infty} \beta^t N_t \log(1+x) &= V^l - V^h \qquad (14) \\ x &\cong \log(1+x) = \left(V^l - V^h \right) [1 - \beta(1+n)]. \end{aligned}$$