

## CHAPTER 32

# What is a Sustainable Public Debt?

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## Abstract

The question of what is a sustainable public debt is paramount in the macroeconomic analysis of fiscal policy. This question is usually formulated as asking whether the outstanding public debt and its projected path are consistent with those of the government's revenues and expenditures (ie, whether fiscal solvency conditions hold). We identify critical flaws in the traditional approach to evaluate debt sustainability, and examine three alternative approaches that provide useful econometric and model-simulation tools to analyze debt sustainability. The first approach is Bohn's nonstructural empirical framework based on a fiscal reaction function that characterizes the dynamics of sustainable debt and primary balances. The second is a structural approach based on a calibrated dynamic general equilibrium framework with a fully specified fiscal sector, which we use to quantify the positive and normative effects of fiscal policies aimed at restoring fiscal solvency in response to changes in debt. The third approach deviates from the others in assuming that governments cannot commit to repay their domestic debt and can thus optimally decide to default even if debt is sustainable in terms of fiscal solvency. We use these three approaches to analyze debt sustainability in the United States and Europe after the sharp increases in public debt following the 2008 crisis, and find that all three raise serious questions about the prospects of fiscal adjustment and its consequences.

## Keywords

Debt sustainability, Fiscal reaction function, Fiscal austerity, Tax policy, Sovereign default

## JEL Classification Codes:

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## 1. INTRODUCTION

The question of what is a sustainable public debt has always been paramount in the macroeconomic analysis of fiscal policy, and the recent surge in the debt of many advanced and emerging economies has made it particularly critical. This question is often understood as equivalent to asking whether the government is solvent. That is, whether the outstanding stock of public debt matches the projected present discounted value of the primary fiscal balance, measuring both at the general government level and including all forms of fiscal revenue as well as all current expenditures, transfers and entitlement payments. This chapter revisits the question of public debt sustainability, identifies critical flaws in traditional ways to approach it, and discusses three alternative approaches that provide useful econometric and model-simulation tools to evaluate debt sustainability.

The first approach is an empirical approach proposed in Bohn's seminal work on fiscal solvency. The advantage of this approach is that it provides a straightforward and powerful method to conduct nonstructural empirical tests. These tests require only data on the primary balance, outstanding debt, and a few control variables. The data are then used to estimate linear and nonlinear *fiscal reaction functions* (FRFs), which map the response of the primary balance to changes in outstanding debt, conditional on the control variables. A positive, statistically significant response coefficient is a sufficient condition for the debt

to be sustainable. A key lesson from Bohn's work, however, is that using this or other time-series econometric tools just to test for fiscal solvency is futile, because the intertemporal government budget constraint holds under very weak time-series assumptions that are generally satisfied in the data. In particular, [Bohn \(2007\)](#) showed that the constraint holds if either the debt or revenues and expenditures (including debt service) are integrated of *any* finite order. In light of this result, he proposed shifting the focus to analyzing the characteristics of the FRFs in order to study the dynamics of fiscal adjustment that have maintained solvency.

We provide new FRF estimation results for historical data spanning the 1791–2014 period for the United States, and for a cross-country panel of advanced and emerging economies for the period 1951–2013. The results are largely in line with previous findings showing that the response coefficient of the primary balance to outstanding debt is positive and statistically significant in most countries (ie, the sufficiency condition for debt sustainability is supported by the data).<sup>a</sup> On the other hand, the results provide clear evidence of a large structural shift in the response coefficients since the 2008 crisis, which is reflected in large negative residuals in the FRFs since 2009. The primary balances predicted by the FRF of the United States for the period 2008–14 are much larger than the observed ones, and the debt and primary balance dynamics that FRFs predict after 2014 for both the United States and European economies yield higher primary surpluses and lower debt ratios than what official projections show. Moreover, in the case of the United States, the pattern of consistent primary deficits since 2009 and continuing until at least 2020 in official projections, is unprecedented. In all previous episodes of large increases in public debt of comparable magnitudes (the Civil War, the two World Wars, and the Great Depression), the primary balance was in surplus 5 years after the debt peaked.

Using the estimated FRFs, we illustrate that there are multiple parameterizations of a FRF that support the same expected present discounted value of primary balances, and thus all of them make the same initial public debt position sustainable. However, these multiple reaction functions yield different short- and long-run dynamics of debt and primary balances, and therefore differ in terms of social welfare and their macro effects. At this point, this nonstructural approach reaches its limits. The standard Lucas-critique argument implies that estimated FRFs cannot be used to study the implications of fiscal policy changes. Hence, comparing different patterns of fiscal adjustment requires a structural framework that models explicitly the mechanisms and distortions by which tax and expenditure policies affect the economy, the structure of financial markets the government can access, and the implications of the government's inability to commit to repay its obligations.

The second approach to study debt sustainability that we examine picks up at this point. We use a calibrated two-country dynamic general equilibrium framework with

<sup>a</sup> Formally, the null hypothesis that the response coefficient is nonpositive is rejected at the standard confidence level.

a fully specified fiscal sector to study the effects of alternative fiscal strategies to restore fiscal solvency in the aftermath of large increases in debt, assuming that the government is committed to repay. The model is calibrated to data from the United States and Europe and used to quantify the positive and normative effects of fiscal policies that governments may use seeking to increase the present value of the primary fiscal balance by enough to match the increases in debt observed since 2008 (ie, by enough to restore fiscal solvency). This framework has many of the standard elements of the workhorse open-economy Neoclassical model with exogenous long-run balanced growth, but it includes modifications designed to make the model consistent with the observed elasticity of tax bases. As a result, the model captures more accurately the relevant tradeoffs between revenue-generating capacity and distortionary effects in the choice of fiscal instruments.

The results show that indeed alternative fiscal policy strategies that are equivalent in that they restore fiscal solvency, have very different effects on welfare and macro aggregates. Moreover, some fiscal policy setups fall short from producing the changes in the equilibrium present discounted value of primary balances that are necessary to match the observed increases in debt. This is particularly true for taxes on capital in the United States and labor taxes in Europe. The dynamic Laffer curves for these taxes (ie, Laffer curves in terms of the present discounted value of the primary fiscal balance) peak below the level required to make the higher post-2008 debts sustainable.

We also find that, in line with findings in the international macroeconomics literature, the fact that the United States and Europe are financially integrated economies implies that the revenue-generating capacity of taxation on capital income is adversely affected by international externalities.<sup>b</sup> At the prevailing tax structures, increases in US capital income taxes (assuming European taxes are constant) generate significantly smaller increases in the present value of US primary balances than if the United States implemented the same taxes under financial autarky. The model also predicts that at its current capital tax rate, Europe is in the inefficient side of its dynamic Laffer curve for the capital income tax. Hence, lowering its tax, assuming the United States keeps its capital tax constant, induces externalities that enlarge European fiscal revenues, and thus the present value of European primary balances rises significantly more than if Europe implemented the same taxes under financial autarky. This does not imply that debt is easier to sustain in Europe but that the incentives for tax competition are strong, and hence that the assumption that US taxes would remain invariant is unlikely to hold.

The results from the empirical and structural approach suggest that public debt sustainability analysis needs to be extended to consider the implications of the government's lack of commitment to repay domestic obligations. In particular, the evidence of

<sup>b</sup> There is a large empirical and theoretical literature on international taxation and tax competition examining the effects of these externalities. See for example, [Frenkel et al. \(1991\)](#), [Huizinga et al. \(2012\)](#), [Klein et al. \(2007\)](#), [Mendoza and Tesar \(1998, 2005\)](#), [Persson and Tabellini \(1995\)](#), and [Sorensen \(2003\)](#).

structural changes weakening the response of primary balances to debt post-2008, and the findings that tax increases may not be able to generate enough revenue to restore fiscal solvency and are hampered by international externalities, indicate that the risk of default on domestic public debt should be considered. In addition, the ongoing European debt crisis and the recurrent turmoil around federal debt ceiling debates in the United States demonstrate that domestic public debt is not in fact the risk-free asset that is generally taken to be. The first two approaches to study debt sustainability covered in this chapter are not useful for addressing this issue, because they are built on the premise that the government is committed to repay. Note also that the risk here is not that of external sovereign default, which is the subject of a different chapter in this Handbook and has been widely studied in the literature. Instead, the risk here is the one that [Reinhart and Rogoff \(2011\)](#) referred to as “the forgotten history of domestic debt.” Historically, there have been episodes in which governments have defaulted outright on their domestic public debt, and until very recently the macro literature had paid little attention to these episodes. Hence, the third approach we examine assumes that governments cannot commit to repay domestic debt, and decide optimally to default even if standard solvency conditions hold, and even when domestic debt holders enter in the payoff function of the sovereign making the default decision. Sustainable debt in this setup is the debt that can be supported as a market equilibrium with positive quantity and price, exposed with positive probability to a government default, and with actual episodes in which default is the equilibrium outcome.

In this framework, the government maximizes a social welfare function that assigns positive weight to the welfare of all domestic agents in the economy, including those who are holders of government debt. Defaulting on public debt is useful as a tool for redistributing resources across agents, but is also costly because debt effectively provides liquidity to credit-constrained agents and serves as a vehicle for tax-smoothing and self-insurance.<sup>c</sup> If default is costless, debt is unsustainable for a utilitarian government because default is always optimal. Debt can be sustainable if default carries a cost or if the government’s social welfare function has a bias in favor of bond holders. In addition, this second assumption can be an equilibrium outcome under majority voting if the fraction of agents that do not own debt is sufficiently large, because these agents benefit from the consumption-smoothing ability that public debt issuance provides for them, and may thus choose a government biased in favor of bond holders over a utilitarian government. A quantitative application of this setup calibrated to data from Europe shows how the

<sup>c</sup> This view of default costs is motivated by the findings of [Aiyagari and McGrattan \(1998\)](#) on the social value of domestic public debt as the vehicle for self insurance in a model of heterogeneous agents assuming the government is committed to repay. [Birkeland and Prescott \(2006\)](#) show that public debt also has social value as a mechanism for tax smoothing when population growth declines, taxes distort labor, and intergenerational transfers fund retirement. Welfare when public debt is used to save for retirement is larger than in a tax-and-transfer system.

tradeoff between these costs and benefits of default determines sustainable debt. Domestic default occurs with low probability and returns on government debt carry default premia, and in the setup with a government biased in favor of bondholders the sustainable debt is large and rises with the concentration of debt ownership.

The rest of this chapter is organized as follows: [Section 2](#) discusses the classic and empirical approaches to evaluate debt sustainability, including the new FRF estimation results. [Section 3](#) focuses on the structural approach. It examines the quantitative predictions of the two-country dynamic general equilibrium model for the positive and normative effects of fiscal policies aimed at restoring fiscal solvency in response to large increases in debt, including the application to the case of the United States and Europe. [Section 4](#) covers the domestic default approach, with the quantitative example based on European data. [Section 5](#) provides a critical assessment of all three approaches and an outlook with directions for future research. [Section 6](#) summarizes the main conclusions.

## 2. EMPIRICAL APPROACH

Several articles and conference volumes survey the large literature on indicators of public debt sustainability and empirical tests of fiscal solvency (eg, [Buiter, 1985](#); [Blanchard, 1990](#); [Blanchard et al., 1990](#); [Chalk and Hemming, 2000](#); IMF, [International Monetary Fund, 2003](#); [Afonso, 2005](#); [Bohn, 2008](#); [Neck and Sturm, 2008](#), and [Escolano, 2010](#)). These surveys generally start by formulating standard concepts of government accounting, and then build around them the arguments to construct indicators of debt sustainability or tests of fiscal solvency. We proceed here in a similar way, but adopting a general formulation following the analysis of government debt in the textbook by [Ljungqvist and Sargent \(2012\)](#). The advantage of this formulation is that it is explicit about the structure of asset markets, which as we show below turns out to be critical for the design of empirical tests of fiscal solvency.

Consider a simple economy in which output and total government outlays (ie, current expenditures and transfer payments) are exogenous functions of a vector of random variables  $s$  denoted  $y(s_t)$  and  $g(s_t)$ , respectively. The exogenous state vector follows a standard discrete Markov process with transition probability matrix  $\pi(s_{t+1}, s_t)$ . Taxes at date  $t$  depend on  $s_t$  and on the outstanding public debt, but since the latter is the result of the history of values of  $s$  up to and including date  $t$ , denoted  $s^t$ , taxes can be expressed as  $\tau_t(s^t)$ . In terms of asset markets, this economy has a full set of state-contingent Arrow securities with a  $j$ -step ahead equilibrium pricing kernel given by  $Q_j(s_{t+j}|s_t) = MRS(c_{t+j}, c_t)\pi^j(s_{t+j}, s_t)$ .<sup>d</sup>

<sup>d</sup>  $MRS(c_{t+j}, c_t) \equiv \beta^j u'(c(s_{t+j})) / u'(c(s_t))$  is the marginal rate of substitution in consumption between date  $t+j$  and date  $t$ . Note also that in this simple economy the resource constraint implies that consumption is exogenous and given by  $c(s_{t+j}) = y(s_{t+j}) - g(s_{t+j})$ .

Public debt outstanding at the beginning of date  $t$  is denoted as  $b_{t-1}(s_t|s^{t-1})$ , which is the amount of date- $t$  goods that the government promised at  $t-1$  to deliver if the economy is in state  $s_t$  at date  $t$  with history  $s^{t-1}$ . The government's budget constraint can then be written as follows:

$$\sum_{s_{t+1}} Q_1(s_{t+1}|s_t) b_t(s_{t+1}|s^t) \pi(s_{t+1}, s_t) - b_{t-1}(s_t|s^{t-1}) = g(s_t) - \tau_t(s^t).$$

Notice that there are no restrictions on what type of financial instruments the government uses to borrow. In particular, the typical case in which the government issues only risk-free debt is not ruled out. In this case, the above budget constraint reduces to the familiar form:  $[b_t(s^t)/R_1(s_t)] - b_{t-1}(s^{t-1}) = g(s_t) - \tau_t(s^t)$ , where  $R_1(s_t)$  is the one-step-ahead risk-free real interest rate (which at equilibrium satisfies  $R_1(s_t)^{-1} = E_t[MRS(c_{t+1}, c_t)]$ ).

Imposing the no-Ponzi game condition  $\liminf_{j \rightarrow \infty} E_t[MRS(c_{t+j}, c_t) b_{t+j}] = 0$  on the above budget constraint, and using the equilibrium asset pricing conditions, yields the following intertemporal government budget constraint (IGBC):

$$b_{t-1} = pb_t + \sum_{j=1}^{\infty} E_t[MRS(c_{t+j}, c_t) pb_{t+j}], \quad (1)$$

where  $pb_t \equiv \tau_t - g_t$  is the primary fiscal balance. This IGBC condition is the familiar fiscal solvency condition that anchors the standard concept of debt sustainability:  $b_{t-1}$  is said to be sustainable if it matches the expected present discounted value of the stream of future primary fiscal balances. Hence, the two main goals of most of the empirical literature on public debt sustainability have been: (a) to construct simple indicators that can be used to assess debt sustainability, and (b) to develop formal econometric tests that can determine whether the hypothesis that IGBC holds can be rejected by the data.

## 2.1 Classic Debt Sustainability Analysis

Classic public debt sustainability analysis focuses on the long-run implications of a deterministic version of the IGBC. This approach uses the government budget constraint evaluated at steady state as a condition that relates the long-run primary fiscal balance as a share of GDP and the debt-output ratio, and defines the latter as the sustainable debt (see Buiter, 1985, Blanchard, 1990, and Blanchard et al., 1990). To derive this condition from the setup described earlier, first remove uncertainty from the government budget constraint with nonstate contingent debt to obtain:  $[b_t/(1+r_t)] - b_{t-1} = -pb_t$ . Then rewrite the equation with government bonds at face value instead of discount bonds:  $b_t - (1+r_t)b_{t-1} = -pb_t$ . Finally, apply a change of variables so that debt and primary balances are measured as GDP ratios, which implies that the effective interest rate becomes  $r_t \equiv (1+i_t)/(1+\gamma_t) - 1$ , where  $i_t$  is the real interest rate and  $\gamma_t$  is the growth

rate of GDP (or alternatively use the nominal interest rate and the growth rate of nominal GDP). Solving for the steady-state debt ratio yields:

$$b^{ss} = \frac{pb^{ss}}{r} \approx \frac{pb^{ss}}{i^r - \gamma}. \quad (2)$$

Thus, the steady-state debt ratio  $b^{ss}$  is the annuity value of the steady state primary balance  $pb^{ss}$ , discounted at the long-run, growth-adjusted interest rate. In policy applications, this condition is used either as an indicator of the primary balance-output ratio needed to stabilize a given debt-output ratio (the so-called “debt stabilizing” primary balance), or as an indicator of the sustainable target debt-output ratio that a given primary balance-output ratio can support. There are also variations of this approach that use the constraint  $b_t - (1 + r_t)b_{t-1} = -pb_t$  to construct estimates of primary balance targets needed to produce desired changes in debt at shorter horizons than the steady state. For instance, imposing the condition that the debt must decline ( $b_t - b_{t-1} < 0$ ), implies that the primary balance must yield a surplus that is at least as large as the growth-adjusted debt service:  $pb_t \geq r_t b_{t-1}$ .

The Classic Approach was developed in the 1980s but remains a tool widely used in policy assessments of sustainable debt. In particular, Annex VI of IMF (2013) instructs IMF economists to use a variation of the Blanchard ratio, called the Exceptional Fiscal Performance Approach, as one of three methodologies for estimating maximum sustainable public debt ranges (the other two methodologies introduce uncertainty and are discussed later in this section). This variation determines a country’s maximum sustainable primary balance and “appropriate” levels of  $i^r$  and  $\gamma$ , and then applies them to the Blanchard ratio to estimate the maximum level of debt that the country can sustain.

The main flaw of the Classic Approach is that it only *defines* what long-run debt is for a given long-run primary balance (or vice versa) if stationarity holds, or *defines* lower bounds on the short-run dynamics of the primary balance. It does not actually connect the outstanding initial debt of a particular period  $b_{t-1}$  with  $b^{ss}$ , where the latter should be  $\lim_{j \rightarrow \infty} b_{t+j}$  starting from  $b_{t-1}$ , and thus it cannot actually guarantee that  $b_{t-1}$  is sustainable in the sense of satisfying the IGBC. In fact, as we show below, for a given  $b_{t-1}$  there are multiple dynamic paths of the primary balance that satisfy IGBC. A subset of these paths converges to stationary debt positions, with different values of  $b^{ss}$  that vary widely depending on the primary balance dynamics, and there is even a subset of these paths for which the debt diverges to infinity but is still consistent with IGBC!

A second important flaw of the Classic approach is the absence of uncertainty and considerations about the asset market structure. Policy institutions have developed several methodologies that introduce uncertainty into debt sustainability analysis. For example, Barnhill and Kopits (2003) proposed incorporating uncertainty by adapting the value-at-risk (VaR) methodology of the financial industry to debt instruments issued by governments. Their methodology aims to quantify the probability of a negative net worth



position for the government. Other methodologies described in IMF (2013) use stochastic time-series simulation tools to examine debt dynamics, estimating models for the individual components of the primary balance or nonstructural vector-autoregression models that include these variables jointly with key macroeconomic aggregates (eg, output growth, inflation) and a set of exogenous variables. The goal is to compute probability density functions of possible debt-output ratios based on forward simulations of the time-series models. The distributions are then used to make assessments of sustainable debt in terms of the probability that the simulated debt ratios are greater or equal than a critical value, or to construct “fan charts” summarizing the confidence intervals of the future evolution of debt. More recently, Ostry et al. (2015) use the fiscal reaction functions estimated by Ghosh et al. (2013) and discussed later in this section to construct measures of “fiscal space,” which are intended to show the space a country has for increasing its debt ratio while still satisfying the IGBC.

IMF (2013) proposes two other stochastic tools as part of the framework for quantifying maximum sustainable debt (complementing the deterministic Exceptional Fiscal Performance estimates discussed earlier). The first is labeled the Early Warning Approach. This method computes a threshold debt ratio above which a country is likely to experience a debt crisis. The threshold is optimized with respect to the type-1 (false alarms of crises) and type-2 (missed warnings of crises) errors it produces, by minimizing the sum of the ratio of missed crises to total crises periods and false alarms to total noncrises periods. The second tool, labeled the Uncertainty Approach, is actually the same as the method proposed by Mendoza and Oviedo (2009), to which we turn next.<sup>e</sup>

The stochastic methods reviewed above have the significant shortcoming that, as with the Blanchard ratio, they cannot guarantee that their sustainable debt estimates satisfy the IGBC. Moreover, they introduce uncertainty without taking into account the fact that typically government debt is in the form of non-state-contingent instruments. The setup proposed by Mendoza and Oviedo (2006, 2009) addresses these two shortcomings. In this setup, the government issues non-state-contingent debt facing stochastic Markov processes for government revenues and outlays (ie, asset markets are incomplete). The key assumption is that the government is committed to repay, which imposes a constraint on public debt akin to Ayagari’s Natural Debt Limit for private debt in Bewley models of heterogeneous agents with incomplete markets.

Following the simple version of this framework presented in Mendoza and Oviedo (2009), assume that output follows a deterministic trend, with an exogenous growth rate given by  $\gamma$ , and that the real interest rate is constant. Assume also that the government

<sup>e</sup> IMF (2013) refers to this approach as “a derivative of the exceptional fiscal performance approach and relies on the same underlying concepts and equations.” As we explain, however, Blanchard ratios and their variations differ significantly from the debt limits and debt dynamics characterized by Mendoza and Oviedo (2009).

keeps its outlays smooth, unless it finds itself unable to borrow more, and when this happens it cuts its outlays to minimum tolerable levels.<sup>f</sup> Since the government cannot have its outlays fall below this minimum level, it does not hold more debt than the amount it could service after a long history in which  $pb(s^t)$  remains at its worst possible realization (ie, the primary balance obtained with the worst realization of revenues,  $\tau^{\min}$ , and public outlays cut to their tolerable minimum  $g^{\min}$ ), which can happen with positive probability. This situation is defined as a state of fiscal crisis and it sets an upper bound on debt denoted the “Natural Public Debt Limit” (NPDL), which is given by the growth-adjusted annuity value of the primary balance in the state of fiscal crisis:

$$b_t \leq NPDL \equiv \frac{\tau^{\min} - g^{\min}}{i^r - \gamma}. \quad (3)$$

This result together with the government budget constraint yields a law of motion for debt that follows this simple rule:  $b_t = \min[NPDL, (1 + r_t)b_{t-1} - pb_t] \geq \bar{b}$ , where  $\bar{b}$  is an assumed lower bound for debt that can be set to zero for simplicity (ie, the government cannot become a net creditor).<sup>g</sup>

Notice that NPDL is lower for governments that have (a) higher variability in public revenues (ie, lower  $\tau^{\min}$  in the support of the Markov process of revenues), (b) less flexibility to adjust public outlays (higher  $g^{\min}$ ), or (c) lower growth rates and/or higher real interest rates. The stark differences between NPDL and  $b^{ss}$  from the classic debt sustainability analysis are also important to note. The expressions are similar, but the two methods yield sharply different implications for debt sustainability: The classic approach will always identify as sustainable debt ratios that are unsustainable according to the NPDL, because in practice  $b^{ss}$  uses the average primary fiscal balance, instead of its worst realization, and as a result it yields a long-run debt ratio that violates the NPDL. Moreover, while  $b^{ss}$  cannot be related to the IGBC, the debt rule  $b_t = \max[NPDL, (1 + r_t)b_{t-1} - pb_t] \geq \bar{b}$  always satisfies the IGBC, because debt is bounded above at the NPDL, which guarantees that the no-Ponzi game condition cannot be violated. Note also, however, that the NPDL is a measure of the largest debt that a government can maintain, and not an estimate of the long-run average debt ratio or of the stationary debt ratio.

<sup>f</sup> This is a useful assumption to keep the setup simple, but is not critical. [Mendoza and Oviedo \(2006\)](#) model government expenditures entering a CRRA utility function as an optimal decision of the government, and here the curvature of the utility function imposes the debt limit in the same way as in Bewley models.

<sup>g</sup> This debt rule has an equivalent representation as a lower bound on the primary balance:  $pb_t \geq (1 + r_t)b_{t-1} - NPDL$ . On the date of a fiscal crisis,  $b_t$  hits NPDL. The next period, if the lowest realization of revenues is drawn again,  $pb_{t+1}$  hits  $\tau^{\min} - g^{\min}$ . Debt and the primary balance remain unchanged until higher revenue realizations are drawn, and the larger surpluses reduce the debt. See section III.3 of [Mendoza and Oviedo \(2009\)](#) for stochastic simulations of a numerical example.

The NPDL can be turned into a policy indicator by characterizing the probabilistic processes of the components of the primary balance together with some simplifying assumptions. On the revenue side, the probabilistic process of tax revenues reflects the uncertainty affecting tax rates and tax bases. This uncertainty includes domestic tax policy variability, the endogenous response of the economy to that variability, and other factors that can be largely exogenous to the domestic economy (eg, the effects of fluctuations in commodity prices and commodity exports on government revenues). On the expenditure side, government expenditures adjust partly in response to policy decisions, but the manner in which they respond varies widely across countries, as the literature on procyclical fiscal policy in emerging economies has shown (eg, see [Alesina and Tabellini, 2005](#); [Kaminsky et al., 2005](#); [Talvi and Vegh, 2005](#)).

The quantitative analysis in [Mendoza and Oviedo \(2009\)](#) treats the revenue and expenditures processes as exogenous, and calibrates them to 1990–2005 data from four Latin American economies.<sup>h</sup> Since the value of the expenditure cuts that each country can commit to is unobservable, they calculate instead the implied cuts in government outlays, relative to each country's average (ie,  $g^{\min} - E[g]$ ), that would be needed so that each country's NPDL is consistent with the largest debt ratio observed in the sample. The largest debt ratios are around 55% for all four countries (Brazil, Colombia, Costa Rica, and Mexico), but the cuts in outlays that make these debt ratios consistent with the NPDL range from 3.8 percentage points of GDP for Costa Rica to 6.2 percentage points for Brazil. This is the case largely because revenues in Brazil have a coefficient of variation of 12.8%, vs 7% in Costa Rica, and hence to support a similar NPDL at a much higher revenue volatility requires higher  $g^{\min}$ . Mendoza and Oviedo also showed that the time-series dynamics of debt follow a random walk with boundaries at NPDL and  $\bar{b}$ .

## 2.2 Bohn's Debt Sustainability Framework

In a series of influential articles published between 1995 and 2011, Henning Bohn made four major contributions to the empirical literature on debt sustainability tests:

1. *IGBC tests that discount future primary balances at the risk-free rates are misspecified, because the correct discount factors are determined by the state-contingent equilibrium pricing kernel* ([Bohn, 1995](#)).<sup>i</sup> Tests affected by this problem include those reported in several well-known empirical studies (eg, [Hamilton and Flavin, 1986](#), [Hansen et al., 1991](#), and [Gali, 1991](#)). Following [Ljungqvist and Sargent \(2012\)](#), this misspecification

<sup>h</sup> [Mendoza and Oviedo \(2006\)](#) endogenize the choice of government outlays and decentralize the private and public borrowing decisions in a small open economy model with nonstate-contingent assets.

<sup>i</sup> [Lucas \(2012\)](#) raised a similar point in a different context. She argued that the relevant discount rate for government flows should not be the risk-free rate but a cost of capital that incorporates the market risk associated with government activities.

error is easy to illustrate by using the equilibrium risk-free rates ( $R_{t+j}^{-1} = E_t[MRS(c_{t+j}, c_t)]$ ) to rewrite the IGBC as follows:

$$b_{t-1} = pb_t + \sum_{j=1}^{\infty} \left[ \frac{E_t[pb_{t+j}]}{R_{t+j}} + cov_t(MRS(c_{t+j}, c_t), pb_{t+j}) \right]. \quad (4)$$

Hence, discounting the primary balances at the risk-free rates is only correct if

$$\sum_{j=1}^{\infty} cov_t(MRS(c_{t+j}, c_t), pb_{t+j}) = 0.$$

This would be true under one of the following assumptions: (a) perfect foresight, (b) risk-neutral private agents, or (c) primary fiscal balances that are uncorrelated with future marginal utilities of consumption. All of these assumptions are unrealistic, and (c) in particular runs contrary to the strong empirical evidence showing that primary balances are not only correlated with macro fluctuations, but show a strikingly distinct pattern across industrial and developing countries: primary balances are procyclical in industrial countries, and acyclical or countercyclical in developing countries. Moreover, [Bohn \(1995\)](#) also showed examples in which this misspecification error leads to incorrect inferences that reject fiscal solvency when it actually does hold. For instance, a rule that maintains  $g/\gamma$  and  $b/\gamma$  constant in a balanced-growth economy with i.i.d. output growth violates the misspecified IGBC if mean output growth is greater or equal than the interest rate, but it does satisfy condition (1).

2. *Testing for debt sustainability is futile, because the IGBC holds under very weak assumptions about the time-series processes of fiscal data that are generally satisfied. The IGBC holds if either debt or revenue and spending inclusive of debt service are integrated of finite but arbitrarily high order (Bohn, 2007).* This invalidates several fiscal solvency tests based on specific stationarity and cointegration conditions (eg, [Hamilton and Flavin, 1986](#); [Trehan and Walsh, 1988](#); [Quintos, 1995](#)), because neither a particular order of integration of the debt data, nor the cointegration of revenues and government outlays is necessary for debt sustainability. As Bohn explains in the proof of this result, the reason is intuitive: In the forward conditional expectation that forms the no-Ponzi game condition, the  $j^{th}$  power of the discount factor asymptotically dominates the expectation  $E_t(b_{t+j})$  as  $j \rightarrow \infty$  if the debt is integrated of any finite order. This occurs because  $E_t(b_{t+j})$  is at most a polynomial of order  $n$  if  $b$  is integrated of order  $n$ , while the discount factor is exponential in  $j$ , and exponential growth dominates polynomial growth. But perhaps of even more significance is the implication that, since integration of finite order is indeed a very weak condition, testing for fiscal solvency or debt sustainability per se is not useful: The data are all but certain to reject the hypotheses that debt or revenue and spending inclusive of debt service are nonstationary after differencing the

data a finite number of times (usually only once!). Bohn (2007) concluded that, in light of this result, using econometric tools to try and identify in the data fiscal reaction functions that support fiscal solvency and studying their dynamics is “more promising for understanding deficit problems.”

3. A linear fiscal reaction function (FRF) with a statistically significant, positive (conditional) response of the primary balance to outstanding debt is sufficient for the IGBC to hold (Bohn, 1998, 2008). Proposition 1 in Bohn (2008) demonstrates that this linear FRF is sufficient to satisfy the IGBC:

$$pb_t = \mu_t + \rho b_{t-1} + \varepsilon_t,$$

for all  $t$ , where  $\rho > 0$ ,  $\mu_t$  is a set of additional determinants of the primary balance, which typically include an intercept and proxies for temporary fluctuations in output and government expenditures, and  $\varepsilon_t$  is i.i.d. The proof only requires that  $\mu_t$  be bounded and that the present value of GDP be finite. Intuitively, the argument of the proof is that with  $pb$  changing by the positive factor  $\rho$  when debt rises, the growth of the debt  $j$  periods ahead is lowered by  $(1-\rho)^j$ . Formally, for any small  $\rho > 0$ , the following holds as  $j \rightarrow \infty$ :  $E_t[MRS(c_{t+j}, c_t)b_{t+j}] \approx (1-\rho)^j b_t \rightarrow 0$ , which in turn implies that the NPG condition and thus the IGBC hold. Note also that while debt sustainability holds for any  $\rho > 0$ , the long-run behavior of the debt ratio differs sharply depending on the relative values of the mean  $r$  and  $\rho$ . To see why, combine the FRF and the government budget constraint to obtain the law of motion of the debt ratio  $b_t = -\mu_t + (1 + r_t - \rho)b_{t-1} + \varepsilon_t$ . Hence, debt is stationary only if  $\rho > r$ , otherwise it explodes, but as long as  $\rho > 0$  it does so at a slow enough pace to still satisfy IGBC.<sup>j</sup> In addition, the IGBC holds for the same value of initial debt for any  $\rho > 0$ , but, if  $\rho > r$ , debt converges to a higher long-run average as  $\rho$  falls.

The above results also show why the steady-state debt  $b^{ss}$  of the classic debt sustainability analysis is not useful for assessing debt sustainability: With the linear FRF, multiple well-defined long-run averages of debt are consistent with debt sustainability, each determined by the particular value of the response coefficient in the range  $\rho > r$ , and even exploding debt is consistent with debt sustainability if  $0 < \rho < r$ . Moreover, in the limit as  $r \rightarrow 0$ , the Blanchard ratio of the classic analysis predicts that debt diverges to infinity ( $b^{ss} \rightarrow \infty$  if  $pb^{ss}$  is finite), while the linear FRF predicts that both  $b$  and  $pb$  are mean-reverting to well-defined long-run averages given by  $-\mu/\rho$  and 0. Similarly, notions of a “maximal sustainable interest rate” are meaningless from

<sup>j</sup> Bohn (2007) shows that this result holds for any of the following three assumptions about the interest rate process: (i)  $r_t = r$  for all  $t$ , (ii)  $r_t$  is a stochastic process that is serially uncorrelated with  $E_t[r_{t+1}] = r$ , or (iii)  $r_t$  is any stochastic process with mean  $r$  subject only to implicit restrictions such that

$$b_t = \frac{1}{1+r} E_t[pb_{t+1} + b_{t+1} - (r_{t+1} - r)b_t].$$

the perspective of assessing whether the debt satisfies the IGBC, because  $\rho > 0$  is sufficient for IGBC to hold regardless of the value of  $r$ .<sup>k</sup>

4. *Empirical tests of the linear FRF based on historical U.S. data and various subsamples reject the hypothesis that  $\rho \leq 0$ , so IGBC holds (Bohn, 1998, 2008).* In his 2008 article, Bohn constructed a dataset going back to 1791, the start of US public debt after the Funding Act of 1790, and found that the response coefficient estimated with 1793–2003 data is positive and significant, ranging from 0.1 to 0.12. Moreover, looking deeper into the fiscal dynamics he found that economic growth has been sufficient to cover the entire servicing costs of US public debt, but there are structural breaks in the response coefficient. The 1793–2003 estimates are about twice as large as those obtained in Bohn (1998) using data for 1916–2005, which is a period that emphasizes the cold-war era of declining debt but high military spending.

Bohn's framework has been applied to cross-country datasets by Mendoza and Ostry (2008) and extended to include a nonlinear specification allowing for default risk by Ghosh et al. (2013).<sup>l</sup> Mendoza and Ostry found estimates of response coefficients for a panel of industrial countries that are similar to those Bohn (1998) obtained for the United States. In addition, they found that the solvency condition holds for a panel that includes both industrial and developing countries, as well as in a subpanel that includes only the latter. They also found, however, that cross-sectional breaks are present in the data at particular debt thresholds. In the combined panel and the subpanels with only advanced or only developing economies, there are high-debt country groups for which the response coefficient is not statistically significantly different from zero. Ghosh et al. found that the response coefficients fall sharply at high debt levels, and obtained estimates of fiscal space that measure the distance between observed debt ratios and the largest debt ratios that can be supported given debt limits implied by the presence of default risk.

## 2.3 Estimated Fiscal Reaction Functions and Their Implications

We provide below new estimation results for linear FRFs for the United States using historical data from 1791 to 2014, and for a cross-country panel using data for the 1951–2013 period. Some of the results are in line with the findings of previous studies, but the key difference is that there is a significant break in the response of the primary

<sup>k</sup> This is not the case if the government cannot commit to repay its debt. In external sovereign default models in the vein of Eaton and Gersovitz (1981), for example, the interest rate is an increasing, convex function of the debt stock, and there exists a debt level at which rationing occurs because future default on newly issued debt becomes a certain event.

<sup>l</sup> The same approach has also been used to test for external solvency (ie, whether the present discounted value of the balance of trade matches the observed net foreign asset position). Durdu et al. (2013) conducted cross-country empirical tests using data for 50 countries over the 1970–2006 period and found that the data cannot reject the hypothesis of external solvency, which in this case is measured as a negative response of net exports to net foreign assets.

balance to debt after 2008. We then use the estimation results and the historical data to put in perspective the current fiscal situation of the United States and Europe. In particular, we show that: (a) primary balance adjustment in the United States is lagging significantly behind what has been observed in the aftermath of previous episodes of large increases in debt, (b) observed primary deficits have been much larger than what the FRFs predict, and (c) hypothetical scenarios with alternative response coefficients produce sharply different patterns of transitional dynamics and long-run debt ratios, but they are all consistent with the same observed initial debt ratios (ie, IGBC holds for all of them).

### 2.3.1 FRF Estimation Results

Table 1 shows estimation results for the FRF of the United States using historical data for the 1791–2014 period. The table shows results for five regression models similar to those estimated in Bohn (1998, 2008). Column (1) shows the base model, which uses as regressors the initial debt ratio, the cyclical component of output, and temporary military expenditures as a measure of transitory fluctuations in government expenditures.<sup>m</sup> Column (2) introduces a nonlinear spline coefficient when the debt is higher than the mean. Column (3) introduces an AR(1) error term. Column (4) adds the squared mean deviation of the debt ratio. Column (5) includes a time trend. Columns (6) and (7) provide modifications that are important for showing the structural instability of the FRF post-2008: Column (6) reruns the base model truncating the sample in last year of the sample used in Bohn (2008) and Column (7) uses a sample that ends in 2008. The signs of the debt, output gap and military expenditures coefficients are the same as in Bohn's regressions, and in particular the response coefficient estimates are generally positive, which satisfies the sufficiency condition for debt sustainability.

In Columns (1)–(5), the point estimates of  $\rho$  range between 0.077 and 0.105, which are lower than Bohn's 2008 estimates based on 1793–2003 data, but higher than his (1998) estimates based on 1916–95 data. The  $\rho$  estimates are always statistically significant, although only at the 90% confidence level in the base and squared-debt models.

Column (6) shows that if we run the linear FRF over the same sample period as in Bohn (2008), the results are very similar to his (see in particular Column 1 of table 7 in his paper).<sup>n</sup> The point estimate of  $\rho$  is 0.105, compared with 0.121 in Bohn's study (both statistically significant at the 99% confidence level). But in our base model of Column (1) we found that using the full sample that runs through 2014 the point estimate of  $\rho$  falls to 0.078. Moreover, excluding the post-2008–crisis data in Column (7), the results

<sup>m</sup> We follow Bohn in measuring this temporary component as the residual of an AR(2) process for military expenditures.

<sup>n</sup> They only differ because we defined military expenditures as the sum of expenditures by the Department of Defense and the Veterans Administration for the full sample, excluding international relations, while Bohn includes Veterans starting in 1940 and adds international relations.

**Table 1** Fiscal reaction function of the United States: 1792–2014

Model:	Base model	Asymmetric response	AR(1) term	Debt squared	Time trend	Bohn's sample (1793–2003)	Prerecession (1793–2008)
Coefficient	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	0.00648 (0.004)	0.00540 (0.003)*	0.00974 (0.008)	0.00653 (0.004)	0.00601 (0.006)	0.00485 (0.003)*	0.00470 (0.003)
Initial debt $d_t^*$	0.07779 (0.040)*	0.08689 (0.030)***	0.10477 (0.032)***	0.07715 (0.038)*	0.07674 (0.035)**	0.10498 (0.023)***	0.10188 (0.022)***
GDP gap	0.07404 (0.078)	0.07300 (0.079)	0.15330 (0.043)***	0.07390 (0.079)	0.07490 (0.077)	0.07987 (0.086)	0.07407 (0.086)
Military expenditure $\max(0, d_t^* - \bar{d})$	−0.72302 (0.133)***	−0.72001 (0.136)*** −0.14487 (0.061)	−0.98955 (0.110)***	−0.72320 (0.133)***	−0.72462 (0.135)***	−0.77835 (0.135)***	−0.76857 (0.135)***
AR(1)			0.89154 (0.029)***				
$(d_t^* - \bar{d})^2$				0.00261 (0.044)			
Time trend					$6.89 \times 10^{-06}$ ( $5.9 \times 10^{-05}$ )		
s.e.	0.0239	0.0240	0.198	0.0120	0.0240	0.0210	0.0209
Adj. R-squared:	0.606	0.605	0.901	0.614	0.605	0.695	0.688
Observations:	223	223	222	223	223	213	217

Note: HAC standard errors shown in parenthesis, 2-lag window prewhitening. “\*”, “\*\*\*”, and “\*\*\*\*” denote that the corresponding coefficient is statistically significant at the 90%, 95%, and 99% confidence levels. Output gap is percent deviation from Hodrick–Prescott trend. Military expenditure includes all Department of Defense and Department of Veterans Affairs outlays.



are very similar to those obtained with the same sample period as Bohn's. Hence, these results suggest that the addition of the post-2008 data, a tumultuous period in the fiscal stance of the United States, produces a structural shift in the FRF.<sup>o</sup> Testing formally for this hypothesis, we found that Chow's forecast test rejects strongly the null hypothesis of no structural change in the value of  $\rho$  when the post-2008 data are added. Hence, the decline in the estimate of  $\rho$  from 0.102 to 0.078 is statistically significant. This change in the response of the primary balance to higher debt ratios may seem small, but it implies that the primary balance adjustment is about 25% smaller, and as we show later this results in large changes in the short- and long-run dynamics of debt.

The regressions with nonlinear features (Column (2) with the debt spline at the mean debt ratio, and Column (4) with the squared deviation from the mean debt ratio) are very different from Bohn's estimates. In Bohn (1998), the FRF with the same spline term has a negative point estimate  $\rho = -0.015$  and a large, positive spline coefficient of 0.105 when debt is above its mean, so that for above-average debt ratios the response of the primary balance is stronger than for below-average debt ratios, and becomes positive with a net effect of 0.09, which is consistent with debt sustainability. In contrast, Table 1 shows a  $\rho$  estimate of 0.09 with a spline coefficient of  $-0.14$ . Hence, these results suggest that the response of the primary balance is weaker for above-average debt ratios, and the net effect is negative at  $-0.05$ , which violates the linear FRF's sufficiency condition for debt sustainability. The spline coefficient is not, however, statistically significant. For the squared-debt regressions, Bohn (2008) estimated a positive coefficient of 0.02, while the coefficient shown in Table 1 is only 0.003 (both not statistically significant). Thus, both the debt-spline and debt-squared regressions are also consistent with the possibility of a structural change in the FRF. In particular, the stronger primary balance response at higher debt ratios that Bohn identified in his 1998 and 2008 studies changed to a much weaker response once the data up to 2014 are introduced. The rationale for this is that the large debt increases since 2008 have been accompanied by adjustments in the primary balance that differ sharply from what has been observed in previous episodes of large debt increases, as we illustrate below.

Tables 2–4 show the results of cross-country panel regressions similar to those reported by Mendoza and Ostry (2008) and Ghosh et al. (2013), but expanded to include data for the 1951–2013 period for 25 advanced and 33 emerging economies. The first six columns of results in these tables show three pairs of regression models. Each pair uses a different measure of government expenditures, since the measure based on military expenditures used in the US regressions is unavailable and/or less relevant as a measure of the temporary component of government expenditures in the international dataset.

<sup>o</sup> Bohn (2008) also found evidence of structural shifts when contrasting his results for 1784–2003 with his 1916–95 results, with sharply lower response coefficients for the shorter sample, which he attributed to the larger weight of the cold-war era (in which debt declined while military spending remained high).

**Table 2** Fiscal reaction functions of advanced economies (1951–2013)

Model	All advanced economies					
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	11.23917 (3.134)***	1.76019 (0.037)***	−1.02696 (0.472)**	−0.07294 (0.195)	−1.42979 (2.651)	0.02521 (0.222)
Previous debt $d_{t-1}$	0.06916 (0.013)***	0.01461 (0.001)***	0.01983 (0.010)**	0.00295 (0.005)	0.02750 (0.010)***	−0.00076 (0.005)
GDP gap	0.17053 (0.050)***	0.28046 (0.058)***	0.31501 (0.065)***	0.34696 (0.060)***	0.34939 (0.073)***	0.40503 (0.073)***
Government Expenditure	−0.35654 (0.078)***	−0.06305 (0.013)***				
Government Expenditure gap			−0.10449 (0.031)***	−0.12511 (0.031)***		
Govt consumption Gap (Nat. Acc.)					−0.20579 (0.064)***	−0.33638 (0.070)***
Country AR(1)	Yes	No	Yes	No	Yes	No
s.e.	1.603	2.814	1.709	2.813	1.796	2.884
Adj. R-squared:	0.766	0.277	0.755	0.306	0.733	0.304
Observations:	1285	1346	1218	1273	1139	1186
Countries:	25	25	25	25	25	25

Note: All regressions include country fixed effect and White cross-section corrected standard errors and covariances. Standard errors shown in parenthesis. “\*”, “\*\*”, and “\*\*\*” denote that the corresponding coefficient is statistically significant at the 90%, 95%, and 99% confidence levels. Output, government expenditure, and government consumption gaps are percent deviation from Hodrick–Prescott trend.

**Table 3** Fiscal reaction functions of emerging economies (1951–2013)

Model	(1)	(2)	(3)	(4)	(5)	(6)
Constant	9.99549 (1.473)***	1.32486 (0.409)***	−2.38214 (0.462)***	−1.88325 (0.284)***	−2.33727 (0.544)***	−1.70461 (0.322)***
Previous debt	0.03806 (0.009)***	0.05657 (0.006)***	0.05452 (0.006)***	0.04519 (0.005)***	0.05280 (0.008)***	0.04376 (0.006)***
$d_{t-1}$						
GDP gap	0.03698 (0.029)	0.07352 (0.027)***	0.15962 (0.034)***	0.15509 (0.027)***	0.07568 (0.042)*	0.06831 (0.030)**
Government Expenditure	−0.44322 (0.049)***	−0.15638 (0.020)***				
Government Expenditure gap			−0.11986 (0.012)***	−0.12420 (0.012)***		
Govt Consumption					−0.01302	−0.02662
Gap (Nat. Acc.)					(0.018)	(0.014)*
Country AR(1)	Yes	No	Yes	No	Yes	No
s.e.	1.854	2.630	1.772	2.450	2.072	2.795
Adj. R-squared:	0.666	0.346	0.698	0.437	0.589	0.321
Observations:	1071	1144	977	1035	967	1022
Countries:	33	33	33	33	33	33

Note: All regressions include country fixed effect and White cross-section corrected standard errors and covariances. Standard errors shown in parenthesis. “\*”, “\*\*\*”, and “\*\*\*\*” denote that the corresponding coefficient is statistically significant at the 90%, 95%, and 99% confidence levels. Output, government expenditure, and government consumption gaps are percent deviation from Hodrick–Prescott trend.

**Table 4** Fiscal reaction functions for advanced and emerging economies (1951–2013)

Model	(1)	(2)	(3)	(4)	(5)	(6)
Constant	10.53960 (1.528)***	1.50777 (0.357)***	−2.23188 (0.400)***	−0.65482 (0.160)***	−2.29040 (0.466)***	−0.57649 (0.172)***
Previous debt $d_{t-1}$	0.05138 (0.007)***	0.02962 (0.004)***	0.04576 (0.006)***	0.01634 (0.004)***	0.04661 (0.006)***	0.01500 (0.004)***
GDP gap	0.07864 (0.031)**	0.12611 (0.030)***	0.20956 (0.043)***	0.20590 (0.032)***	0.16205 (0.051)***	0.15198 (0.036)***
Government Expenditure	−0.40043 (0.047)***	−0.08823 (0.015)***				
Government Expenditure Gap			−0.11558 (0.014)***	−0.12788 (0.016)***		
Govt consumption Gap (Nat. Acc.)					−0.03764 (0.021)*	−0.07534 (0.020)***
Country AR(1)	Yes	No	Yes	No	Yes	No
s.e.	1.729	2.796	1.756	2.727	1.970	2.915
Adj R-squared:	0.720	0.275	0.718	0.328	0.656	0.254
Observations:	2356	2490	2195	2308	2106	2208
Countries:	58	58	58	58	58	58

*Note:* All regressions include country fixed effect and White cross-section corrected standard errors and covariances. Standard errors shown in parenthesis. “\*,” “\*\*,” and “\*\*\*” denote that the corresponding coefficient is statistically significant at the 90%, 95%, and 99% confidence levels. Output, government expenditure, and government consumption gaps are percent deviation from Hodrick–Prescott trend.

Models (1) and (2) use total real government outlays (ie, current expenditures plus all other noninterest expenditures, including transfer payments), models (3) and (4) use the cyclical component of total real outlays, and models (5) and (6) follow [Mendoza and Ostry \(2008\)](#) and use the cyclical component of real government absorption from the national accounts (ie, real current government expenditures). Models (1), (3) and (5) include country-specific AR(1) terms, which Mendoza and Ostry also found important to consider, while model (2), (4), and (6) do not.

Two caveats about the measures of government expenditures used in these regressions. First, they are less representative of unexpected increases in government expenditures, particularly the HP cyclical component because of the double-sided nature of the HP filter. Second, since the primary balance is the difference between total revenues and expenditures, adding the latter as a regressor implies that revenues are the only endogenous component of the dependent variable that can respond to changes in debt. This is less true when we use only the cyclical component of expenditures and/or use only current expenditures instead of total outlays, but it remains a potential limitation. Interestingly, the coefficients on government expenditures do have the same sign as in the US regressions with temporary military expenditures (although they are about half the size), and they are statistically significant at the 99% confidence level. These caveats do imply, however, that the coefficients on government expenditures cannot be interpreted as measuring only the response of the primary balance to unexpected increases in government expenditures, but can reflect also differences in the cyclical stance of fiscal policies and in the degree of access to debt markets (see [Mendoza and Ostry, 2008](#) for a discussion of these issues).

[Table 2](#) shows that, as in Mendoza and Ostry, considering the country-specific AR(1) terms in the cross-country panel is important. The advanced economies' response coefficients are higher and with significantly smaller standard errors when the autocorrelation of error terms is corrected. Hence, we focus the rest of the discussion of the panel results on the results with AR(1) terms.

The advanced economies' response coefficients of the primary balance on debt in the AR(1) models are positive and statistically significant in general. The coefficients are smaller in the regressions that use cyclical components of either total outlays or current expenditures (models (3) and (5)) than in the one that uses the level of government outlays (model (1)), but across the first two the  $\rho$  coefficients are similar (0.02 vs 0.028). Following again Mendoza and Ostry, we focus on the regressions that use the cyclical components of current government expenditures.

Comparing the FRFs with country AR(1) terms and using the cyclical component of current government expenditures across the three panel datasets, [Tables 2–4](#) show that the estimates of  $\rho$  are 0.028 for advanced economies, 0.053 for emerging economies, and 0.047 for the combined panel. Mendoza and Ostry obtained estimates of 0.02 for advanced economies and 0.036 for both emerging economies and the combined panel.

The results are somewhat different, but the two are consistent in producing larger values of  $\rho$  for emerging economies and the combined panel than for advanced economies.

The difference in the response coefficients across advanced and emerging economies highlights important features of their debt dynamics. Condition (4) suggests that countries with procyclical fiscal policy (ie, acyclical or countercyclical primary balances) can sustain higher debt ratios than countries with countercyclical fiscal policy (ie, procyclical primary balances). Yet we observe the opposite in the data: Advanced economies conduct countercyclical fiscal policy and show higher average debt ratios than emerging economies, which display procyclical or acyclical fiscal policy (ie, significantly lower primary balance–output gap correlations). Indeed, the higher  $\rho$  of the emerging economies implies that these countries converge to lower mean debt ratios in the long run. As [Mendoza and Ostry \(2008\)](#) concluded, this higher  $\rho$  is not an indicator of “more sustainable” fiscal policies in emerging economies, but evidence of the fact that past increases in debt of a given magnitude in these countries require a stronger conditional response of the primary balance, and hence less reliance on debt markets, than in advanced economies.

### 2.3.2 Implications for Europe and the United States

Public debt and fiscal deficits rose sharply in several advanced economies after the 2008 global financial crisis, in response to both expansionary fiscal policies and policies aimed at stabilizing financial systems. To put in perspective the magnitude of this recent surge in debt, it is useful to examine Bohn’s historical dataset of public debt and primary balances for the United States. Defining a public debt crisis as a year-on-year increase in the public debt ratio larger than twice the historical standard deviation, which is equivalent to more than 8.15 percentage points in Bohn’s dataset, we identify five debt crisis events (see [Fig. 1](#)): The two world wars (World War I with an increase of 28.7 percentage points of GDP over 1918–19 and World War II with 59.3 percentage points over 1943–45), the Civil War (19.7 percentage points over 1862–63), the Great Depression (18.5 percentage points over 1932–33), and the Great Recession (22.3 percentage points over 2009–10). The Great Recession episode is the third largest, ahead of the Civil War and the Great Depression episodes.

[Fig. 2](#) illustrates the short-run dynamics of the US primary fiscal balance after each of the five debt crises. Each crisis started with large deficits, ranging from 4% of GDP for the Great Depression to nearly 20% of GDP for World War II, but the Great Recession episode is unique in that the primary balance remains in deficit 4 years after the crisis. In the three war-related crises, a large primary deficit turned into a small surplus within 3 years. By contrast, the latest baseline scenario from the Congressional Budget Office (*Updated Budget and Economic Outlook: 2015–2025*, January 2015), projects that the US primary balance will continue in deficit for the next 10 years. The primary deficit is projected to shrink to 0.6% of GDP in 2018 and then hover near 1% through 2025. In addition,

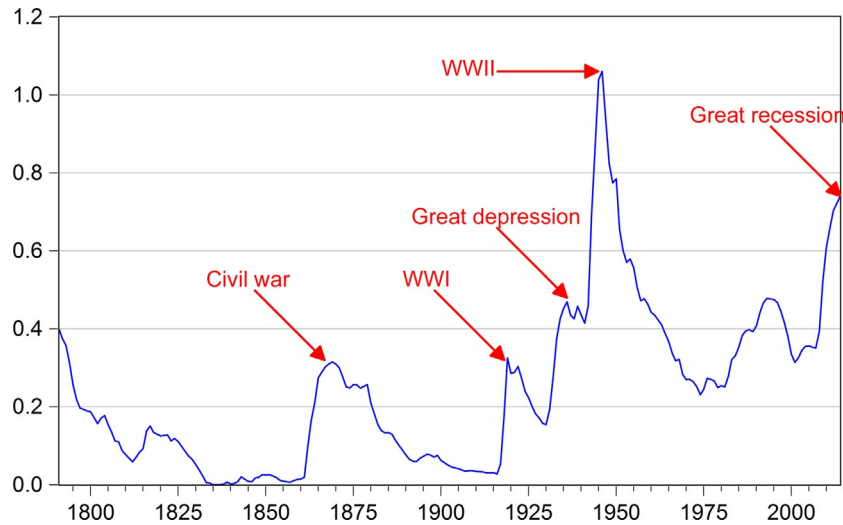


Fig. 1 US government debt as percentage of GDP.

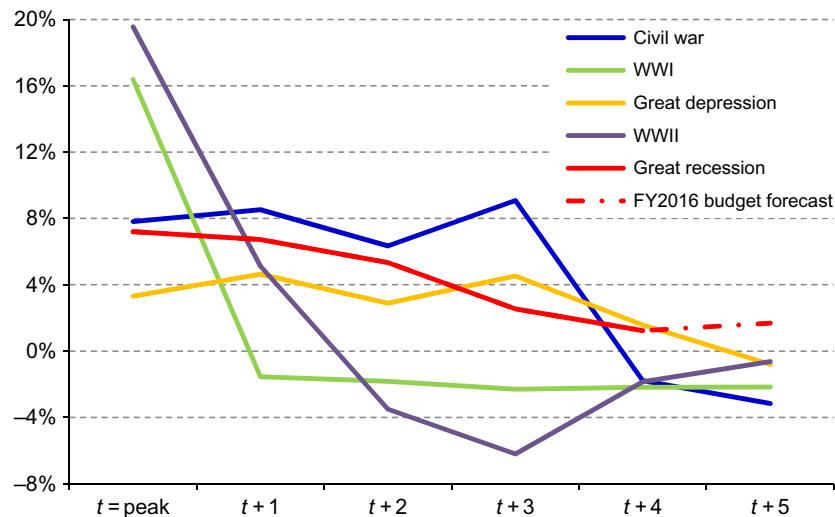


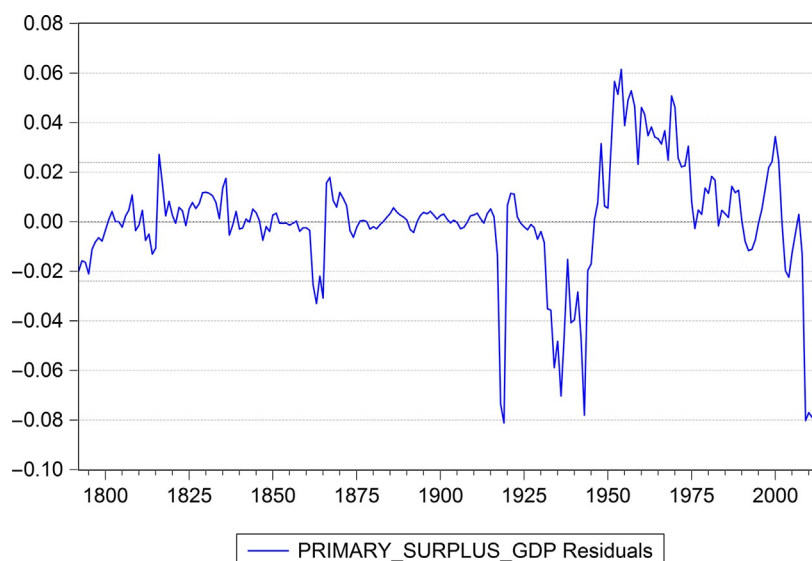
Fig. 2 US government deficits after debt crises.

relative to the Great Depression, the first three deficits of the Great Recession were nearly twice as large, and by 5 years after the debt crisis of the Great Depression the United States had a primary surplus of nearly 1% of GDP. In summary, the post-2008 increase in public debt has been of historic proportions, and the absence of primary surpluses in both the 4 years after the surge in debt and the projections for 2015–25 is *unprecedented* in US history.

Many advanced European economies have not fared much better. Weighted by GDP, the average public debt ratio of the 15 largest European economies rose from 38% to 58% between 2007 and 2011. The increase was particularly large in the five countries at the center of the European debt crisis (Greece, Ireland, Italy, Portugal and Spain), where the debt ratio weighted by GDP rose from 75% to 105%, but even in some of the largest European economies public debt rose sharply (by 33 and 27 percentage points in the United Kingdom and France, respectively).

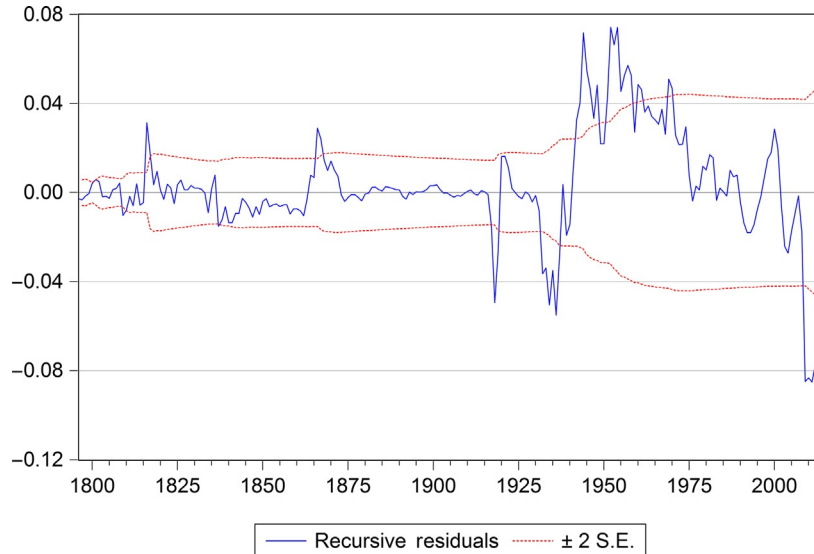
The estimated FRFs can be used to examine the implications of these rapid increases in public debt ratios for debt sustainability and for the short- and long-run dynamics of debt and deficits. Consider first the regression residuals. Fig. 3 shows the residuals of the US fiscal reaction function estimated in the base model (1) of Table 1, and Fig. 4 shows rolling residuals from the same regression. These two plots show that the residuals for 2008–14 are significantly negative, and much larger in absolute value than the residuals in the rest of the sample period. In fact, the residuals for 2009–11 are twice as large as the corresponding minus-two-standard-error bound. Thus, the primary deficits observed during the post-2008 years have been much larger than what the FRFs predicted, even after accounting for the larger deficits that the FRFs allow on account of the depth of the recession and expansionary government expenditures. These large residuals are of course consistent with the results documented earlier showing evidence of structural change in the FRF when the post-2008 data are added.

The structural change in the FRF can also be illustrated by comparing the actual primary balances from 2009 to 2014 and the government-projected primary balances for



**Fig. 3** Residuals for the US fiscal reaction function. *Note:* These residuals correspond to the Base Model (1) in Table 1. The dotted lines are at two s.d. above and below zero.



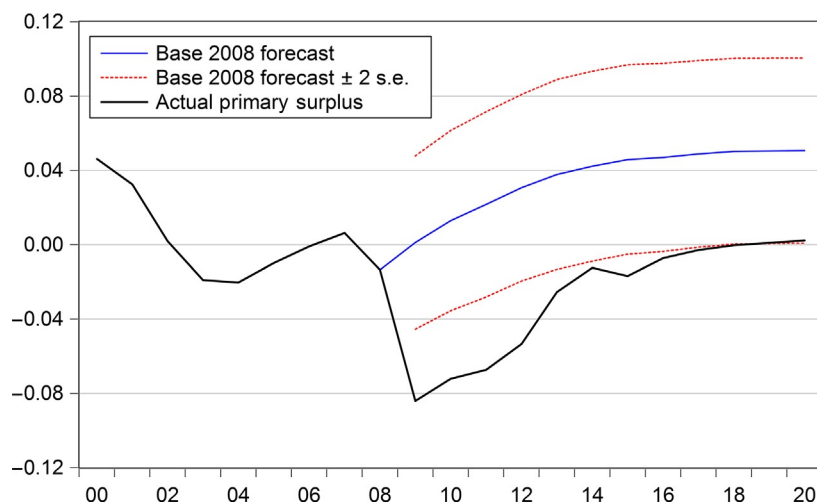


**Fig. 4** Rolling residuals for the US fiscal reaction function. *Note:* For each sample 1791- $t$ , the baseline specification, model (1) in Table 1, is estimated and the residual at time  $t$  is reported together with the 2 standard deviation band for the errors in that sample.

2015 to 2020 in the *President's Budget for Fiscal Year 2016* with the out-of-sample forecast that the FRF estimated with data up to 2008 in Column (7) of Table 1 produces (see Fig. 5). To construct this forecast, we use the observed realizations of the cyclical components of output and government expenditures from 2009 to 2014, and for 2015 to 2020 we use again data from the projections in the *President's Budget*.

As Fig. 5 shows, for the period 2009–14, the primary balance showed deficits significantly larger than what the FRF predicted, and also much larger than the deficit at the minus-two-standard-error bound of the forecast band. The mean forecast of the FRF predicted a rising primary surplus from zero to about 4% of GDP between 2009 and 2014, while the data showed deficits narrowing from 8% to about 2% of GDP. In addition, the primary deficits projected in the *President's Budget* are also much larger than predicted by the mean forecast of the FRF, with the projections at or below the minus-two-standard error band. Bohn (2011) warned that already by 2011 there were signs of a likely structural break, because his estimated FRFs called for primary surpluses when the debt ratio surpassed 55–60%, while the 2012 *Budget* projected large and persistent primary deficits at debt ratios much higher than those.

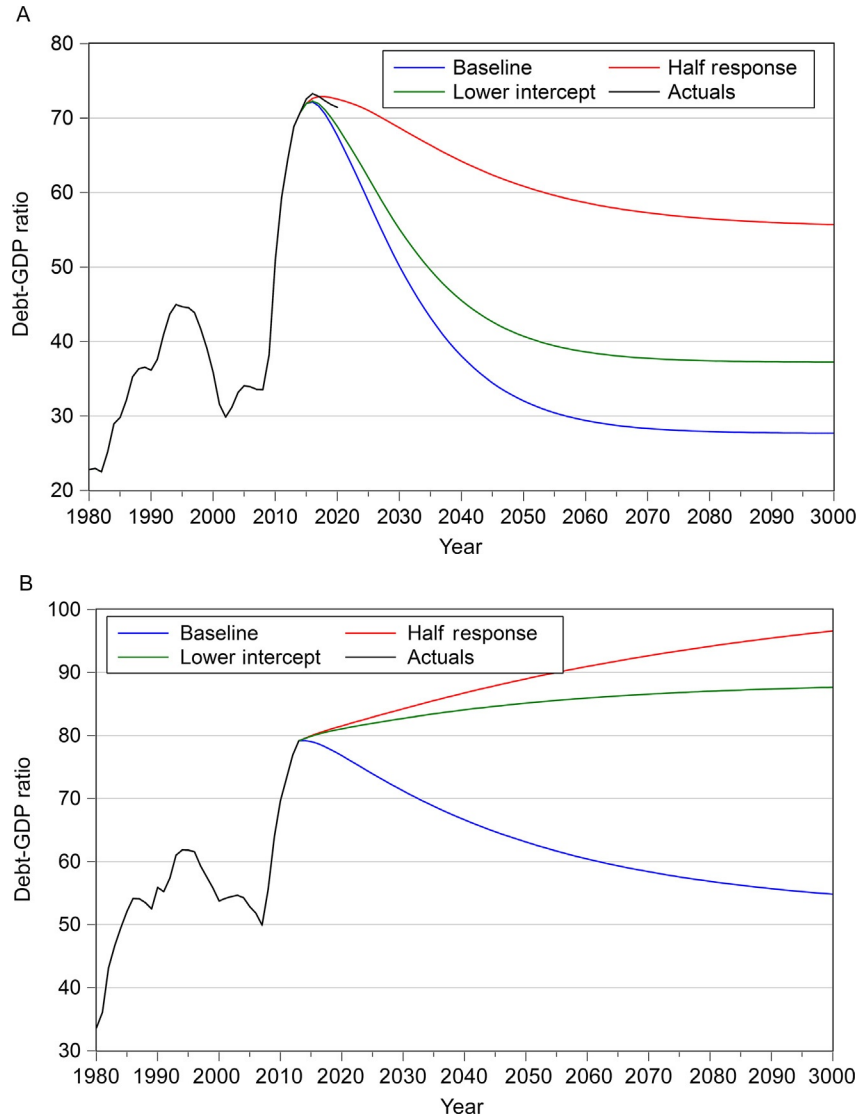
The estimated FRF results can also be used to study projected time-series paths for public debt and the primary balance as of the latest actual observations (2014). To simulate the debt dynamics, we use the law of motion for public debt that results from combining the government budget constraint and the FRF mentioned earlier:  $b_t = -\mu_t + (1 + r_t - \rho)b_{t-1} + \varepsilon_t$ . We consider baseline scenarios in which we use estimated



**Fig. 5** US primary surplus actual value and 2008 based forecast. *Note:* The forecast is based on model (7) in Table 1 which has the sample restricted to 1791–2008. Given actual values of debt-to-GDP ratio, GDP gap, and military expenditure a forecast of the primary surplus to GDP ratio is generated for the sample 2009–20. Actual variables from 2015 onward correspond to estimates included in The president's budget for fiscal year 2016. Chow's forecast test rejects the null hypothesis of no structural change starting in 2009 with 99.9% confidence.

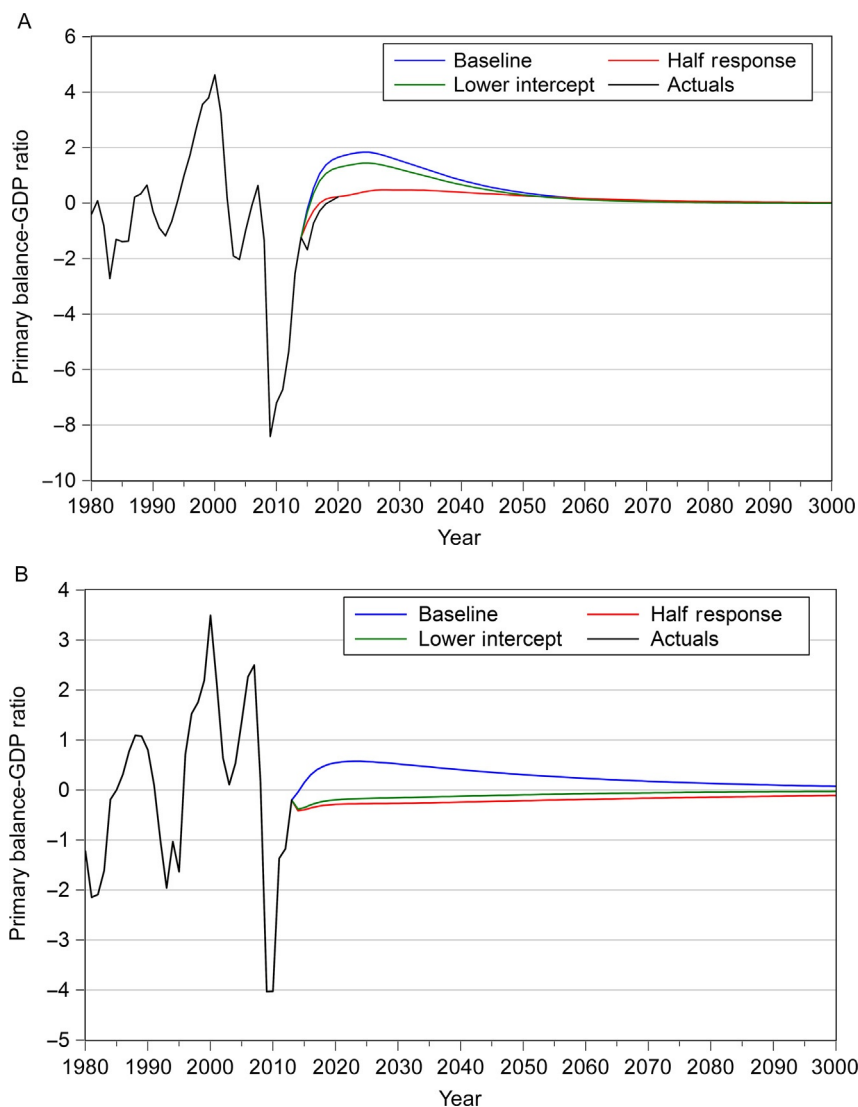
$\rho$  coefficients for Europe and the United States, and simulate forward starting from the 2014 observations. For the United States, we used model (3) in Table 1. For Europe, we use model (5) from Table 2 and take a simple cross-section average among European industrialized countries. Projections of the future values of the fluctuations in output and government expenditures are generated with simple univariate AR models. In addition, we compare these baseline projection scenarios with scenarios in which we lower the response coefficient to half of the regression estimates or lower the intercept of the FRFs. Recall from the earlier discussion that changing these parameters, as long as  $\rho > 0$ , generates the same present discounted value of the primary balance as the baseline scenarios, but as we show below the transitional dynamics and long-run debt ratios they produce are very different. These simulations also require assumptions about the values of the real interest rate and the growth rate that determine  $1 + r$ . For simplicity, we assume that  $r = 0$ , which rules out the range in which debt can grow infinitely large but still be consistent with the IGBC (ie, the range  $0 < \rho < r$ ), and it also implies that primary balances converge to zero in the long run.<sup>P</sup>

<sup>P</sup> Real interest rates on government debt and rates of output growth in large industrial countries are low but with expectations of an eventual increase. Rather than taking a stance on the difference between the two, we just assumed here that they are equal.



**Fig. 6** Debt-to-GDP actuals and simulations since 2014. (A) US debt to GDP. (B) Europe debt to GDP. *Note:* For the United States: Model (3) in Table 1 is used in conjunction with estimated AR(2) processes for the output gap and military expenditure, plus the government budget constraint. For Europe: Model (5) in Table 2 is used in conjunction with estimated AR(1) processes for the output gap and government consumption gap in each country, and a simple average among advanced European countries is taken.

Fig. 6 and 7 show the projected paths of debt ratios and primary balances for the baseline and the alternative scenarios, for both the United States and Europe. These plots show that under the baseline scenario the countries should be reporting primary surpluses that will decline monotonically over time, and should therefore display a monotonically



**Fig. 7** Primary balance to GDP actuals and simulations since 2014. (A) US primary balance to GDP. (B) Europe primary balance to GDP. *Note:* For details on the construction of this simulations see note on Fig. 6.

declining path for the debt ratio converging back to the average observed in the sample period of the FRF estimates. With lower  $\rho$  or lower intercept, the initial surpluses can be significantly smaller or even turned into deficits, but the long-run mean debt ratio would increase significantly. In the case of the United States, for example, the long-run average of the debt ratio would rise from 29% in the baseline case to around 57% in the scenario with lower  $\rho$ .

All the debt and primary balance paths shown in Figs. 6 and 7 satisfy the same IGBC, and therefore make the same initial debt ratio sustainable, but clearly their macroeconomic implications cannot be the same. Unfortunately, at this point the FRF approach reaches its limits. To evaluate the positive and normative implications of alternative paths of fiscal adjustment, we need a structural framework that can be used to quantify the implications of particular revenue and expenditure policies for equilibrium allocations and prices and for social welfare.

### 3. STRUCTURAL APPROACH

This section presents a two-country dynamic general equilibrium framework of fiscal adjustment, and uses it to quantify the positive and normative effects of alternative fiscal policy strategies to restore fiscal solvency (ie, maintain debt sustainability) in the United States and Europe after the recent surge in public debt ratios. The structure of the model is similar to the Neoclassical models widely studied in the large quantitative literature on optimal taxation, the effects of tax reforms, and international tax competition (see, for example, Lucas, 1990, Chari et al., 1994, Cooley and Hansen, 1992, Mendoza and Tesar, 1998, 2005, Prescott, 2004, Trabandt and Uhlig, 2011, etc.). In particular, we use the two-country model proposed by Mendoza et al. (2014), which introduces modifications to the Neoclassical model that allow it to match empirical estimates of the elasticity of tax bases to change in tax rates. This is done by introducing endogenous capacity utilization and by limiting the tax allowance for depreciation of physical capital to approximate the allowance reflected in the data.<sup>9</sup>

#### 3.1 Dynamic Equilibrium Model

Consider a world economy that consists of two countries or regions: home ( $H$ ) and foreign ( $F$ ). Each country is inhabited by an infinitely-lived representative household, and has a representative firm that produces a single tradable good using as inputs labor,  $l$ , and units of utilized capital,  $k = mk$  (where  $k$  is installed physical capital and  $m$  is the utilization rate). Capital and labor are immobile across countries, but the countries are perfectly integrated in goods and asset markets. Trade in assets is limited to one-period discount bonds denoted by  $b$  and sold at a price  $q$ . Assuming this simple asset-market structure is without loss of generality, because the model is deterministic.

Following King et al. (1988), growth is exogenous and driven by labor-augmenting technological change that occurs at a rate  $\gamma$ . Accordingly, stationarity of all variables (except labor and leisure) is induced by dividing them by the level

<sup>9</sup> Dynamic models of taxation that consider endogenous capacity utilization include the theoretical analysis of optimal capital income taxes by Ferraro (2010) and the quantitative analysis of the effects of taxes in an RBC model by Greenwood and Huffman (1991).

of this technological factor.<sup>r</sup> The stationarity-inducing transformation of the model also requires discounting utility flows at the rate  $\tilde{\beta} = \beta(1 + \gamma)^{1-\sigma}$ , where  $\beta$  is the standard subjective discount factor and  $\sigma$  is the coefficient of relative risk aversion of CRRA preferences, and adjusting the laws of motion of  $k$  and  $b$  so that the date  $t + 1$  stocks grow by the balanced-growth factor  $1 + \gamma$ .

We describe below the structure of preferences, technology and the government sector of the home country. The same structure applies to the foreign country, and when needed foreign country variables are identified by an asterisk.

### 3.1.1 Households, Firms, and Government

#### 3.1.1.1 Households

The preferences of the representative home household are standard:

$$\sum_{t=0}^{\infty} \tilde{\beta}^t \frac{(c_t(1 - l_t)^a)^{1-\sigma}}{1 - \sigma}, \sigma > 1, a > 0, \text{ and } 0 < \tilde{\beta} < 1. \quad (5)$$

The period utility function is CRRA in terms of a CES composite good made of consumption,  $c_t$ , and leisure,  $1 - l_t$  (assuming a unit time endowment).  $\frac{1}{\sigma}$  is the intertemporal elasticity of substitution in consumption, and  $a$  governs both the Frisch and intertemporal elasticities of labor supply for a given value of  $\sigma$ .<sup>s</sup>

The household takes as given proportional tax rates on consumption, labor income and capital income, denoted  $\tau_C$ ,  $\tau_L$ , and  $\tau_K$ , respectively, lump-sum government transfers or entitlement payments, denoted by  $e_t$ , the rental rates of labor  $w_t$  and capital services  $r_t$ , and the prices of domestic government bonds and international-traded bonds,  $q_t^g$  and  $q_t$ .<sup>t</sup>

The household rents  $\tilde{k}$  and  $l$  to firms, and makes the investment and capacity utilization decisions. As is common in models with endogenous utilization, the rate of depreciation of the capital stock increases with the utilization rate, according to a convex function  $\delta(m) = \chi_0 m^{\chi_1} / \chi_1$ , with  $\chi_1 > 1$  and  $\chi_0 > 0$  so that  $0 \leq \delta(m) \leq 1$ .

Investment incurs quadratic adjustment costs:

$$\phi(k_{t+1}, k_t, m_t) = \frac{\eta}{2} \left( \frac{(1 + \gamma)k_{t+1} - (1 - \delta(m_t))k_t}{k_t} - z \right)^2 k_t,$$

<sup>r</sup> The assumption that growth is exogenous implies that tax policies do not affect long-run growth, in line with the empirical findings of [Mendoza et al. \(1997\)](#).

<sup>s</sup> We are using the standard functional form of the utility function from the canonical exogenous balanced growth model as in [King et al. \(1988\)](#) and many RBC applications. This function implies a constant Frisch elasticity for  $\sigma = 1$ . See [Trabandt and Uhlig \(2011\)](#) for a generalized formulation of the utility function that maintains the constant Frisch elasticity when  $\sigma > 1$ , and a discussion of the role of the Frisch elasticity in the use of Neoclassical models to quantify the macroeconomic effects of tax changes.

<sup>t</sup> The gross yields in these bonds are simply the reciprocal of these prices.

where the coefficient  $\eta$  determines the speed of adjustment of the capital stock, while  $z$  is a constant set equal to the long-run investment-capital ratio, so that at steady state the capital adjustment cost is zero.

The household chooses intertemporal sequences of consumption, leisure, investment inclusive of adjustment costs  $x$ , international bonds, domestic government bonds  $d$ , and utilization to maximize (5) subject to a sequence of period budget constraints given by:

$$(1 + \tau_c)c_t + x_t + (1 + \gamma)(q_t b_{t+1} + q_t^g d_{t+1}) = (1 - \tau_L)w_t l_t + (1 - \tau_K)r_t m_t k_t + \theta \tau_K \bar{\delta} k_t + b_t + d_t + e_t, \quad (6)$$

and the following law of motion for the capital stock:

$$x_t = (1 + \gamma)k_{t+1} - (1 - \delta(m_t))k_t + \phi(k_{t+1}, k_t, m_t),$$

for  $t = 0, \dots, \infty$ , given the initial conditions  $k_0 > 0$ ,  $b_0$ , and  $d_0$ .

The left-hand-side of equation (6) includes all the uses of household income, and the right-hand-side includes all the sources of income net of income taxes. We impose a standard no-Ponzi-game condition on households, and hence the present value of total household expenditures equals the present value of after-tax income plus initial asset holdings.

Notice that in calculating post-tax income in the above budget constraints, we consider a capital tax allowance  $\theta \tau_K \bar{\delta} k_t$  for a fraction  $\theta$  of depreciation costs. This formulation of the depreciation allowance reflects two assumptions about how the allowance works in actual tax codes: First, depreciation allowances are usually set in terms of fixed depreciation rates applied to the book or tax value of capital, instead of the true physical depreciation rate that varies with utilization. Hence, we set the depreciation rate for the capital tax allowance at a constant rate  $\bar{\delta}$  that differs from the actual physical depreciation rate  $\delta(m)$ . The second assumption is that the depreciation allowance only applies to a fraction  $\theta$  of the capital stock, because in practice it generally applies only to the capital income of businesses and self-employed, and not to residential capital.<sup>u</sup>

We assume that capital income is taxed according to the residence principle, in line with features of the tax systems in the United States and Europe, but countries are allowed to tax capital income at different rates.<sup>v</sup> This also implies, however, that in order

<sup>u</sup> Using the standard 100% depreciation allowance also has two unrealistic implications. First, it renders  $m$  independent of  $\tau_K$  in the long-run. Second, in the short-run  $\tau_K$  affects the utilization decision margin only to the extent that it reduces the marginal benefit of utilization when traded off against the marginal cost due to changes in the marginal cost of investment.

<sup>v</sup> In principle, the choice of residence vs source based taxation can be viewed as part of the choices made along with the values of tax rates. Indeed, [Huizinga \(1995\)](#) shows that generally optimal taxation would call for a mix of source- and residence-based taxation. In practice, however, most tax systems are effectively residence-based, because widespread bilateral tax treaties provide for source-based-determined tax payments of residents of one country to claim credits for taxes paid to foreign governments.

to support a competitive equilibrium with different capital taxes across countries we must assume that physical capital is owned entirely by domestic residents. Without this assumption, cross-country arbitrage of returns across capital and bonds at common world prices implies equalization of pre- and post-tax returns on capital, which therefore requires identical capital income taxes across countries. For the same reason, we must assume that international bond payments are taxed at a common world rate, which we set to zero for simplicity. For more details, see [Mendoza and Tesar \(1998\)](#). Other forms of financial-market segmentation, such as trading costs or short-selling constraints, could be introduced for the same purpose, but make the model less tractable.

### 3.1.1.2 Firms

Firms hire labor and effective capital services to maximize profits, given by  $y_t - w_t l_t - r_t \tilde{k}_t$ , taking factor rental rates as given. The production function is assumed to be Cobb–Douglas:

$$y_t = F(\tilde{k}_t, l_t) = \tilde{k}_t^{1-\alpha} l_t^\alpha$$

where  $\alpha$  is labor's share of income and  $0 < \alpha < 1$ . Firms behave competitively and thus choose  $\tilde{k}_t$  and  $l_t$  according to standard conditions:

$$(1 - \alpha) \tilde{k}_t^{-\alpha} l_t^\alpha = r_t,$$

$$\alpha \tilde{k}_t l_t^{\alpha-1} = w_t.$$

Because of the linear homogeneity of the production technology, these factor demand conditions imply that at equilibrium  $y_t = w_t l_t + r_t \tilde{k}_t$ .

### 3.1.1.3 Government

Fiscal policy has three components. First, government outlays, which include predetermined sequences of government purchases of goods,  $g_t$ , and transfer/entitlement payments,  $e_t$ , for  $t = 0, \dots, \infty$ . In our baseline results, we assume that  $g_t = \bar{g}$  and  $e_t = \bar{e}$  where  $\bar{g}$  and  $\bar{e}$  are the steady state levels of government purchases and transfers before the post-2008 surge in public debt. Because entitlements are lump-sum transfer payments, they are always nondistortionary in this representative agent setup, but still a calibrated value of  $\bar{e}$  creates the need for the government to raise distortionary tax revenue, since we do not allow for lump-sum taxation. Government purchases do not enter in household utility or the production function, and hence it would follow trivially that a strategy to restore fiscal solvency after an increase in debt should include setting  $g_t = 0$ . We rule out this possibility because it is unrealistic, and also because if the model is modified to allow government purchases to provide utility or production benefits, cuts in these purchases would be distortionary in a way analogous to raising taxes.



The second component of fiscal policy is the tax structure. This includes time invariant tax rates on consumption  $\tau_C$ , labor income  $\tau_L$ , capital income  $\tau_K$ , and the depreciation allowance limited to a fraction  $\theta$  of depreciation expenses.

The third component is government debt,  $d_t$ . We assume the government is committed to repay its debt, and thus it must satisfy the following sequence of budget constraints for  $t = 0, \dots, \infty$ :

$$d_t - (1 + \gamma)q_t^g d_{t+1} = \tau_C c_t + \tau_L w_t l_t + \tau_K (r_t m_t - \theta \bar{\delta}) k_t - (g_t + e_t).$$

The right-hand-side of this equation is the primary fiscal balance, which is financed with the change in debt net of debt service in the left-hand-side of the constraint.

Public debt is sustainable in this setup in the same sense as we defined it in [Section 2](#). The IGBC must hold (or equivalently, the government must also satisfy a no-Ponzi-game condition): The present value of the primary fiscal balance equals the initial public debt  $d_0$ . Since we calibrate the model using shares of GDP, it is useful to rewrite the IGBC also in shares of GDP. Defining the primary balance as  $pb_t \equiv \tau_C c_t + \tau_L w_t l_t + \tau_K (r_t m_t - \theta - \delta) k_t - (g_t + e_t)$ , the IGBC in shares of GDP is:

$$\frac{d_0}{\gamma_{-1}} = \psi_0 \left[ \frac{pb_0}{\gamma_0} + \sum_{t=1}^{\infty} \left( \left[ \prod_{i=0}^{t-1} v_i \right] \frac{pb_t}{\gamma_t} \right) \right], \quad (7)$$

where  $v_i \equiv (1 + \gamma)\psi_i q_i^g$  and  $\psi_i \equiv \gamma_{i+1}/\gamma_i$ . In this expression, primary balances are discounted to account for long-run growth at rate  $\gamma$ , transitional growth  $\psi_i$  as the economy converges to the long-run, and the equilibrium price of public debt  $q_i^g$ . Since  $\gamma_0$  is endogenous (ie, it responds to increases in  $d_0$  and the fiscal policy adjustments needed to offset them), we write the debt ratio in the left-hand-side as a share of pre-debt-shock output  $\gamma_{-1}$ , which is predetermined.

Combining the budget constraints of the household and the government, and the firm's zero-profit condition, we obtain the home resource constraint:

$$F(m_t k_t, l_t) - c_t - g_t - x_t = (1 + \gamma)q_t b_{t+1} - b_t.$$

### 3.1.2 Equilibrium, Tax Distortions, and International Externalities

A competitive equilibrium for the model is a sequence of prices  $\{r_t, r_t^*, q_t, q_t^g, q_t^{g*}, w_t, w_t^*\}$  and allocations  $\{k_{t+1}, k_{t+1}^*, m_{t+1}, m_{t+1}^*, b_{t+1}, b_{t+1}^*, x_t, x_t^*, l_t, l_t^*, c_t, c_t^*, d_{t+1}, d_{t+1}^*\}$  for  $t = 0, \dots, \infty$  such that: (a) households in each region maximize utility subject to their corresponding budget constraints and no-Ponzi game constraints, taking as given all fiscal policy variables, pretax prices, and factor rental rates; (b) firms maximize profits subject to the Cobb–Douglas technology taking as given pretax factor rental rates; (c) the government budget constraints hold for given tax rates and exogenous sequences

of government purchases and entitlements; and (d) the following market-clearing conditions hold in the global markets of goods and bonds:

$$\begin{aligned}\omega(y_t - c_t - x_t - g_t) + (1 - \omega)(y_t^* - c_t^* - x_t^* - g_t^*) &= 0, \\ \omega b_t + (1 - \omega)b_t^* &= 0,\end{aligned}$$

where  $\omega$  denotes the initial relative size of the two regions.

The model's optimality conditions are useful for characterizing the model's tax distortions and their international externalities. Consider first the Euler equations for capital (excluding adjustment costs for simplicity), international bonds and domestic government bonds. These equations yield the following arbitrage conditions:

$$\begin{aligned}\frac{(1 + \gamma)u_1(c_t, 1 - l_t)}{\beta u_1(c_{t+1}, 1 - l_{t+1})} &= (1 - \tau_K)F_1(m_{t+1}k_{t+1}, l_{t+1})m_{t+1} + 1 - \delta(m_{t+1}) + \tau_K\theta\bar{\delta} = \frac{1}{q_t} = \frac{1}{q_t^g}, \\ \frac{(1 + \gamma)u_1(c_t^*, 1 - l_t^*)}{\beta u_1(c_{t+1}^*, 1 - l_{t+1}^*)} &= (1 - \tau_K^*)F_1(m_{t+1}^*k_{t+1}^*, l_{t+1}^*)m_{t+1}^* + 1 - \delta(m_{t+1}^*) + \tau_K^*\theta\bar{\delta} = \frac{1}{q_t} = \frac{1}{q_t^{g*}}.\end{aligned}\tag{8}$$

Fully integrated financial markets imply that intertemporal marginal rates of substitution in consumption are equalized across regions, and are also equal to the rate of return on international bonds. Since physical capital is immobile across countries, and capital income taxes are residence-based, households in each region face their own region's tax on capital income. Arbitrage equalizes the after-tax returns on capital across regions, but pre-tax returns differ, and hence differences in tax rates are reflected in differences in capital stocks and output across regions. Arbitrage in asset markets also implies that bond prices are equalized. Hence, at equilibrium:  $q_t = q_t^g = q_t^{g*}$ .

As shown in [Mendoza and Tesar \(1998\)](#), unilateral changes in the capital income tax result in a permanent reallocation of physical capital, and ultimately a permanent shift in wealth, from a high-tax to a low-tax region. Thus, even though physical capital is immobile across countries, perfect mobility of financial capital and arbitrage of asset returns induces movements akin to international mobility of physical capital. In the stationary state with balanced growth, however, the global interest rate  $R$  (the inverse of the bond price,  $R \equiv 1/q$ ) is a function of  $\beta$ ,  $\gamma$  and  $\sigma$ :

$$R = \frac{(1 + \gamma)^\sigma}{\beta},$$

and thus is independent of tax rates. The interest rate does change along the transition path and alters the paths of consumption, output and international asset holdings. In particular, as is standard in the international tax competition literature, each country would have an incentive to behave strategically by tilting the path of the world interest rate in its

favor to attract more capital. When both countries attempt this, the outcome is lower capital taxes but also lower welfare for both (which is the well-known race-to-the-bottom result of the tax competition literature).

Consider next the optimality condition for labor:

$$\frac{u_2(c_t, 1 - l_t)}{u_1(c_t, 1 - l_t)} = \frac{1 - \tau_L}{1 + \tau_C} F_2(k_t, l_t).$$

Labor and consumption taxes drive the standard wedge  $(1 - \tau_W) \equiv (1 - \tau_L)/(1 + \tau_C)$  between the leisure-consumption marginal rate of substitution and the pre-tax real wage (which is equal to the marginal product of labor). Since government outlays are kept constant and the consumption tax is constant, consumption taxation does not distort saving plans, and hence any  $(\tau_C, \tau_L)$  pair consistent with the same  $\tau_W$  yields identical allocations, prices, and welfare.

Many Neoclassical and Neoknesian dynamic equilibrium models feature tax distortions like the ones discussed above, but they also tend to underestimate the elasticity of the capital tax base to changes in capital taxes, because  $k$  is predetermined at the beginning of each period, and changes gradually as it converges to steady state. In the model we described, the elasticity of the capital tax base can be adjusted to match the data because capital income taxes have an additional distortion absent from the other models: They distort capacity utilization decisions. In particular, the optimality condition for the choice of  $m_t$  is:

$$F_1(m_t k_t, l_t) = \frac{1 + \Phi_t}{1 - \tau_K} \delta'(m_t), \quad (9)$$

where  $\Phi_t = \eta \left( \frac{(1 + \gamma)k_{t+1} - (1 - \delta(m_t))k_t}{k_t} - z \right)$  is the marginal adjustment cost of investment. The capital tax creates a wedge between the marginal benefit of utilization on the left-hand-side of this condition and the marginal cost of utilization on the right-hand-side. An increase in  $\tau_K$ , everything else constant, reduces the utilization rate.<sup>w</sup> Intuitively, a higher capital tax reduces the after-tax marginal benefit of utilization, and thus reduces the rate of utilization. Note also that the magnitude of this distortion depends on where the capital stock is relative to its steady state, because the sign of  $\Phi_t$  depends on Tobin's  $Q$ , which is given by  $Q_t = 1 + \Phi_t$ . If  $Q_t > 1$  ( $\Phi_t > 0$ ), the desired investment rate is higher than the steady-state investment rate. In this case,  $Q_t > 1$  increases the marginal cost of utilization (because higher utilization means faster depreciation, which makes it harder to attain the higher target capital stock). The opposite happens if  $Q_t < 1$  ( $\Phi_t < 0$ ). In this case, the faster depreciation at higher utilization rates makes it easier to

<sup>w</sup> This follows from the concavity of the production function and the fact that  $\delta(m_t)$  is increasing and convex.

run down the capital stock to reach its lower target level. Thus, an increase in  $\tau_K$  induces a larger decline in the utilization rate when the desired investment rate is higher than its long-run target (ie,  $\Phi_t > 0$ ).

The interaction of endogenous utilization and the limited depreciation allowance plays an important role in this setup. Endogenous utilization means that the government cannot treat the existing (predetermined)  $k$  as an inelastic source of taxation, because effective capital services decline with the capital tax rate even when the capital stock is already installed. This weakens the revenue-generating capacity of capital taxation, and it also makes capital taxes more distorting, since it gives agents an additional margin of adjustment in response to capital tax hikes (ie, capital taxes increase the post-tax marginal cost of utilization, as shown in eq. 9). The limited depreciation allowance widens the base of the capital tax, but it also strengthens the distortionary effect of  $\tau_K$  by reducing the post-tax marginal return on capital (see eq. 8). As we show in the quantitative results, the two mechanisms result in a dynamic Laffer curve with a standard bell shape and consistent with empirical estimates of the capital tax base elasticity, while removing them results in a Laffer curve that is nearly-linearly increasing for a wide range of capital taxes.

The cross-country externalities from tax changes work through three distinct transmission channels that result from the tax distortions discussed in the previous paragraphs. First, relative prices, because national tax changes alter the prices of financial assets (including internationally traded assets and public debt instruments) as well as the rental prices of effective capital units and labor. Second, the distribution of wealth across the regions, because efficiency effects of tax changes by one region affect the allocations of capital and net foreign assets across regions (even when physical capital is not directly mobile). Third, the erosion of tax revenues, because via the first two channels the tax policies of one region affect the ability of the other region to raise tax revenue. When one region responds to a debt shock by altering its tax rates, it generates external effects on the other region via these three channels. Given the high degree of financial and trade integration in the world economy today, abstracting from these considerations in quantitative estimates of the effects of fiscal policy is a significant shortcoming.

### 3.2 Calibration to Europe and the United States

We use data from the United States and the 15 largest European countries to calibrate the model at a quarterly frequency.<sup>x</sup> We calibrate the home region (US) to the United States, and the foreign region (EU15) to the aggregate of the 15 European countries. The EU15 aggregates are GDP-weighted averages. Table 5 presents key macroeconomic statistics and fiscal variables for the all the countries and the two region aggregates in 2008.

<sup>x</sup> The European countries include Austria, Belgium, Denmark, Finland, Greece, France, Germany, Ireland, Italy, the Netherlands, Poland, Portugal, Spain, Sweden, and the United Kingdom. These countries account for over 94% of the European Union's GDP.

**Table 5** Macroeconomic stance as of 2008

	EU15											GDP-weighted ave.		
	AUT	BEL	DEU	ESP	FRA	GBR	ITA	NLD	POL	SWE	Other	EU15	US	All
<b>(a) Macro aggregates</b>														
$\tau_C$	0.19	0.17	0.17	0.12	0.17	0.14	0.13	0.20	0.21	0.26	0.23	0.17	0.04	0.11
$\tau_L$	0.51	0.47	0.41	0.35	0.45	0.30	0.48	0.47	0.38	0.55	0.39	0.41	0.27	0.35
$\tau_K$	0.25	0.45	0.24	0.25	0.38	0.40	0.38	0.26	0.16	0.37	0.31	0.32	0.37	0.34
$c/\gamma$	0.53	0.52	0.56	0.57	0.57	0.64	0.59	0.45	0.62	0.47	0.58	0.57	0.68	0.62
$x/\gamma$	0.22	0.24	0.19	0.29	0.22	0.17	0.21	0.20	0.24	0.20	0.23	0.21	0.21	0.21
$g/\gamma$	0.19	0.23	0.18	0.19	0.23	0.22	0.20	0.26	0.19	0.26	0.21	0.21	0.16	0.19
$tb/\gamma$	0.06	0.01	0.06	-0.06	-0.02	-0.02	-0.01	0.08	-0.04	0.07	-0.02	0.00	-0.05	-0.02
Rev/ $\gamma$	0.48	0.49	0.44	0.37	0.50	0.42	0.46	0.47	0.40	0.54	0.45	0.45	0.32	0.39
Total Exp/ $\gamma$	0.49	0.50	0.44	0.41	0.53	0.47	0.49	0.46	0.43	0.52	0.48	0.47	0.39	0.43
<b>(b) Debt shocks</b>														
$d_{2007}/\gamma_{2007}$	0.31	0.73	0.43	0.18	0.36	0.28	0.87	0.28	0.17	-0.23	0.13	0.38	0.43	0.40
$d_{2011}/\gamma_{2011}$	0.45	0.80	0.51	0.46	0.63	0.62	1.00	0.38	0.32	-0.25	0.45	0.58	0.74	0.65
$\Delta d/\gamma$	0.14	0.07	0.09	0.28	0.27	0.33	0.14	0.10	0.15	-0.02	0.32	0.20	0.31	0.25

Other is a GDP-weighted average of Denmark, Finland, Greece, Ireland, and Portugal.

Source: OECD Revenue Statistics, OECD National income Accounts, and EuroStat. Tax rates are author's calculations based on Mendoza, E.G., Razin, A., Tesar, L.L. 1994. Effective tax rates in macroeconomics: cross-country estimates of tax rates on factor incomes and consumption. J. Monet. Econ. 34 (3), 297323. "Total Exp" is total noninterest government outlays.

The first three rows of [Table 5](#) show estimates of effective tax rates on consumption, labor, and capital calculated from revenue and national income accounts statistics using the methodology originally introduced by [Mendoza et al. \(1994\)](#) (MRT). The United States and EU15 have significantly different tax structures. Consumption and labor tax rates are much higher in EU15 than in the United States (0.17 vs 0.04 for  $\tau_C$  and 0.41 vs 0.27 for  $\tau_L$ ), while capital taxes are higher in the United States (0.37 vs 0.32). The labor and consumption tax rates imply a consumption-leisure tax wedge  $\tau_W$  of 0.298 for the United States vs 0.496 in EU15. Thus, EU15 has much higher effective tax distortion on labor supply. Notice also that inside of EU15 there is also some tax heterogeneity, particularly with respect to Great Britain, which has higher capital tax and lower labor tax than most of the other EU15 countries.

With regard to aggregate expenditure–GDP ratios, the United States has a much higher consumption share than EU15, by 11 percentage points. EU15 has a larger government expenditure share (current purchases of goods and services, excluding transfers) than the United States by 5 percentage points. Their investment shares are about the same, at 0.21. For net exports, the United States has a deficit of 5% while EU15 has a balanced trade (with the caveat that the latter includes all trade the individual EU15 countries conduct with each other and with the rest of the world). In light of this, we set the trade balance to zero in both countries for simplicity. In terms of fiscal flows, both total tax revenues and government outlays (including expenditures and transfer payments) as shares of GDP are higher in EU15 than in the United States, by 13 and 8 percentage points, respectively. Thus, the two regions differ sharply in all three fiscal instruments (taxes, current government expenditures, and transfer payments).

The bottom panel of [Table 5](#) reports government debt to GDP ratios and their change between end–2007 (beginning of 2008) and end–2011. These changes are our estimate of the increases in debt (or “debt shocks”) that each country and region experienced, and hence they are the key exogenous impulse used in the quantitative experiments. These debt ratios correspond to general government net financial liabilities as a share of GDP as reported in *Eurostat*. As the table shows, debt ratios between end–2007 and 2011 rose sharply for all countries except Sweden, where the general government actually has a net asset position (ie, negative net liabilities) that changed very little. The size of the debt shocks differs substantially across the two regions. The United States entered the Great Recession with a higher government debt to output ratio than EU15 (0.43 vs 0.38) and experienced a larger increase in the debt ratio (0.31 vs 0.20).

[Table 6](#) lists the calibrated parameter values and the main source for each value. The calibration is set so as to represent the balanced-growth steady state that prevailed before the debt shocks occurred using 2008 empirical observations for the corresponding allocations. The value of  $\omega$  is set at 0.46 so as to match the observation that the United States accounts for about 46% of the combined GDP of the United States and EU15 in 2008. Tax rates, government expenditure shares and debt ratios are calibrated to the values in the United States and EU15 columns of [Table 5](#), respectively. The limit on the

**Table 6** Parameter values

<b>Preferences:</b>		<b>US</b>	<b>EU15</b>	<b>Sources</b>
$\beta$	Discount factor	0.998		Steady state Euler equation for capital
$\sigma$	Risk aversion	2.000		Standard DSGE value
$a$	Labor supply elasticity	2.675		$\bar{l} = 0.18$ (Prescott, 2004)
<b>Technology:</b>				
$\alpha$	Labor income share	0.61		Trabandt and Uhlig (2011)
$\gamma$	Growth rate	0.0038		Real GDP p.c. growth of sample countries (Eurostat 1995–2011)
$\eta$	Capital adjustment cost	2		Elasticity of capital tax base (Gruber and Rauh, 2007; Dwenger and Steiner, 2012)
$\bar{m}$	Capacity utilization	1		Steady state normalization
$\delta(\bar{m})$	Depreciation rate	0.0163		Capital law of motion, $x/\gamma = 0.19$ , $k/\gamma = 2.62$ (OECD, AMECO)
$\chi_0$	$\delta(m)$ coefficient	0.023	0.024	Optimality condition for utilization given $\delta(\bar{m})$ , $\bar{m}$
$\chi_1$	$\delta(m)$ exponent	1.44	1.45	Set to yield $\delta(\bar{m}) = 0.0164$
$\omega$	Country size	0.46	0.54	GDP share in all sample countries
<b>Fiscal policy:</b>				
$g/\gamma$	Gov't exp share in GDP	0.16	0.21	OECD National Income Accounts
$\tau_C$	Consumption tax	0.04	0.17	MRT modified
$\tau_L$	Labor income tax	0.27	0.41	MRT modified
$\tau_K$	Capital income tax	0.37	0.32	MRT modified
$\theta$	Depreciation allowance limitation	0.20		$(REV_K^{corp}/REV_K)(K^{NR}/K)$ , OECD Revenue Statistics and EU KLEMS

Note: The implied growth adjusted discount factor  $\tilde{\beta}$  is 0.995, and the implied precrisis annual interest rate is 3.8%.  $REV_K^{corp}/REV_K$  is the ratio of corporate tax revenue to total capital tax revenue.  $K^{NR}/K$  is the ratio of nonresidential fixed capital to total fixed capital.

depreciation allowance,  $\theta$ , is set to capture the facts that tax allowances for depreciation costs apply only to capital income taxation levied on businesses and self-employed, and do not apply to residential capital (which is included in  $k$ ). Hence, the value of  $\theta$  is set as  $\theta = (REV_K^{corp}/REV_K)(K^{NR}/K)$ , where  $(REV_K^{corp}/REV_K)$  is the ratio of revenue from corporate capital income taxes to total capital income tax revenue, and  $(K^{NR}/K)$  is the ratio of nonresidential fixed capital to total fixed capital. Using 2007 data from OECD *Revenue Statistics* for revenues, and from the European Union's *EU KLEMS* database for capital stocks for the ten countries with sufficient data coverage,<sup>y</sup> these ratios range from 0.32% to 0.5% for  $(REV_K^{corp}/REV_K)$  and from 27% to 52% for  $(K^{NR}/K)$ . Weighting by

<sup>y</sup> These countries are Austria, Denmark, Finland, Germany, Italy, Netherlands, Spain, Sweden, the United Kingdom, and the United States.

GDP, the aggregate value of  $\theta$  is 0.20. Also the value for the United States is close to the weighted value for the European countries.

The technology and preference parameters are set the same across the United States and EU15, except the parameters  $\chi_0$  and  $\chi_1$  in the depreciation function. The common parameters are calibrated to target the weighted average statistics for all sample countries. The labor share of income,  $\alpha$ , is set to 0.61, following [Trabandt and Uhlig \(2011\)](#). The quarterly rate of labor-augmenting technological change,  $\gamma$ , is 0.0038, which corresponds to the 1.51% weighted average annual growth rate in real GDP per capita of all the countries in our sample between 1995 and 2011, based on Eurostat data. We normalize the long-run capacity utilization rate to  $\bar{m} = 1$ . Given  $\gamma$  at 0.0038,  $x/\gamma$  at 0.19 and  $k/\gamma$  at 2.62 from the data, we solve for the long-run depreciation rate from the steady-state law of motion of the capital stock,  $x/\gamma = (\gamma + \delta(\bar{m}))k/\gamma$ .<sup>z</sup> This yields  $\delta(\bar{m}) = 0.0163$  per quarter. The constant depreciation rate for claiming the depreciation tax allowance,  $\bar{\delta}$ , is set equal to the steady state depreciation rate of 0.0163.

The value of  $\chi_0$  follows then from the optimality condition for utilization at steady state, which yields  $\chi_0 = \delta(\bar{m}) + \frac{1 + \gamma - \beta}{\beta} - \tau_K \bar{\delta}$ . Given this, the value of  $\chi_1$  follows from evaluating the depreciation rate function at steady state, which implies  $\chi_0 \bar{m}^{\chi_1} / \chi_1 = \delta(\bar{m})$ . Given the different capital tax rates in the United States and EU15, the implied values for  $\chi_0$  and  $\chi_1$  are slightly different across countries:  $\chi_0$  is 0.0233 in the United States and 0.0235 in EU15, and  $\chi_1$  is 1.435 in the United States and 1.445 in EU15.

The preference parameter,  $\sigma$ , is set at a commonly used value of 2. The exponent of leisure in utility is set at  $a = 2.675$ , which is taken from [Mendoza and Tesar \(1998\)](#). This value supports a labor allocation of 18.2 h, which is in the range of the 1993–96 averages of hours worked per person aged 15–64 reported by [Prescott \(2004\)](#). The value of  $\beta$  follows from the steady-state Euler equation for capital accumulation, using the values set above for the other parameters that appear in this equation:

$$\frac{\gamma}{\tilde{\beta}} = 1 + (1 - \tau_K)(1 - \alpha)\frac{\gamma}{k} - \delta(\bar{m}) + \tau_K \theta \bar{\delta}.$$

This yields  $\tilde{\beta} = 0.995$ , and then since  $\tilde{\beta} = \beta(1 + \gamma)^{1 - \sigma}$  it follows that  $\beta = 0.998$ . The values of  $\beta$ ,  $\gamma$  and  $\sigma$  pin down the steady-state gross real interest rate,  $R = \beta^{-1}(1 + \gamma)^\sigma = 1.0093$ . This is equivalent to a net annual real interest rate of about 3.8%.

Once  $R$  is determined, the steady-state ratio of net foreign assets to GDP is pinned down by the net exports-GDP ratio. Since we set  $tb/\gamma = 0$ ,  $b/\gamma = (tb/\gamma) / [(1 + \gamma)R^{-1} - 1] = 0$ . In addition, the steady-state government budget constraint yields

<sup>z</sup> Investment rates are from the OECD National Income Accounts and capital-output ratios are from the AMECO database of the European Commission.



an implied ratio of government entitlement payments to GDP  $e/\gamma = Rev/\gamma - g/\gamma - (d/\gamma)[1 - (1 + \gamma)R^{-1}] = 0.196$ . Under this calibration approach, both  $b/\gamma$  and  $e/\gamma$  are obtained as residuals, given that the values of all the terms in the right-hand-side of the equations that determine them have already been set. Hence, they generally will not match their empirical counterparts. In particular, for entitlement payments the model underestimates the 2008 observed ratio of entitlement payments to GDP (0.196 in the model vs 0.26 in the data for All EU). Notice, however, that when the model is used to evaluate tax policies to restore fiscal solvency, the fact that entitlement payments are lower than in the data strengthens our results, because lower entitlements means a lower required amount of revenue than what would be needed to support observed transfer payments, thus making it easier to restore solvency. We show below that restoring fiscal solvency is difficult and implies nontrivial tax adjustments with sizable welfare costs and cross-country spillovers, all of which would be larger with higher government revenue requirements due to higher entitlement payments.

The value of the investment-adjustment-cost parameter,  $\eta$ , cannot be set using steady-state conditions, because adjustment costs wash out at steady state. Hence, we set the value of  $\eta$  so that the model is consistent with the mid-point of the empirical estimates of the short-run elasticity of the capital tax base to changes in capital tax rates. The range of empirical estimates is 0.1–0.5, so the target midpoint is 0.3.<sup>aa</sup> Under the baseline symmetric calibration, the model matches this short-run elasticity with  $\eta = 2.0$ . This is also in line with estimates in [House and Shapiro \(2008\)](#) of the response of investment in long-lived capital goods to relatively temporary changes in the cost of capital goods.<sup>ab</sup>

[Table 7](#) reports the 2008 GDP ratios of key macro-aggregates in the data and the model's corresponding steady-state allocations for the US–EU15 calibration. As noted earlier, this calibration captures the observed differences in the size of the regions, their fiscal policy parameters, and their public debt–GDP ratios. Notice in particular that the consumption–output ratios and the fiscal revenue–output ratios from the data were not directly targeted in the calibration, but the two are closely matched by the model. Hence, the model's initial stationary equilibrium before the increases in public debt is a reasonably good match to the observed initial conditions in the data.

<sup>aa</sup> The main estimate of the elasticity of the *corporate* tax base relative to corporate taxes in the United States obtained by [Gruber and Rauh \(2007\)](#) is 0.2. [Dwenger and Steiner \(2012\)](#) obtained around 0.5 for Germany. Grubler and Rauh also reviewed the large literature estimating the elasticity of *individual* tax bases (which include both labor and capital income taxes collected from individuals) to individual tax rates and noted this: “The broad consensus...is that the elasticity of taxable income with respect to the tax rate is roughly 0.4. Moreover, the elasticity of actual income generation through labor supply/savings, as opposed to reported income, is much lower. And most of the response of taxable income to taxation appears to arise from higher income groups.”

<sup>ab</sup> They estimated an elasticity of substitution between capital and consumption goods in the 6–14 range. In the variant of our model without utilization choice, this elasticity is equal to  $1/(\eta\delta)$ . Hence, for  $\delta(\bar{m}) = 0.0164$ , elasticities in that range imply values of  $\eta$  in the 1–2.5 range.

**Table 7** Balanced growth allocations (GDP ratios) of 2008  
**United States**

	<b>United States</b>		<b>EU15</b>	
	<b>Data</b>	<b>Model</b>	<b>Data</b>	<b>Model</b>
$c/\gamma$	0.68	0.63	0.57	0.56
$i/\gamma$	0.21	0.21	0.21	0.23
$g/\gamma^*$	0.16	0.16	0.21	0.21
$tb/\gamma$	− 0.05	0.00	0.00	0.00
$Rev/\gamma$	0.32	0.32	0.45	0.46
$d/\gamma^*$	0.76	0.76	0.60	0.60

### 3.3 Quantitative Results

The goal of the quantitative experiments is to use the numerical solutions of the model to study whether alternative fiscal policies can restore fiscal solvency, which requires increasing the present discounted value of the primary balance in the right-hand-side of (7) by as much as the observed increases in debt.<sup>ac</sup> Notice that the change in this present value reflects changes in the endogenous equilibrium dynamics of the primary balance–GDP ratio in response to the changes in fiscal policy variables. In turn, the changes in primary balance dynamics reflect the effects of these policy changes on equilibrium allocations and prices that determine tax bases, and the computation of the present value reflects also the response of the equilibrium interest rates (ie, debt prices).

We conduct a set of experiments in which we assume that the United States or EU15 implement unilateral increases in either capital or labor tax rates, so we can quantify the effects on equilibrium allocations and prices, sustainable debt (ie, primary balance dynamics), and social welfare in both regions. We also compare these results with those obtained if the same tax changes are implemented assuming the countries are closed economies, so we can highlight the cross-country externalities of unilateral tax changes.

The model is solved numerically using a modified version of the algorithm developed by [Mendoza and Tesar \(1998, 2005\)](#), which is based on a first-order approximation to the equilibrium conditions around the steady state. Standard perturbation methods cannot be applied directly, because trade in bonds implies that, when the model's pre-debt-crisis steady state is perturbed, the equilibrium transition paths of allocations and prices, and the new steady-state equilibrium need to be solved for simultaneously.<sup>ad</sup> This is because

<sup>ac</sup> The observed increases in debt between end–2007 (beginning of 2008) and end–2011 can be viewed as exogenous increases in  $d_0/\gamma_{-1}$  in the left-hand-side of the IGBC (7). As reported in [Table 5](#), the US debt ratio rose by 31 percentage points from 41%, and that of the EU15 rose by 20 percentage points from 38%.

<sup>ad</sup> Alternative solution methods that make the interest rate or the discount factor ad-hoc functions of net foreign assets (NFA), or that assume that holding these assets is costly, are also not useful, because they impose calibrated NFA positions that cannot be affected by tax changes, whereas the “true” model without these modifications can yield substantial world redistribution of wealth as a result of tax policy changes.

in models of this class stationary equilibria depend on initial conditions, and thus cannot be determined separately from the models' dynamics. Mendoza and Tesar dealt with this problem by developing a solution method that nests a perturbation routine for solving transitional dynamics within a shooting algorithm. This method iterates on candidate values of the new long-run net foreign asset positions to which the model converges after being perturbed by debt and tax changes, until the candidate values match the positions the model converges to when simulated forward to its new steady state starting from the calibrated pre-debt-crisis initial conditions.

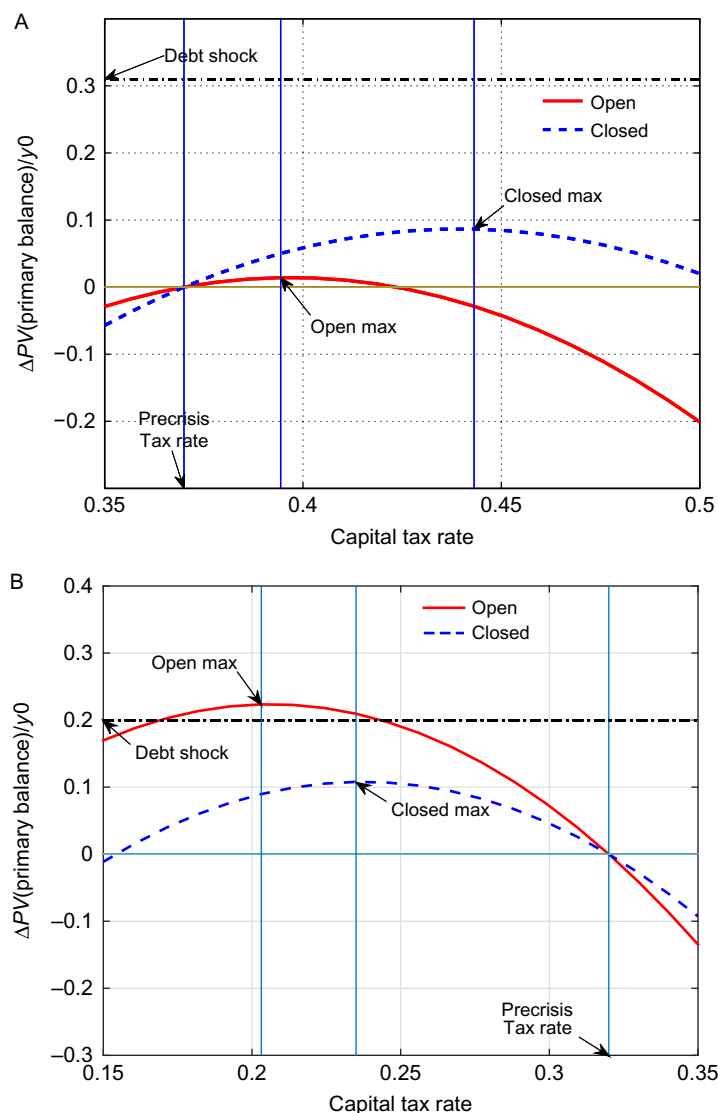
### 3.3.1 *Dynamic Laffer Curves*

We start the analysis of the quantitative results by constructing “Dynamic Laffer Curves” (DLC) that show how unilateral changes in capital or labor taxes in one region affect that region's sustainable public debt. These curves map values of  $\tau_K$  or  $\tau_L$  into the equilibrium present discounted value of the primary fiscal balance. For each value that a given tax rate in the horizontal axis takes, we solve the model to compute the intertemporal sequence of total tax revenue, which varies as equilibrium allocations and prices vary, while government purchases and entitlement payments are kept constant. Then we compute the present value of the primary balance, which therefore captures the effect of changes in the equilibrium sequence of interest rates. We take the ratio of this present value to the initial output  $y_{-1}$  (ie, GDP in the steady state calibrated to pre-2008 data) so that it corresponds to the term in the right-hand-side of the IGBC (7), and plot the result as a *change* relative to the 2007 public debt ratio. Hence, the values along the vertical axis of the DLCs show the change in  $d_0/y_{-1}$  that particular values of  $\tau_K$  or  $\tau_L$  can support as sustainable debt at equilibrium (ie, debt that satisfies the IGBC with equality). By construction, the curves cross the zero line at the calibrated tax rates of the initial stationary equilibrium, because those tax rates yield exactly the same present discounted value of the primary balance as the initial calibration. To make the observed debt increases sustainable, there needs to be a value of the tax rate in the horizontal axis such that the DLC returns a value in the vertical axis that matches the observed change in debt.

Since the “passive” region whose taxes are not being changed unilaterally is affected by spillovers of the other region's tax changes, there needs to be an adjustment in the passive region so that its IGBC is unchanged (ie, it maintains the same present discounted value of primary fiscal balances). We refer to this adjustment as maintaining “revenue neutrality” in the passive region. In principle this can be done by changing transfers, taxes or government purchases. However, since we have assumed already that government purchases are kept constant in both regions, reducing distortionary tax rates in response to favorable tax spillovers would be more desirable than increasing transfer payments, which are nondistortionary. Hence, we maintain revenue neutrality in the passive region by adjusting the labor tax rate.

### 3.3.1.1 Dynamic Laffer Curves for Capital Taxes

The DLCs for capital taxes are plotted in Fig. 8. The panel (A) is for the US region, and the panel (B) is for EU15. The solid lines show the open-economy curves and the dotted lines are for when the countries are in autarky. As explained above, the DLCs intersect the zero line at the initial tax rates of  $\tau_K = 0.37$  and  $\tau_K^* = 0.32$  by construction. We also show in the plots the increases in debt observed in each region, as shown in Table 5: The



**Fig. 8** Dynamic Laffer curves of capital tax rates. (A) United States. (B) EU15.

US net public debt ratio rose 31 percentage points and that of EU15 rose 20 percentage points. These increases are marked with the “Debt Shock” line in Fig. 8.

Fig. 8 shows that the DLCs of the United States and EU15 are very different, with those for EU15 seating higher, shifted to the left, and showing more curvature than those for the United States. Hence, unilateral changes in capital tax rates show a capacity to sustain larger debt increases in EU15 than in the United States, and can do so at lower tax rates. These marked differences are the result of the heterogeneity in fiscal policies present in the data and captured in the calibration, and in the open-economy scenario they are also partly explained by the international externalities of the unilateral tax changes assumed in constructing the DLCs. EU15 has higher revenue-generating capacity because of higher labor and consumption taxes at identical labor income shares and similar consumption shares, although in terms of primary balance the higher revenue is partly offset by higher government purchases. On the other hand, the United States has a lower capital tax rate and by enough to make a significant difference in the inefficiencies created by capital taxes across the two regions, as we illustrate in more detail below. Moreover, the magnitude of heterogeneity in the capital tax DLCs that results from a given magnitude of heterogeneity in fiscal variables depends on the model’s modifications made to match the observed elasticity of the capital base. We illustrate below that DLCs are very different if we remove capacity utilization and the limited depreciation allowance.

Beyond the difference in position and shape of the capital tax DLCs across the United States and EU15, these DLCs deliver three striking results: First, unilateral changes in the US capital tax cannot restore fiscal solvency and make the observed increase in debt unsustainable (the peaks of the DLCs of the US region either as a closed or an open economy are significantly below the debt shock line). The maximum point of the open-economy DLC is attained at  $\tau_K = 0.402$ , which produces an increase in the present value of the primary balance of only 2 percentage points of GDP, far short of the required 31. In contrast, the maximum point of the open-economy DLC for EU15 is attained around  $\tau_K^* = 0.21$ , which rises the present value of the primary balance by 22 percentage points of GDP, slightly more than the required 20. Under autarky, however, the EU15 DLC also peaks below the required level, and hence capital taxes also cannot restore fiscal solvency for EU15 as a closed economy. This result also reflects the strong cross-country externalities that we discuss in more detail below (ie, unilateral capital tax *cuts* yield significantly more sustainable debt for EU15 as an open economy than under autarky).

Second, capital income taxes in EU15 are highly inefficient. The current capital tax rate is on the increasing segment of the DLC for the United States but on the decreasing segment for EU15. This has two important implications. One is that EU15 could have sustained the calibrated initial debt ratio of 38% at capital taxes below 15%, instead of the 32% tax rate obtained from the data. The second is that to make the observed 20 percentage points increase in debt sustainable, EU15 can *reduce* its capital tax almost in half to

about 17% in the open-economy DLC. In both cases, the sharply lower capital taxes would be much less distortionary and thus would increase efficiency significantly.

Third, cross-country externalities of capital income taxes are very strong, and under our baseline calibration, they hurt (favor) the capacity to sustain debt of the United States (EU15). For the United States, the DLC under autarky is steeper than in the open-economy case, and it peaks at a higher tax rate of 43% and with a higher increase in the present value of the primary balance of about 10 percentage points. Thus, the United States can always sustain more debt, or support higher debt increases relative to the calibrated baseline, for a given increase in  $\tau_K$  under autarky than as an open economy. This occurs because by increasing its capital tax *unilaterally* as an open economy the United States not only suffers the efficiency losses in capital accumulation and utilization, but it also triggers reallocation of physical capital from the United States to EU15, which results in reductions (increases) in the United States (EU15) factor payments and consumption, and thus lower (higher) tax bases in the United States (EU15). The same mechanism explains why reducing the capital tax in EU15 unilaterally generates much less revenue under autarky than in the open-economy case. In the latter, cutting the EU15 capital tax unilaterally triggers the same forces as a unilateral increase in the US capital tax.

This quantitative evidence of strong externalities of capital taxes across financially integrated economies demonstrates that evaluating “fiscal space,” or the capacity to sustain debt, using closed-economy models leads to seriously flawed estimates of the effectiveness of capital taxes as a tool to restore debt sustainability. The results also suggest that incentives for strategic interaction leading to capital income tax competition are strong, and get stronger as higher debts need to be reconciled with fiscal solvency (as evidenced by the history of corporate tax competition inside the EU since the 1980s). [Mendoza et al. \(2014\)](#) study this issue using a calibration that splits the European Union into two regions, one including the countries most affected by the European debt crisis (Greece, Ireland, Italy, Portugal, and Spain) and the second including the rest of the Eurozone members.

### 3.3.1.2 Dynamic Laffer Curves of Labor Tax Rates

[Fig. 9](#) shows the DLCs for the labor tax rate. Notice that the open-economy and autarky DLCs are similar within each region (although more similar for EU15 than for the United States), which indicates that international externalities are much weaker in this case. This is natural, because labor is an immobile factor, and although it can still trigger cross-country spillovers via general-equilibrium effects, these are much weaker than the first-order effects created by unilateral changes of capital taxes via the condition that arbitrages after-tax returns on all assets across countries.

The main result of the DLCs for labor taxes is that the DLCs for the United States are much higher than those for EU15. Since the international externalities are weak for the

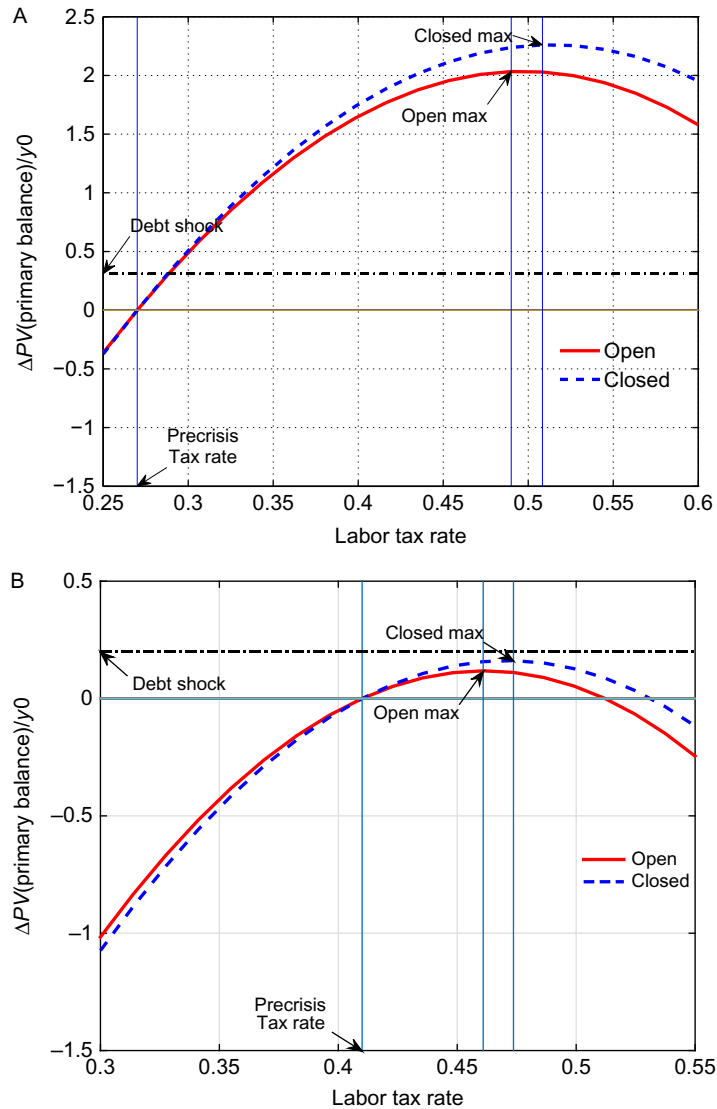


Fig. 9 Dynamic Laffer curves of labor tax rates. (A) United States. (B) EU15.

labor tax, this result is only due to the different initial conditions resulting from the fiscal heterogeneity captured in our calibration, and in particular to the large differences in initial labor and consumption taxes (41 vs 27% for labor and 17 vs 4% for consumption in EU15 vs the United States, respectively). Increasing the calibrated  $\tau_L$  for the US region to the EU15 rate of 41%, keeping all other US parameters unchanged, shifts down its labor tax DLC almost uniformly by about 200 percentage points in the 0.25–0.55 interval of

labor tax rates. This happens because, for an increase in the labor tax of a given size, the difference in initial conditions implies that the US region generates a larger increase in the present value of total tax revenue than EU15, and since the present value of government outlays is nearly unchanged in both, the larger present value of revenue is amplified into a significantly larger increase in the present value of the primary balance.<sup>ae</sup>

The US open-economy DLC for  $\tau_L$  is considerably steeper than for  $\tau_K$ , and it peaks at a tax rate of 0.48, which would make sustainable an initial debt ratio larger than in the initial baseline by 200 percentage points of GDP, much more than the 31 percentage points required by the data. The labor tax rate that the United States as an open or closed economy needs to make the observed debt increase sustainable is about 29%, which is just a two-percentage-point increase relative to the initial tax rate. Hence, these results show that, from the perspective of macroeconomic efficiency that representative-agent models of financially integrated economies like the one we are using emphasize, labor taxes are a significantly more effective tool for restoring fiscal solvency in the United States than capital taxes.

The DLC of EU15 yields much less positive results. Since the initial consumption-labor wedge is already much higher in this region than in the United States, the fiscal space of the labor tax rate is very limited. In either the closed- or open-economy cases, the DLC peaks at a labor tax rate of 46% and yields an increase of only about 10 percentage points in the present value of the primary balance, which is half of the 20-percentage-points increase EU15 needs make the observed debt increase sustainable.

It is interesting to note that the debt increase in the United States was about 10 percentage points larger than in Europe, yet the model predicts that given the initial conditions in tax rates and government outlays before the increases in debt, unilateral tax adjustments in Europe cannot generate a sufficient increase in the present value of the primary balance to make their higher debt sustainable. The exception is the capital tax in the open-economy scenario, in which this is possible only because EU15 would benefit significantly from a negative externality on the US region. In contrast, the results show that a modest increase in labor taxes (or consumption taxes since they are equivalent in this model) can restore fiscal solvency in the United States.

It is useful to compare the results we reported here with those of similar exercises in other existing studies based on Neoclassical models, particularly those by [Trabandt and](#)

<sup>ae</sup> The percent change in the present value of the primary balance after a tax change of a given magnitude relative to before (assuming that the present value of government outlays does not change) can be expressed as  $z[1 + PDV(g + e)/PDV(pb)]$ , where  $z$  is the percent change in the present value of tax revenues after the tax change relative to before, and  $PDV(g + e)$  and  $PDV(pb)$  are the pretax-change present values of total government outlays and the primary balance, respectively. Hence, for  $z > 0$  and since total outlays are much larger than the primary balance [ $PDV(g + e)/PDV(pb)] \gg 1$ , a given difference in  $z$  across the United States and EU15 translates into a much larger percent difference in the present value of the primary balance.



Uhlig (2011, 2012) and Auray et al. (2013). Trabandt and Uhlig (2011, 2012) used a closed-economy model without endogenous capacity utilization and focused mainly on steady-state Laffer curves (ie, Laffer curves that map tax rates into steady state tax revenues), while the DLCs studied here are for present values taking into account both transitional dynamics and steady-state changes caused by tax changes relative to the calibrated tax rates. Qualitatively, the results in Trabandt and Uhlig (2011) are similar to the ones in this chapter because they find that capital tax hikes generate much smaller increases in revenue than labor taxes. They find that the maximum increases in steady-state tax revenue obtained with capital (labor) taxes are 6 (30)% for the United States and 1 (8)% for Europe. Quantitatively; however, the results reported here differ not only because both transitional dynamics and steady-states are included, but also because the two-country model with capacity utilization captures the cross-country externalities of tax policy and the observed elasticity of the capital tax base, and these two features undermine the revenue-generating capacity of tax hikes.

Trabandt and Uhlig (2012) extend their analysis to gauge the sustainability of observed debt levels in response to hypothetical permanent increases in interest rates. Keeping government transfers, total outlays and debt constant at observed levels, they calculate the maximum real interest rate at which the revenue generated at the peak of steady-state Laffer curves would satisfy the steady-state government budget constraint. That is, effectively they compute the interest rate at which the Blanchard ratio of the previous section holds with debt and spending set at observed levels and tax revenue set at the maxima of steady-state Laffer curves. They find that the maximum real interest rate for the United States is larger than for European countries if labor taxes are moved to the peak of the Laffer curves. These calculations, however, inherit the limitations of the Blanchard ratios as measures of sustainable debt discussed in the previous section, and imply unusually large primary fiscal surpluses. For instance, depending on the debt measure used, Trabandt and Uhlig estimate the maximum interest rate for the United States in the 12–15.5% range. With a 92% debt ratio, a 1.5% annualized output growth rate and the 12% interest rate, the US economy requires a 9.6% steady-state primary surplus. The largest primary surplus observed in US history using Bohn's historical dataset starting in 1790 was 6.3%, and the average was just 0.4%. Moreover, moving the labor tax to the peak of the Laffer curve reduces steady-state output by 27%, which suggests that the welfare cost of the tax hike is quite large.

Auray et al. (2013) use a Neoclassical model of a small open economy to conduct a quantitative comparison of tax policies aimed at lowering European debt ratios. They introduce a FRF in the class of the ones examined in the previous section: Increases of the debt ratio at date  $t$  above its date- $t$  target induce increases in the date- $t$  primary surplus above its date- $t$  target. The primary balance adjustment is obtained by adjusting one of the tax rates as needed to satisfy the FRF. In this environment, lowering the debt ratio requires higher tax rates in the short term in exchange for lower rates in the long

term as steady-state debt service falls. They find that a cut of 10 percentage points in the debt ratio can be attained with an increase in welfare using the capital income tax, roughly no change in welfare using the consumption tax, and a welfare loss using the labor income tax. Qualitatively, the model studied here would produce similar results if applied to a similar debt-reduction experiment. Since the capital income tax is highly distorting, using the benefit of the lower debt service burden to cut the capital income tax would be best for welfare and efficiency. Their setup, however, is not calibrated to match the capital tax base elasticity and abstracts from cross-country externalities because of the small-open-economy assumption.

### 3.3.2 Macroeconomic Effects of Tax Rate Changes

We analyze next the macroeconomic effects of unilateral changes in capital and labor tax rates. In the first experiment, the United States increases its capital tax rate from the initial value of 0.37 to 0.402, which is the maximum point of the open-economy DLC for the United States. Table 8 shows the effects of this change on both regions in the open-economy model and on the US region as a closed economy. EU15 reduces its labor tax rate from 0.41 to 0.40 to maintain revenue neutrality, which is the result of favorable externalities from the tax hike in the United States.

The capital tax hike in the United States as an open economy leads to an overall welfare cost of 2.19% vs 2.22% as a closed economy, while EU15 obtains a welfare gain of 0.74%.<sup>af</sup> Comparing the US outcomes as an open economy relative to the closed economy under the same 40.2% capital tax rate, we find that the sustainable debt (ie, the present value of the primary balance) rises by a factor of 4.5 (from 1.37% to 6.16%). The welfare loss is nearly the same (2.2%), but normalizing by the amount of revenue generated, the United States is much better off in autarky. Thus, seen from this perspective, the United States would have strong incentives for either engaging in strategic interaction (ie, tax competition) or for considering measures to limit international capital mobility.

The 0.74% welfare gain that EU15 obtains from the US unilateral capital tax hike is a measure of the normative effect of the cross-country externalities of capital tax changes. The United States can raise more revenue by increasing  $\tau_K$  along the upward-sloping region of its DLC, but its ability to do so is significantly hampered by the adverse externality it faces due to the erosion of its tax bases. In EU15, the same externality indirectly improves government finances, or reduces the distortions associated with tax collection, and provides it with an unintended welfare gain.

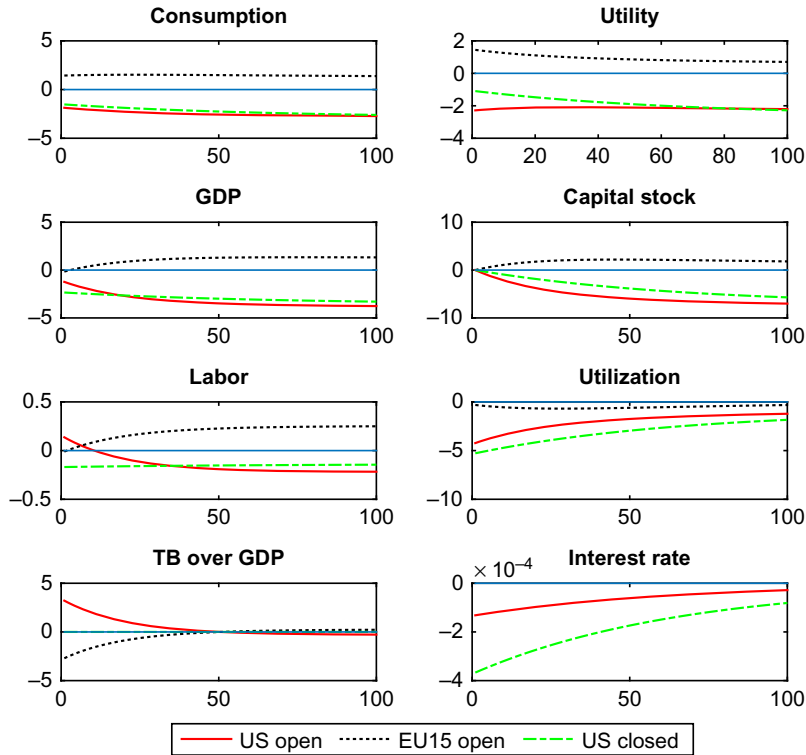
<sup>af</sup> Welfare effects are computed as in Lucas (1987), in terms of a percent change in consumption constant across all periods that equates lifetime utility under a given tax rate change with that attained in the initial steady state. The overall effect includes transitional dynamics across the pre- and post-tax-change steady states, as well as changes across steady states. The steady-state effect only includes the latter.

**Table 8** Macroeconomic effects of an increase in US capital tax rate (the EU15 maintains revenue neutrality with labor tax)

Tax rates	Open economy				Closed economy	
	United States		EU15		United States	
	Old	New	Old	New	Old	New
$\tau_K$	0.37	0.40	0.32	0.32	0.37	0.40
$\tau_C$	0.04	0.04	0.17	0.17	0.04	0.04
$\tau_L$	0.27	0.27	0.41	0.40	0.27	0.27
PV of fiscal deficit over precrisis GDP as percentage point change from original ss		1.37		0.00		6.16
<b>Welfare effects (percent)</b>						
Steady-state gain		−2.27		0.59		−2.55
Overall gain		−2.19		0.74		−2.22
<b>Percentage changes</b>	<b>Impact effect</b>	<b>Long-run effect</b>	<b>Impact effect</b>	<b>Long-run effect</b>	<b>Impact effect</b>	<b>Long-run effect</b>
$\gamma$	−1.23	−3.87	−0.15	1.25	−2.35	−3.57
$c$	−1.87	−2.83	1.44	1.28	−1.53	−2.91
$k$	0.00	−7.61	0.00	1.25	0.00	−7.32
<b>Percentage point changes</b>						
$tb/\gamma$	3.21	−0.30	−2.70	0.24		
$i/\gamma$	−3.01	−1.02	1.77	0.00	−0.91	−1.02
$r$	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00
$l$	0.11	−0.17	−0.01	0.21	−0.13	−0.11
$m$	−4.23	−0.866	−0.315	−0.000	−5.277	−0.866

The impact and long-run effects on key macro-aggregates in both regions are shown in the bottom half of [Table 8](#). The corresponding transition paths of macroeconomic variables as the economies move from the precrisis steady state to the new steady state are illustrated in [Fig. 10](#). The increase in  $\tau_K$  causes US capital to fall over time to a level 7.6% below the precrisis level, while EU15's capital rises to a level 1.25% above the pre-tax-change level. Capacity utilization falls at home in both the short run and the long run, which is a key component of the model capturing the reduced revenue-generating capacity of capital tax hikes when the endogeneity of capacity utilization is considered. We show later in this section that this mechanism indeed drives the elasticity of the capital tax base in the model, which matches that of the data and is higher than what standard representative-agent models of taxation show.

On impact when the United States increases its capital tax, labor increases in the United States and falls slightly in EU15, but this pattern reverses during the transition



**Fig. 10** Responses of macro variables to a US capital tax rate increase.

to steady state because of the lower (higher) capital stock in US (EU15) region in the new steady state. Consequently, US output contracts by almost 4% in the long-run, underscoring efficiency losses due to the capital tax increase and the costs of the fiscal adjustment. The United States increases its net foreign asset position (NFA) by running trade surpluses ( $tb/\gamma$ ) in the early stages of transition, while EU15 decreases its NFA position by running trade deficits. The US trade surpluses reflect saving to smooth out the cost of the efficiency losses, as output follows a monotonically decreasing path. Still, utility levels are lower than when the United States implements the same capital tax under autarky, because of the negative cross-country spillovers.

We next look at the responses of fiscal variables when the United States increases its capital tax, plotted in Fig. 11. In the United States, tax revenue from capital income increases almost immediately to a higher constant level when  $\tau_K$  rises, while the revenues from labor and consumption taxes decline both on impact and in the long run. Labor and consumption tax rates are not changing, but both tax bases fall on impact and then decline monotonically to their new, lower steady states. The primary fiscal balance and total revenue both rise initially but then converge to about the same levels as in the precrisis stationary equilibrium. For the primary balance, this pattern is implied by the pattern of the

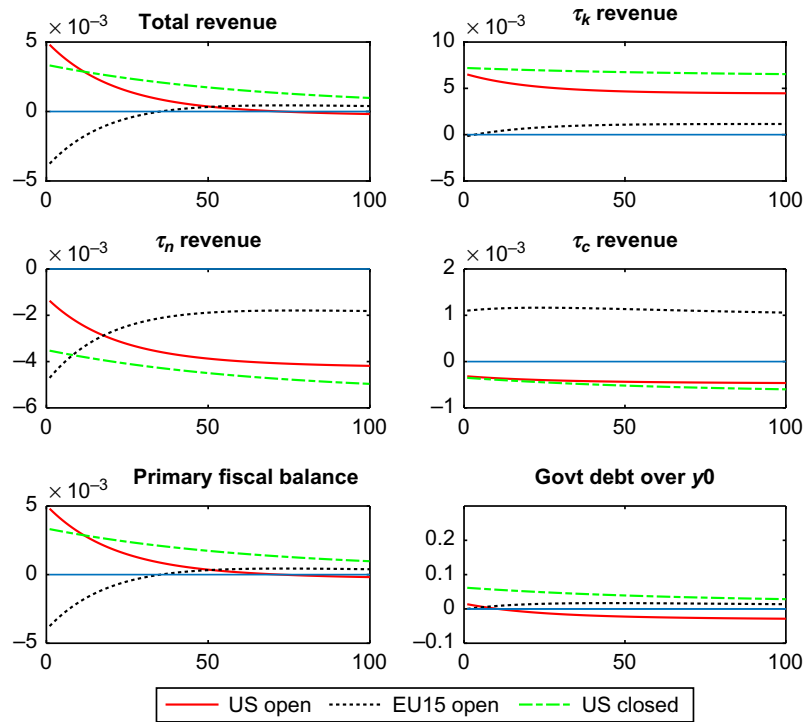


Fig. 11 Responses of fiscal variables to a US capital tax rate increase.

total revenue, since government expenditures and entitlements are held constant. For total revenue, the transitional increase indicates that the rise in capital tax revenue more than offsets the decline in the revenue from the other taxes in the transition, while in the long-run they almost offset each other exactly. This is possible because the change in  $\tau_K$  to 0.4 is on the increasing side of the Laffer curve, and in fact it is the maximum point of the curve. Hence, this capital tax hike does not reduce capital tax revenues.

The public debt dynamics in the bottom-right panel of Fig. 11 shows that on impact, government debt in the United States responds to the 40% tax rate by increasing 5 percentage points, reflecting the extra initial debt that can be supported at the higher capital tax rate. Since the primary fiscal balance rises on impact and then declines monotonically, the debt ratio also falls monotonically during the transition, and converges to a ratio that is actually about 4 percentage points below the precrisis level. Hence, the initial debt increase allowed by the capital tax hike is followed by a protracted decline in debt converging to a debt ratio even lower than in the precrisis steady state. If the United States implements the same tax hike under autarky, it generates significantly larger revenues and primary balances, and hence the debt ratio increases more initially and converges to a higher steady state of 1 percentage points above the precrisis level. This is again a

reflection of the cross-country externalities faced by the United States as an open economy, since equally sized tax hikes produce significantly higher revenues under autarky.

The cross-country externalities are also reflected in the fiscal dynamics of EU15 shown in Fig. 11. Maintaining revenue neutrality (in present value) still allows both its revenue and primary balance to fall initially, while in the long run both converge to very similar levels as in the precrisis steady state. Removing the labor tax adjustment in EU15 that maintains revenue neutrality, the present value of its primary balance as a share of GDP would increase by 10.1 percentage points relative to the precrisis ratio, and both its revenue and primary balances would be higher than in the plots shown in Fig. 11. The welfare gain, however, would be negligible instead of 0.74% in lifetime consumption.

The next experiment examines the effects of lowering the EU15 capital tax rate so as to move it out of the decreasing segment of the DLC. To make this change analogous to the one in the previous experiment, we change the EU15 capital tax to the value at the maximum point of the DLC for EU15, which is about 21%. Table 9 summarizes the results. The cut in the EU15 capital tax rate generates an increase of about 22 percentage points in sustainable debt (just a notch above what is required to make the observed debt increase sustainable), and a large welfare gain of 6.9% for this region. Its capital stock rises over time to a level 26% higher than in the pre-tax-change steady state. Output, consumption, labor supply, and utilization all rise in both the short-run and the long-run in EU15, while the trade balance moves initially into a large trade deficit and then converges to a small surplus. The same tax cut in EU15 as a closed economy yields a much smaller rise in sustainable debt, of just under 10 percentage points, though the welfare gain is about the same as in the open economy. This result indicates that in this case the welfare gain largely reflects the reduction of the large inefficiencies due to the initial capital tax being in the decreasing side of the DLC. In the US region, the tax cut in EU15 causes a welfare loss of 0.2%, with capital declining 1.5 percent from the pre-tax-change level.

The next two experiments focus on changes in labor tax rates. The DLCs for the labor tax rate (Fig. 9) show that the US region has substantial capacity to raise tax revenues and sustain higher debt ratios by raising labor taxes. We examine in particular an increase of the labor tax rate that completely offsets the observed debt increase, which as we noted earlier is only about 2 percentage points higher than in the initial calibration (ie, the labor tax in the United States rises from 27% to 29%). The results are reported in Table 10. The declines in US output, consumption, capital, and welfare are much smaller than with the capital tax hike. Since the international spillovers are small, this tax change produces a welfare gain of just 0.18% in EU15. For the same reason, comparing the United States results as a closed vs open economy, the change in the present value of the primary balance is almost the same, in contrast with the large difference obtained for the capital tax. Also, keep in mind that the capital tax hike, even though it was set at the maximum point of the capital tax DLC of the United States as open economy, cannot generate enough revenue to offset the observed debt increase, whereas the labor tax hike does.

**Table 9** Macroeconomic effects of a decrease in EU15 capital tax rate (the United States maintains revenue neutrality with labor tax)

Tax rates	Open economy				Closed economy	
	United States		EU15		EU15	
	Old	New	Old	New	Old	New
$\tau_K$	0.37	0.37	0.32	0.20	0.37	0.37
$\tau_C$	0.04	0.04	0.17	0.17	0.04	0.17
$\tau_L$	0.27	0.28	0.41	0.41	0.27	0.41
PV of fiscal deficit over precrisis GDP as percentage point change from original ss		−0.00		22.34		9.62
<b>Welfare effects (percent)</b>						
Steady-state gain		0.36		7.35		7.93
Overall gain		−0.23		6.86		6.99
<b>Percentage changes</b>	<b>Impact effect</b>	<b>Long-run effect</b>	<b>Impact effect</b>	<b>Long-run effect</b>	<b>Impact effect</b>	<b>Long-run effect</b>
$\gamma$	2.30	−1.40	6.05	12.77	8.38	11.99
$c$	−1.59	−0.64	5.82	9.03	5.14	9.19
$k$	0.00	−1.50	0.00	26.10	0.00	25.23
<b>Percentage point changes</b>						
$tb/\gamma$	8.92	−0.75	−6.57	0.56		
$i/\gamma$	−5.64	0.00	8.18	3.66	3.31	3.66
$r$	0.00	−0.00	0.00	−0.00	0.00	−0.00
$l$	0.47	−0.31	0.05	0.48	0.43	0.36
$m$	2.34	0.00	12.93	3.31	14.94	3.31

Now consider the case of increasing the EU15 labor tax. As explained earlier in discussing the labor DLCs, the EU15 initial consumption/labor wedge is already high, so the capacity for raising tax revenues using labor taxes is limited. In this experiment, we increase the labor tax in EU15 to the rate at the maximum point of the labor tax DLC of EU15 as an open economy, which implies a labor tax rate of 0.465. The results are summarized in [Table 11](#). The higher EU15 labor tax increases the present value of the primary balance-GDP ratio by only 0.118, falling well short of the observed debt increase of 0.2. The welfare loss is large, at nearly 5%, with output, consumption, capital, and labor falling. EU15 can produce a higher present value of the primary balance (0.16) in the closed economy at a similar welfare loss. Again the international spillover for the labor tax rate is small, so the US region makes a negligible welfare gain.

Taken together these findings are consistent with two familiar results from tax analysis in representative-agent models, which emphasize the efficiency costs of tax distortions. First, the capital tax rate is the most distorting tax. Second, in open-economy models,

**Table 10** Macroeconomic effects of an increase in the US labor tax rate (the EU15 maintains revenue neutrality with labor tax)

Tax rates	United States		EU15		United States	
	Old	New	Old	New	Old	New
$\tau_K$	0.37	0.37	0.32	0.32	0.37	0.37
$\tau_C$	0.04	0.04	0.17	0.17	0.04	0.04
$\tau_L$	0.27	0.29	0.41	0.41	0.27	0.29
PV of fiscal deficit over precrisis GDP as percentage point change from original ss		31.00		0.00		31.95
<b>Welfare effects (percent)</b>						
Steady-state gain		−0.92		0.15		−0.98
Overall gain		−0.90		0.18		−0.91
<b>Percentage changes</b>	<b>Impact effect</b>	<b>Long-run effect</b>	<b>Impact effect</b>	<b>Long-run effect</b>	<b>Impact effect</b>	<b>Long-run effect</b>
$\gamma$	−1.16	−1.75	−0.02	0.30	−1.41	−1.68
$c$	−1.88	−2.09	0.34	0.31	−1.80	−2.10
$k$	0.00	−1.75	0.00	0.30	0.00	−1.68
<b>Percentage point changes</b>						
$tb/\gamma$	0.72	−0.07	−0.61	0.06		
$i/\gamma$	−0.46	0.00	0.40	0.00	0.02	−0.00
$r$	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00
$l$	−0.29	−0.35	0.00	0.05	−0.35	−0.34
$m$	−0.73	0.00	−0.06	−0.00	−0.96	0.00

taxation of a mobile factor (ie, capital) yields less revenue at greater welfare loss than taxation of the immobile factor (ie, labor). This is in line with our results showing that the cross-country tax externalities are strong for capital taxes but weak for labor taxes.

The sharp differences we found between the United States and EU15 also have important policy implications in terms of debates about debt-sustainability and the effects of fiscal adjustment via capital and labor taxes in Europe and the United States. With capital taxes, the model suggests that the United States is on the increasing side of the Laffer curve, though it cannot restore fiscal solvency for the observed debt shock of 31 percentage points (neither as an open economy nor as a closed economy). In contrast, the model suggests that Europe is on the decreasing side of the Laffer curve, and can make its observed debt increase of 20 percentage point sustainable by reducing its capital taxes and moving away from the decreasing side of the Laffer curve, and in the process make a substantial welfare gain. This is only possible, however, because the United States is assumed to maintain its capital tax rate unchanged as Europe's drops, which results in



**Table 11** Macroeconomic effects of an increase in the EU15 labor tax rate (the United States maintains revenue neutrality with labor tax)

Tax rates	United States		EU15		EU15	
	Old	New	Old	New	Old	New
$\tau_K$	0.37	0.37	0.32	0.32	0.37	0.37
$\tau_C$	0.04	0.04	0.17	0.17	0.04	0.17
$\tau_L$	0.27	0.27	0.41	0.47	0.27	0.47
PV of fiscal deficit over precrisis GDP as percentage point change from original ss		0.00		11.75		16.02
<b>Welfare effects (percent)</b>						
Steady-state gain		−0.12		−5.04		−5.19
Overall gain		0.07		−4.91		−4.92
<b>Percentage changes</b>	<b>Impact effect</b>	<b>Long-run effect</b>	<b>Impact effect</b>	<b>Long-run effect</b>	<b>Impact effect</b>	<b>Long-run effect</b>
$\gamma$	−0.68	0.41	−4.28	−6.20	−5.06	−5.99
$c$	0.45	0.16	−7.35	−8.18	−7.13	−8.22
$k$	0.00	0.41	0.00	−6.20	0.00	−5.99
<b>Percentage point changes</b>						
$tb/\gamma$	−2.47	0.22	2.16	−0.20		
$i/\gamma$	1.64	−0.00	−1.29	−0.00	0.11	−0.00
$r$	−0.00	−0.00	−0.00	−0.00	−0.00	−0.00
$l$	−0.14	0.08	−0.90	−1.05	−1.04	−1.01
$m$	−0.67	−0.00	−2.87	0.00	−3.59	−0.00

large externalities that benefit Europe at the expense of the United States. Capital tax hikes under autarky cannot restore fiscal solvency for Europe either.

With labor taxes, although the model indicates that both the United States and Europe are on the increasing side of their DLCs, the US pre-2008 started with a much smaller consumption/labor distortion than Europe. As a result, the United States has substantial fiscal space to easily offset the debt increase with a small labor tax hike and a small welfare cost of 0.9%. In contrast, the model suggests that Europe cannot restore fiscal solvency after the observed increase in debt using labor taxes.

### 3.3.3 Why Are Utilization and Limited Depreciation Allowance Important?

As explained earlier, we borrowed from [Mendoza et al. \(2014\)](#) the idea of using endogenous capacity utilization and a limited tax allowance for depreciation expenses to build into the model a mechanism that produces capital tax base elasticities in line with empirical estimates. In contrast, standard dynamic equilibrium models without these features

tend to have unrealistically low responses of the capital base to increases in capital taxes. To illustrate this point, we follow again Mendoza et al. in comparing DLCs for capital taxes in three scenarios (see Fig. 12): (i) a standard Neoclassical model with exogenous utilization and a full depreciation allowance ( $\theta = 1$ ), shown as a dashed-dotted line; (ii) the same model but with a limited depreciation allowance ( $\theta = 0.2$ ), shown as a dotted line; and (iii) the baseline calibration of our model with both endogenous utilization and a limited depreciation allowance (using again  $\theta = 0.2$ ), shown as a solid line. All other

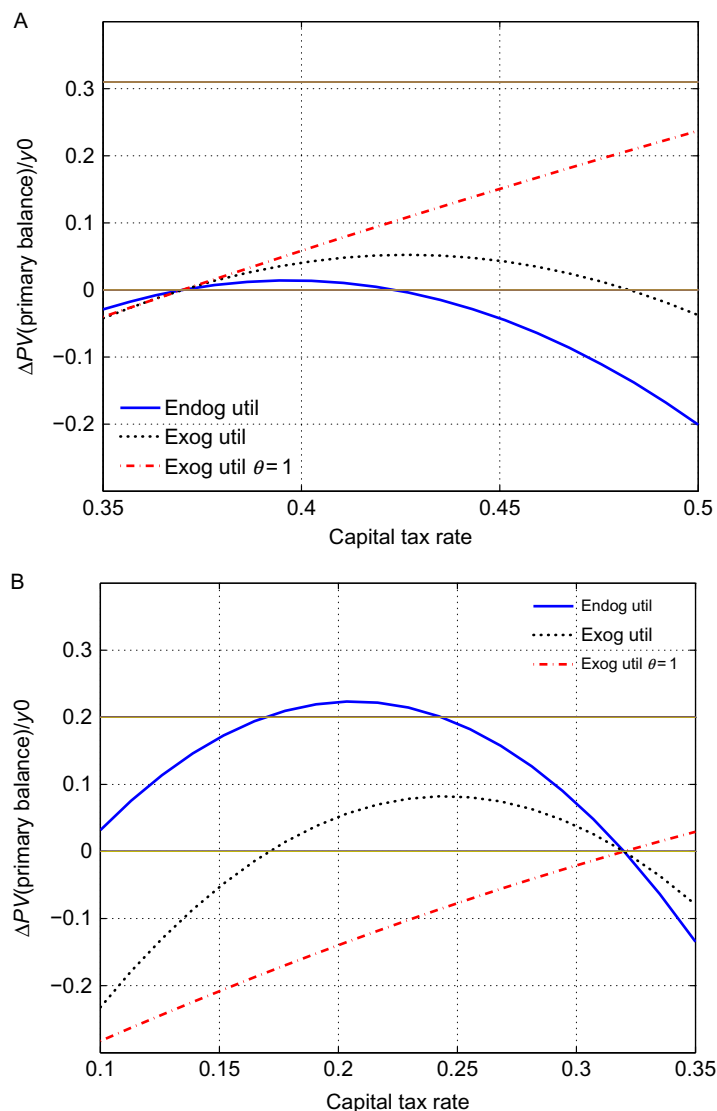


Fig. 12 Comparing dynamic Laffer curves for the capital tax rate. (A) United States. (B) EU15.

parameter values are kept the same. We show the three cases for the United States and EU15 region in panels (A) and (B) of the figure, respectively.

The DLCs for the three cases intersect at the initial calibrated tax rates of 0.37 and 0.32 for the United States and EU15 by construction. To the right of this point, the curves for case (i) are always above the other two, and the ones for case (ii) are always above the ones for case (iii). The opposite occurs to the left of the intersection points.

Consider the US plots. In case (i), the DLC has a positive, approximately linear slope in the 0.35–0.5 domain of capital tax rates. This curve continues to be increasing even when we extend the capital tax rate to 0.9, which is in line with the results obtained by [Trabandt and Uhlig \(2011\)](#).<sup>ag</sup> This behavior of the DLC for the capital tax follows from the fact that at any given date the capital stock is predetermined and has a low short-run elasticity. As a result, the government can raise substantial revenue over the transition period because the capital stock declines only gradually. The increased tax revenue during the transition dominates the fall in the steady-state, resulting in a nondecreasing DLC (recall the DLC is based on present value calculations).

Introducing limited depreciation allowance without endogenizing the utilization choice (case (ii)) has two effects that induce concavity in the DLC. First, it increases the effective rate of taxation on capital income, and thus weakens the incentive to accumulate capital and lowers the steady-state capital-output ratio and tax bases. On the other hand, it has a positive impact on revenue by widening the capital tax base. The first effect dominates the latter when the capital tax rate rises relative to the initial tax of 0.37, resulting in sharply lower DLC curve values than in case (i).

In case (iii) the tax allowance is again limited but now capacity utilization is endogenous. This introduces additional effects that operate via the distortions on efficiency and the ability to raise revenue discussed earlier: On the side of tax distortions, equation (9) implies that endogenous utilization adds to the efficiency costs of capital income taxation by introducing a wedge between the marginal cost and benefits of capital utilization. On the revenue side, endogenous utilization allows agents to make adjustments in effective capital (reducing it when taxes rise and increasing it when it falls), and thus alters the amount of taxable capital income. Hence, when utilization falls in response to increases in capital tax rates, it also weakens the government's ability to raise capital tax revenue. These effects lead to a bell-shaped DLC that has more curvature and is significantly below those in cases (i) and (ii). Thus, endogenous utilization makes capital taxes more distorting and weakens significantly the revenue-generating capacity of capital taxes.<sup>ah</sup>

<sup>ag</sup> They find that present-value Laffer curves of capital tax revenue peak at very high tax rates (discounting with the constant steady state interest rate) or have a positive slope over the full range (discounting with equilibrium interest rates).

<sup>ah</sup> Mendoza et al. also found that removing the limited depreciation allowance from case (iii) still results in a DLC below those of cases (i) and (ii), but it is also flatter and increasing for a wider range of capital taxes than case (iii).

Panel (B) of Fig. 12 shows DLCs for the three cases in the EU15 region. The results are analogous to Panel (A) but emphasizing now the region to the left of the intersection point, which is at the initial tax of 32%. In case (i), again the DLC has an increasing positive slope over a large range of the capital tax rate. Case (ii) shows that limiting the depreciation allowance again induces concavity in the DLC, with the EU15 initial capital tax already in the decreasing segment of the curve. Comparing with case (iii), the exogenous utilization case generates much less revenue. As in the US results, this occurs because with endogenous utilization, reductions in capital taxes lead to higher utilization rates that result in higher levels of capital income and higher wages, thus widening the two income tax bases.

The effects of endogenous utilization and limited depreciation have significant implications for the elasticity of the capital income tax base with respect to the capital tax. In particular, as Mendoza et al. (2014) showed, the model can be calibrated to match a short-run elasticity consistent with empirical estimates because of the combined effects of those two features. As documented earlier, the empirical literature finds estimates of the short-run elasticity of the capital tax base in the 0.1–0.5 range. Table 12 reports the model's comparable elasticity estimates and the effects on output, labor, and utilization 1 year after a 1% increase in the capital tax (relative to the calibrated baseline values), again for cases (i), (ii), and (iii) and in both the United States and EU15 regions.

The United States and EU15 results differ somewhat quantitatively, but qualitatively they make identical points: The neoclassical model with or without limited depreciation allowance (cases (i) and (ii)) yields short-run elasticities with the wrong sign (ie, the capital tax base *rises* in the short run in response to capital tax rate increases). The reason is that capital does not change much, since capital is predetermined in the period of the tax hike and changes little in the first period after because of investment adjustment costs, and

**Table 12** Short-run elasticity of US capital tax base

	Elasticity	$y_1$	$l_1$	$m_1$
Empirical estimates	[0.1, 0.5]			
Model implications for the United States				
Exog. utilization and $\theta = 1$	−0.09	0.04%	0.011	
Exog. utilization and $\theta = 0.2$	−0.09	0.08%	0.028	
Endog. utilization and $\theta = 0.2$	0.29	−0.15%	0.010	−0.471
Model implications for the EU15				
Exog. utilization and $\theta = 1$	−0.04	0.01%	0.004	
Exog. utilization and $\theta = 0.2$	−0.02	0.03%	0.008	
Endog. utilization and $\theta = 0.2$	0.32	−0.14%	0.004	−0.393

*Note:* Elasticity is measured as the percentage decrease of capital tax base in the first year after a 1% increase in the capital tax rate is introduced. For empirical estimates, see Gruber and Rauh (2007) and Dwenger and Steiner (2012).  $y_1$  and  $m_1$  provides the percent deviation from the initial steady state in the impact year.  $l_1$  denotes the percentage points change from the initial steady state.

labor supply rises due to a negative income shock from the tax hike. Since capital does not fall much and labor rises, output rises on impact, and thus taxable labor and capital income both rise, producing an elasticity of the opposite sign than that found in the data. In contrast, the model with endogenous utilization (case (iii)), generates a decline in output on impact due to a substantial drop in the utilization rate, despite the rise in labor supply. With the calibrated values of  $\eta$ , the model generates short-run elasticities of 0.29 and 0.32 for the United States and EU15, respectively, which are both well inside the range of empirical estimates.

It is also worth noting that with exogenous utilization, the model can produce a capital tax base elasticity in line with empirical evidence only if we set  $\eta$  to an unrealistically low value. The short-run elasticity of the capital tax base is negative for any  $\eta > 1$ , and it becomes positive and higher than 0.1 only for  $\eta < 0.1$ .<sup>ai</sup> This is significantly below the empirically relevant range of 1–2.5 documented in the calibration section. Moreover, at the value of  $\eta = 2$  determined in our baseline calibration, the model without utilization choice yields a capital tax base elasticity of  $-0.09$ .

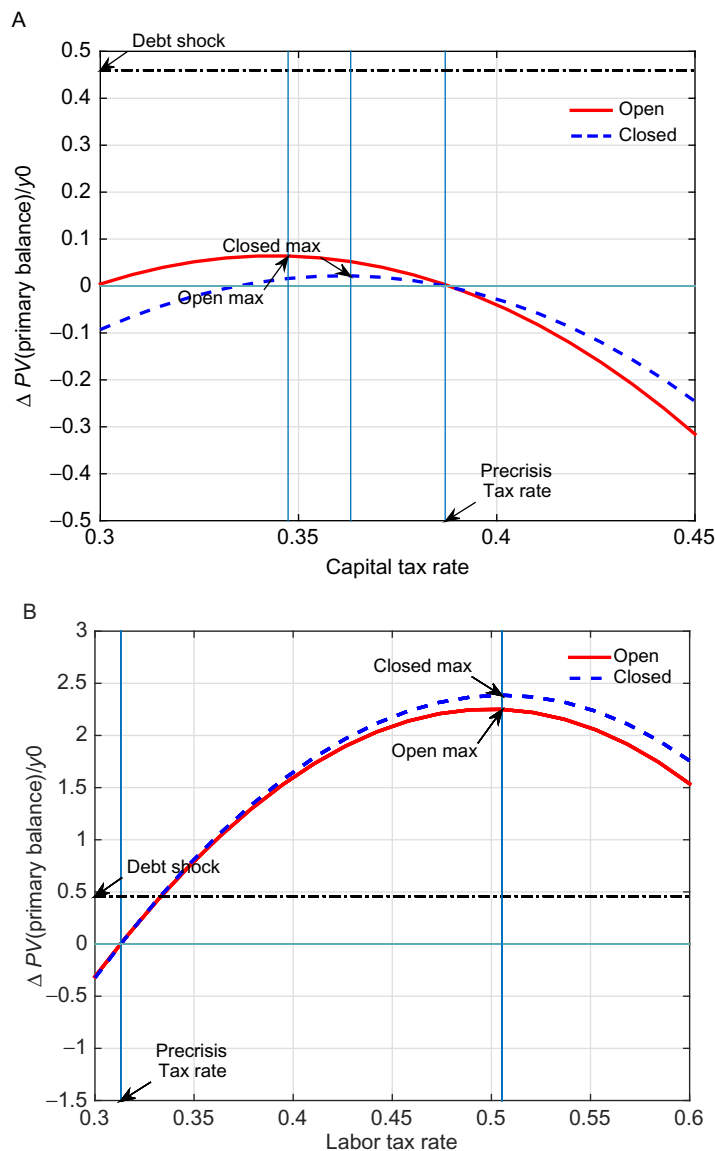
### 3.3.4 Further Considerations

We close this section with some important considerations and caveats of the structural analysis. In particular, we discuss the predictions of the structural framework for the case of Japan, which is challenging because of its high debt ratio, and the implications of considering the possibility of taxes on wealth or the capital stock.

Japan had a very high public debt to GDP ratio already before the global financial crisis, at about 82% by the end of 2007. By the end of 2011, its debt ratio had increased 46 percentage points to 128%. Hence the level and the change of Japan's debt ratio are both larger than what we saw in the United States and Europe.

What does the structural approach to debt sustainability tell us about the Japanese case? To answer this question, we reset the model so that the foreign region is now a proxy for Japan instead of EU15 and recompute the DLCs. In particular, we calibrate the foreign tax rates to match Japan's precrisis tax structure, using the same Mendoza-Razin-Tesar method we used for the United States and Europe. In 2007, Japan's capital tax rate was 39%, the labor tax rate was 31% and the consumption tax was 6%. This tax structure is similar to that of the United States. In fact, Japan's consumption-leisure tax wedge  $\tau_W$  is 0.35, which is much closer to the 0.3 estimate for the United States than 0.5 for Europe. We also reset the relative country size to match the fact that Japan's GDP per capita is about 78% that of the United States. The rest of the structural parameters are kept the same as in our baseline analysis. The DLCs for Japan are shown in Fig. 13. The panel (A) is the DLC for the capital tax and the panel (B) is for the labor tax.

<sup>ai</sup> The intuition is simple. As  $\eta$  approaches zero the marginal adjustment cost of investment approaches zero, and hence the capital stock 1 year after the tax hike can respond with large declines.



**Fig. 13** Dynamic Laffer curves for Japan. (A) Capital tax. (B) Labor tax.

In general, the DLC results for Japan are a more extreme version of those for the United States: The capital tax cannot restore fiscal solvency because Japan's DLC for this tax peaks well below the required increase, while there is a lot of room for labor (or consumption) taxes to do it. One important difference is that the precrisis high capital tax rate in Japan is inefficient (ie, in the decreasing segment of the DLC). Because of this, the tax

externalities work in the opposite direction to those observed for the US DLC, and so cutting the capital tax in Japan relative to the precrisis rate as a closed economy yields a smaller increase in the present value of the primary balance than as an open economy. One important caveat to the above results is that Japan has been stuck with slow growth and deflation for about two decades. Although raising consumption and labor taxes helps balance government budgets, higher taxes still cause efficiency and welfare losses. Japan did increase its consumption tax from 5% to 8% in April 2014, but after that the economy tipped back into recession and a further hike of the consumption tax to 10% was postponed. Moreover, if we reduce the long-run growth rate in the model to the 0.8% per-capita GDP growth rate observed on average in Japan between 2001 and 2014, the two DLCs shift downward sharply. The capital tax becomes effectively useless as it yields negligible amounts of extra revenue. The labor tax needed to make the debt sustainable is significantly higher, and thus the associated efficiency and welfare losses are larger as well.

Another caveat is that our analysis abstracts from Japan's aging demographics, rising pressures on government finance from public pensions and medical expenses, etc. These considerations place heavy burdens on the sustainability of public debt. [Imrohoroglu and Sudo \(2011\)](#) and [Hansen and Imrohoroglu \(2013\)](#) use a Neoclassical growth model to quantify the implications of the projected low population growth rate and permanent increase in total government outlays on fiscal sustainability. Imrohoroglu and Sudo find that even an increase in the consumption tax to 15% and an annual GDP growth of 3% over the next 20 years is not sufficient to restore fiscal balance unless expenditures are also contained. Hansen and Imrohoroglu find that fiscal sustainability requires the consumption tax rate be set to unprecedentedly high levels of 40–60%. Moreover, [Imrohoroglu et al. \(2016\)](#) and [Braun and Joines \(2015\)](#) use overlapping generation models and also find that current fiscal policies are not sustainable and large fiscal adjustments are needed.<sup>aj</sup>

Another important consideration in assessing the results of the structural analysis is that we abstracted from the possibility of taxing wealth, in particular taxing the initial capital stock. The optimal taxation literature has made the well-known argument that from an efficiency standpoint taxing the initial, predetermined capital stock is optimal. However, the argument hinges on the assumption of government commitment, which sets aside key issues of time consistency and the implications of lack of commitment.

In our model, a wealth tax would be equivalent to confiscation of a fraction of  $k_0$  unexpectedly. Since utilization is endogenous, this tax would also affect utilization as of date 0: The marginal product of utilization declines with lower capital, utilization falls, and thus capital income and capital income tax revenue fall. But more importantly, three arguments raise serious questions about the possibility of taxing wealth in this way.

<sup>aj</sup> In the next section we discuss the implications of unfunded pension and entitlement liabilities for debt sustainability when the government is not committed to repay and responds to distributional incentives to default.

First, the government would have to sell confiscated capital to raise revenue (in the realistic scenario in which confiscated capital and government outlays involve different goods and services), which would lower the price at which capital goods can be sold. Second, the expectation of future confiscation of capital would not be zero, and to the extent that is positive it would act as a tax on future capital accumulation and capital income. Third, as an implication of the first two arguments, the wealth tax actually looks more like a government default that would seem to necessitate modeling government behavior without commitment (in fact, in a setup without utilization and capital as the only productive factor, the government confiscating some of  $k_0$  is equivalent to defaulting on a fraction of the date-0 debt repayment).

Perhaps because of the above arguments, the history of wealth taxes has not been a happy one. Wealth taxes were discarded by Austria, Denmark, and Germany in 1997, by Finland, Iceland, and Luxembourg in 2006 and by Sweden in 2007. Interestingly, these countries claimed to ditch the wealth tax in efforts to get more revenue, not less. Moreover, implementing wealth taxation faces serious hurdles, particularly for the valuation of assets and for preventing tax evasion. Global financial integration also makes taxing wealth more difficult, because the expectation of potential future confiscation via wealth taxes mentioned above discourages investment and encourages capital flight (see the discussion in [Eichengreen, 1989](#) and the recent experience with “tax inversions” in the United States).

To summarize where the chapter is at this point, we first explored the question of public debt sustainability from the viewpoint of an empirical approach based on the estimation and analysis of fiscal reaction functions. We found that the sufficiency condition for public debt to be sustainable (ie, for IGBC to hold), reflected in a positive conditional response of the primary balance to public debt, cannot be rejected by the data. At the same time, however, there is clear evidence that the fiscal dynamics observed in the aftermath of the recent surge in debt in advanced economies represent a significant structural break in the reaction functions. In plain terms, primary deficits have been too large, and are projected to remain too large, to be in line with the path projected by the reaction functions, and also relative to the fiscal adjustment process observed in previous episodes of large surges in debt.

The main limitation of the empirical approach is that it cannot say much about the macroeconomic effects of multiple fiscal adjustment paths that can restore debt sustainability. To address this issue, this section explored a structural approach that takes a variation of the workhorse two-country Neoclassical dynamic equilibrium model with an explicit fiscal sector. Capacity utilization and a limited tax allowance for depreciation expenses were used to match the observed elasticity of the capital tax base to capital tax changes. Then we calibrated this model to the United States and European data and used it to quantify the effects of unilateral changes in capital and labor taxes aimed at altering the ability of countries to sustain debt. The results suggest striking differences



across Europe and the United States. For the United States, the results suggest that changes in capital taxes cannot make the observed increase in debt sustainable, while small increases in labor taxes could. For Europe, the model predicts that the ability of the tax system to make higher debt ratios sustainable is nearly fully exhausted. Capital taxation is highly inefficient and in the decreasing segment of DLCs, so cuts in capital taxes would be needed to restore fiscal solvency. Labor taxes are near the peak of the DLC, and even if increased to the maximum point they fail to increase the present value of the primary balance to make the observed surge in debt sustainable. Moreover, international externalities of capital income taxes are quantitatively large, suggesting that incentives for strategic interaction, and the classic race-to-the-bottom in capital income taxation are nontrivial.

In short, the results from the empirical and the structural approaches to evaluate debt sustainability cast doubt on the presumption that the high debt ratios reached by many advanced economies in the years since 2008 will be fully repaid. To examine debt sustainability allowing for the possibility of nonrepayment, however, we must consider a third approach that relaxes the assumption that the government is committed to repay domestic debt, which is central to the two approaches we have covered. In the next section of this chapter we turn our attention to this issue.

#### 4. DOMESTIC DEFAULT APPROACH

We now examine debt sustainability from the perspective of a framework that abandons the assumption of a government committed to repay domestic debt. The emphasis is on the risk of de-jure, or outright, default on domestic public debt, not the far more studied issues of external sovereign default, which is the subject of another chapter in this Handbook, or de-facto default on domestic debt via inflation. Interest on domestic sovereign default is motivated by the seminal empirical study of [Reinhart and Rogoff \(2011\)](#), which documents episodes of outright default on domestic public debt in a cross-country historical dataset going back to 1750.<sup>ak</sup> [Hall and Sargent \(2014\)](#) describe in detail a similar episode in the process by which the US government handled the management of its debt in the aftermath of the Revolutionary War.

Reinhart and Rogoff noted that the literature has paid little attention to domestic sovereign default, and thus chose to title their paper *The Forgotten History of Domestic Debt*. As we document below, the situation has changed somewhat recently, but relatively speaking the study of domestic government defaults remains largely uncharted territory.

<sup>ak</sup> Reinhart and Rogoff identified 68 outright domestic default episodes, which occurred via mechanisms such as forcible conversions, lower coupon rates, unilateral reductions of principal, and suspensions of payments.

The ongoing European debt crisis also highlights the importance of studying domestic sovereign default, because four features of the crisis (thinking of Europe as a whole) make it resemble more a domestic default than an external default. First, countries in the Eurozone are highly integrated, with the majority of their public debt denominated in their common currency and held by European residents. Hence, a default means, to a large extent, a suspension of payments to “domestic” (ie, European) agents instead of external creditors. Second, domestic public-debt-GDP ratios are high in the Eurozone in general, and very large in the countries at the epicenter of the crisis (Greece, Ireland, Italy, Spain, and Portugal). Third, the Eurozone’s common currency and common central bank rule out the possibility of individual governments resorting to inflation as a means to lighten their debt burden without an outright default. Fourth, and perhaps most important from the standpoint of the theory proposed in this section, European-wide institutions such as the European Central Bank (ECB) and the European Commission are weighting the interests of both creditors and debtors in assessing the pros and cons of sovereign defaults by individual countries, and creditors and debtors are aware of these institutions’ concern and of their key role in influencing expectations and default risk.

Table 13 shows that the Eurozone’s fiscal crisis has been characterized by rapid increases in public debt ratios and sovereign spreads that coincided with rising government expenditure ratios. The table also shows that debt ownership, as proxied by Gini coefficients of wealth distributions, is unevenly distributed in the seven countries listed, with mean and median Gini coefficients of around two-thirds. The degree of concentration in the ownership of public debt plays a key role in the framework of optimal

**Table 13** Euro area: Key fiscal statistics and wealth inequality

Moment (%)	Gov. debt		Gov. exp.		Spreads		Gini Wealth
	Avg.	2011	Avg.	“Crisis peak”	Avg.	“Crisis peak”	
France	34.87	62.72	23.40	24.90	0.08	1.04	0.73
Germany	33.34	52.16	18.80	20.00	—	—	0.67
Greece	84.25	133.09	18.40	23.60	0.37	21.00	0.65
Ireland	14.07	64.97	16.10	20.50	0.11	6.99	0.58
Italy	95.46	100.22	19.40	21.40	0.27	3.99	0.61
Portugal	35.21	75.83	20.00	22.10	0.20	9.05	0.67
Spain	39.97	45.60	17.60	21.40	0.13	4.35	0.57
Avg.	48.17	76.37	19.10	21.99	0.22	7.74	0.64
Median	35.21	64.97	18.80	21.40	0.17	5.67	0.65

Note: Author’s calculations are based on OECD Statistics, Eurostat, ECSB, and Davies et al. (2009). “Gov. debt” refers to total general government net financial liabilities (avg 1990–2007); “Gov. Exp.” corresponds to government purchases in national accounts (avg 2000–07); “Sov spreads” correspond to the difference between interest rates of the given country and Germany for bonds of similar maturity (avg 2000–07). For a given country  $i$ , they are computed as  $(1 + r^i)/(1 + r^{\text{Ger}}) - 1$ . “Crisis Peak” refers to the maximum value observed during 2008–12 using data from Eurostat. “Gini wealth” are Gini wealth coefficients for 2000 from Davies, J., Sandström, S., Shorrocks, A., Wolff, E. 2009. The level and distribution of global household wealth. NBER Working Paper 15508, appendix V.

domestic default examined in this section. The framework also predicts that spreads and the probability of default at higher when government outlays are higher.

The model on which this section is based follows the work of [D'Erasmus and Mendoza \(2013\)](#) and [D'Erasmus and Mendoza \(2014\)](#). The goal is to analyze the optimal default and borrowing decisions of a government unable to commit to repay debt placed with domestic creditors in an environment with incomplete markets. The key difference with standard external default models is in that the payoff of the government includes the utility of agents who are government bondholders, as well as nonbondholders. As a result, the main incentive to default is to redistribute resources across these two groups of agents.<sup>al</sup> Default is assumed to be nondiscriminatory (ie, the government cannot discriminate across any of its creditors when it defaults). There is explicit aggregate risk in the form of shocks to government outlays, and also implicit in the form of default risk.

Government bondholders and nonbondholders are modeled with identical CRRA preferences. Default is useful as a vehicle for redistribution across the two, but it also has costs. We explore the case in which there is an exogenous cost in terms of disposable income, similar to the exogenous income costs typical of the external default literature. But there can also be endogenous costs related to the reduced ability to smooth taxation and provide liquidity, and, in long-horizon environments, to the loss of access to government bonds as the asset used for self-insurance.

In this framework, public debt is sustainable when it is supported as part of the equilibrium without commitment. This implies that a particular price and stock of defaultable government bonds are sustainable only if they are consistent with the optimal debt-issuance and default plans of the government, the optimal savings plans of private agents, and the bond market-clearing condition. Sustainable debt thus factors in the risk of default, which implies paying positive risk premia on current debt issuance when future default is possible. Debt becomes unsustainable when default becomes the optimal choice *ex post*, or is unsustainable *ex ante* for debt levels that cannot be issued at a positive price (ie, when a given debt issued at  $t$  entails a 100% probability of default at  $t+1$ ).

This model is not necessarily limited to a situation in which private agents hold directly government debt. It is also applicable to situations in which pension funds hold government bonds and retirement accounts are structured as individual accounts, or where the financial sector holds domestic sovereign debt and households hold claims

<sup>al</sup> The model should not be viewed as focusing necessarily on redistribution across the poor and rich, but across agents that hold public debt and those who do not. The two are correlated but need not be the same. For instance, [Hall and Sargent \(2014\)](#) describe how the domestic default after the US Revolutionary War implied redistribution from bondholders in the South to nonbondholders in the North, with both groups generally wealthy. Similarly, in the European debt crisis, a Greek default can be viewed as redistributing from German tax payers to Greek households and not according to their overall wealth.

on the financial sector. Moreover, the general principle that domestic default is driven by government's distributional incentives traded off against exogenous or endogenous default costs applies to more complex environments that include implicit (or contingent) government liabilities due, for example, to expected funding shortfalls in entitlement programs. Default in these cases can take the form of reforms like increasing retirement eligibility ages or imposing income ceilings in eligibility for programs like medicare. For simplicity, however, the quantitative analysis conducted later in this section is calibrated to data that includes only explicit government debt (total general government net financial liabilities as defined in Eurostat).

We develop the argument using the two-period model proposed by [D'Erasmus and Mendoza \(2013\)](#), which highlights the importance of the distributional incentives of default at the expense of setting aside endogenous default costs due to the loss of access to self-insurance assets. [D'Erasmus and Mendoza \(2014\)](#) and [Dovis et al. \(2014\)](#) study the role of distributional incentives to default on domestic debt, and the use of public debt in infinite horizon models with domestic agent heterogeneity. The two differ in that [Dovis et al. \(2014\)](#) assume complete domestic asset markets, which removes the role of public debt as providing social insurance for domestic agents. In addition, they focus on the solution to the Ramsey problem, in which default is not observed along the equilibrium path. D'Erasmus and Mendoza study an economy with incomplete markets, which turns the loss of the vehicle for self-insurance, and the severity of the associated liquidity constraints, into an endogenous cost of default that plays a central role in their results. They also solve for Markov-perfect equilibria in which default is possible as an equilibrium outcome.

The model discussed here is also related to the literature that analyzes the role of public debt as a self-insurance mechanism and a tool for altering consumption dispersion in heterogeneous-agents models without default (eg, [Aiyagari and McGrattan \(1998\)](#), [Golosov and Sargent \(2012\)](#), [Azzimonti et al. \(2014\)](#), [Floden \(2001\)](#), [Heathcote \(2005\)](#), and [Aiyagari et al. \(2002\)](#)). A recent article by [Pouzo and Presno \(2014\)](#) introduces the possibility of default into models in this class. They study optimal taxation and public debt dynamics in a representative-agent setup similar to [Aiyagari et al. \(2002\)](#) but allowing for default and renegotiation.

The recent interest in domestic sovereign default also includes a strand of literature focusing on the consequences of default on domestic agents, its relation with secondary markets, discriminatory vs nondiscriminatory default, and the role of domestic debt in providing liquidity to the corporate sector (see [Guembel and Sussman, 2009](#), [Broner et al., 2010](#), [Broner and Ventura, 2011](#), [Gennaioli et al., 2014](#), [Basu, 2009](#), [Brutti, 2011](#), [Mengus, 2014](#), and [Di Casola and Sichlimiris, 2014](#)). There are also some recent studies motivated by the 2008 financial crisis that focus on the interaction between sovereign debt and domestic financial institutions such as [Sosa-Padilla \(2012\)](#), [Bocola \(2014\)](#), [Boz et al. \(2014\)](#), and [Perez \(2015\)](#).

#### 4.1 Model Structure

Consider a two-period economy  $t = 0, 1$  inhabited by a continuum of agents with aggregate unit measure. All agents have the same preferences, which are given by:

$$u(c_0) + \beta E[u(c_1)], \quad u(c) = \frac{c^{1-\sigma}}{1-\sigma}$$

where  $\beta \in (0, 1)$  is the discount factor and  $c_t$  for  $t = 0, 1$  is individual consumption. The utility function  $u(\cdot)$  takes the standard CRRA form.

All agents receive a nonstochastic endowment  $y$  each period and pay lump-sum taxes  $\tau_t$ , which are uniform across agents. Taxes and newly issued government debt are used to pay for government consumption  $g_t$  and repayment of outstanding government debt. The (exogenous) initial supply of outstanding government bonds at  $t = 0$  is denoted  $B_0$ . Agents differ in their initial wealth position, which is characterized by their holdings of government debt at the beginning of the first period.<sup>am</sup> Given  $B_0$ , the initial wealth distribution is defined by a fraction  $\gamma$  of households who are the  $L$ -type individuals with initial bond holdings  $b_0^L$ , and a fraction  $(1 - \gamma)$  who are the  $H$ -types and hold  $b_0^H$ , where  $b_0^H = \frac{B_0 - \gamma b_0^L}{1 - \gamma} \geq b_0^L \geq 0$ . This value of  $b_0^H$  is the amount consistent with market-clearing in the government bond market at  $t = 0$ , since we are assuming that the debt is entirely held by domestic agents. The initial distribution of wealth is exogenous, but the distribution at the beginning of the second period is endogenously determined by the agents' savings choices of the first period.

The budget constraints of the two types of households in the first period are given by:

$$c_0^i + q_0 b_1^i = y + b_0^i - \tau_0 \quad \text{for } i = L, H. \quad (10)$$

Agents collect the payout on their initial holdings of government debt ( $b_0^i$ ), receive endowment income  $y$ , and pay lump-sum taxes  $\tau_0$ . These net-of-tax resources are used to pay for consumption and purchases of new government bonds  $b_1^i$ . Agents are not allowed to take short positions in government bonds, which is equivalent to assuming that bond purchases must satisfy the familiar no-borrowing condition often used in heterogeneous-agents models:  $b_1^i \geq 0$ .

The budget constraints in the second period differ depending on whether the government defaults or not. If the government repays, the budget constraints take the standard form:

$$c_1^i = y + b_1^i - \tau_1 \quad \text{for } i = L, H. \quad (11)$$

<sup>am</sup> [Andreasen et al. \(2011\)](#), [Ferriere \(2014\)](#), and [Jeon and Kabukcuoglu \(2014\)](#) study environments in which domestic income heterogeneity plays a central role in the determination of external defaults.

If the government defaults, there is no repayment on the outstanding debt, and the agents' budget constraints are:

$$c_1^i = (1 - \phi(g_1))\gamma - \tau_1 \quad \text{for } i = L, H. \quad (12)$$

As is standard in the external sovereign default literature, we allow for default to impose an exogenous cost that reduces income by a fraction  $\phi$ . This cost is often modeled as a function of the realization of a stochastic endowment income, but since income is constant in this setup, we model it as a function of the realization of government expenditures in the second period  $g_1$ . In particular, the cost is a nonincreasing, step-wise function:  $\phi(g_1) \geq 0$ , with  $\phi'(g_1) \leq 0$  for  $g_1 \leq \bar{g}_1$ ,  $\phi'(g_1) = 0$  otherwise, and  $\phi''(g_1) = 0$ . Hence,  $\bar{g}_1$  is a threshold high value of  $g_1$  above which the marginal cost of default is zero. This formulation is analogous to the step-wise default cost as a function of income proposed by [Arellano \(2008\)](#) and now widely used in the external default literature, and it also captures the idea of asymmetric costs of tax collection (see [Barro, 1979](#) and [Calvo, 1988](#)). Note, however, that for the model to support equilibria with debt under a utilitarian government all we need is  $\phi(g_1) > 0$ . The additional structure is useful for the quantitative analysis and for making it easier to compare the model with the standard external default models.<sup>an</sup>

At the beginning of  $t = 0$ , the government has outstanding debt  $B_0$  and can issue one-period, nonstate contingent discount bonds  $B_1 \in \mathcal{B} \equiv [0, \infty)$  at the price  $q_0 \geq 0$ . Each period it collects lump-sum revenues  $\tau_t$  and pays for outlays  $g_t$ . Since  $g_0$  is known at the beginning of the first period, the relevant uncertainty with respect to government expenditures is for  $g_1$ , which follows a log-normal distribution  $N((1 - \rho_g)\mu_g + \rho_g \ln(g_0), \frac{\sigma_g^2}{(1 - \rho_g^2)})$ .<sup>ao</sup> We do not restrict the sign of  $\tau_t$ , so  $\tau_t < 0$  represents lump-sum transfers.<sup>ap</sup>

<sup>an</sup> In external default models, the nonlinear cost makes default more costly in “good” states, which alters default incentives to make default more frequent in “bad” states, and it also contributes to support higher debt levels.

<sup>ao</sup> This is similar to an AR(1) process and allows us to control the correlation between  $g_0$  and  $g_1$  via  $\rho_g$ , the mean of the shock via  $\mu_g$  and the variance of the unpredicted portion via  $\sigma_g^2$ . Note that if  $\ln(g_0) = \mu_g$ ,

$$g_1 \sim N(\mu_g, \frac{\sigma_g^2}{(1 - \rho_g^2)}).$$

<sup>ap</sup> Some studies in the sovereign debt literature have examined models that include tax and expenditure policies, as well as settings with foreign and domestic lenders, but always maintaining the representative agent assumption (eg, [Cuadra et al., 2010](#); [Vasishtha, 2010](#)). More recently [Dias et al. \(2012\)](#) examined the benefits of debt relief from the perspective of a *global* social planner with utilitarian preferences. Also in this literature, [Aguiar and Amador \(2013\)](#) analyze the interaction between public debt, taxes and default risk and [Lorenzoni and Werning \(2013\)](#) study the dynamics of debt and interest rates in a model where default is driven by insolvency and debt issuance driven by a fiscal reaction function.

At equilibrium, the price of debt issued in the first period must be such that the government bond market clears:

$$B_t = \gamma b_t^L + (1 - \gamma) b_t^H \quad \text{for } t = 0, 1. \quad (13)$$

This condition is satisfied by construction in period 0. In period 1, however, the price moves endogenously to clear the market.

The government has the option to default at  $t = 1$ . The default decision is denoted by  $d_1 \in \{0, 1\}$  where  $d_1 = 0$  implies repayment. The government evaluates the values of repayment and default using welfare weight  $\omega$  for  $L$ -type agents and  $1 - \omega$  for  $H$ -type agents. This specification encompasses cases in which, for political reasons for example, the welfare weights are biased toward a particular type so  $\omega \neq \gamma$  or the case in which the government acts as a utilitarian social planner in which  $\omega = \gamma$ .<sup>aq</sup> At the moment of default, the government evaluates welfare using the following function:

$$\omega u(c_1^L) + (1 - \omega) u(c_1^H).$$

At  $t = 0$ , the government budget constraint is

$$\tau_0 = g_0 + B_0 - q_0 B_1. \quad (14)$$

The level of taxes in period 1 is determined after the default decision. If the government repays, taxes are set to satisfy the following government budget constraint:

$$\tau_1^{d_1=0} = g_1 + B_1. \quad (15)$$

Notice that, since this is a two-period model, equilibrium requires that there are no outstanding assets at the end of period 1 (ie,  $b_2^i = B_2 = 0$  and  $q_1 = 0$ ). If the government defaults, taxes are simply set to pay for government purchases:

$$\tau_1^{d_1=1} = g_1. \quad (16)$$

The analysis of the model's equilibrium proceeds in three stages. First, characterize the households' optimal savings problem and determine their payoff (or value) functions, taking as given the government debt, taxes and default decision. Second, study how optimal government taxes and the default decision are determined. Third, examine the optimal choice of debt issuance that internalizes the outcomes of the first two stages. We characterize these problems as functions of  $B_1$ ,  $g_1$ ,  $\gamma$  and  $\omega$ , keeping the initial conditions  $(g_0, B_0, b_0^L)$  as exogenous parameters. Hence, for given  $\gamma$  and  $\omega$ , we can index the value

<sup>aq</sup> This relates to the literature on political economy and sovereign default, which largely focuses on external default (eg, Amador, 2003, Dixit and Londregan, 2000, D'Erasmus, 2011, Guembel and Sussman, 2009, Hatchondo et al., 2009, and Tabellini, 1991), but includes studies like those of Alesina and Tabellini (1990) and Aghion and Bolton (1990) that focus on political economy aspects of government debt in a closed economy, and the work of Aguiar et al. (2013) on optimal policy in a monetary union subject to self-fulfilling debt crises.

of a household as of  $t = 0$ , before  $g_1$  is realized, as a function of  $\{B_1\}$ . Given this, the level of taxes  $\tau_0$  is determined by the government budget constraint once the equilibrium bond price  $q_0$  is set. Bond prices are forward looking and depend on the default decision of the government in period 1, which will be given by the decision rule  $d(B_1, g_1, \gamma, \omega)$ .

## 4.2 Optimization Problems and Equilibrium

Given  $B_1$ ,  $\gamma$ , and  $\omega$  a household with initial debt holdings  $b_0^i$  for  $i = L, H$  chooses  $b_1^i$  by solving this maximization problem:

$$v^i(B_1, \gamma, \omega) = \max_{b_1^i} \left\{ u(\gamma + b_0^i - q_0 b_1^i - \tau_0) + \beta E_{g_1} \left[ (1 - d_1) u(\gamma + b_1^i - \tau_1^{d_1=0}) + d_1 u(\gamma(1 - \phi(g_1)) - \tau_1^{d_1=1}) \right] \right\}, \quad (17)$$

subject to  $b_1^i \geq 0$ . The term  $E_{g_1}[\cdot]$  represents the expected payoff across the repayment and default states in period 1. Notice in particular that the payoff in case of default does not depend on the level of individual debt holdings ( $b_1^i$ ), reflecting the fact that the government cannot discriminate across households when it defaults.

A key feature of the above problem is that agents take into account the possibility of default in choosing their optimal bond holdings. The first-order condition, evaluated at the equilibrium level of taxes, yields this Euler equation:

$$u'(c_0^i) \geq \beta(1/q_0) E_{g_1} \left[ u'(\gamma - g_1 + b_1^i - B_1)(1 - d_1(B_1, g_1, \gamma)) \right], = \text{if } b_1^i > 0 \quad (18)$$

In states in which, given  $(B_1, \gamma, \omega)$ , the value of  $g_1$  is such that the government chooses to default ( $d_1(B_1, g_1, \gamma, \omega) = 1$ ), the marginal benefit of an extra unit of debt is zero.<sup>ar</sup> Thus, conditional on  $B_1$ , a larger default set (ie, a larger set of values of  $g_1$  such that the government defaults), implies that the expected marginal benefit of an extra unit of savings decreases. As a result, everything else equal, a higher default probability results in a lower demand for government bonds, a lower equilibrium bond price, and higher taxes. This has important redistributive implications, because when choosing the optimal debt issuance, the government will internalize how, by altering the bond supply, it affects the expected probability of default and the equilibrium bond prices. Note also that from the agents' perspective, the default choice  $d_1(B_1, g_1, \gamma, \omega)$  is independent of  $b_1^i$ .

The above Euler equation is useful for highlighting some important properties of the equilibrium pricing function of bonds:

1. The premium over a world risk-free rate (defined as  $q_0/\beta$ , where  $1/\beta$  can be viewed as a hypothetical opportunity cost of funds for an investor, analogous to the role played by the world interest rate in the standard external default model) generally differs from the default probability for two reasons: (a) agents are risk averse, and (b) in the repayment state, agents face higher taxes, whereas in the standard model investors are not

<sup>ar</sup> Utility in the case of default equals  $u(\gamma(1 - \phi(g_1)) - g_1)$ , which is independent of  $b_1^i$ .



- taxed to repay the debt. For agents with positive bond holdings, the above optimality condition implies that the premium over the risk-free rate is  $E_{g_1} [u'(\gamma - g_1 + b_1^i - B_1)(1 - d_1)/u'(c_0^i)]$ .
2. If the Euler equation for  $H$ -type agents holds with equality (ie,  $b_1^H > 0$ ) and  $L$ -type agents are *credit constrained* (ie,  $b_1^L = 0$ ), the  $H$ -type agents are the marginal investor and their Euler equation can be used to derive the equilibrium price.
  3. For sufficiently high values of  $B_1, \gamma$  or  $1 - \omega$  the government chooses  $d_1(B_1, g_1, \gamma, \omega) = 1$  for all  $g_1$ . In these cases, the expected marginal benefit of purchasing government bonds vanishes from the agents' Euler equation, and hence the equilibrium for that  $B_1$  does not exist, since agents would not be willing to buy debt at any finite price.<sup>as</sup> These values of  $B_1$  are therefore unsustainable ex ante (ie, these debt levels cannot be sold at a positive price).

The equilibrium bond pricing functions  $q_0(B_1, \gamma, \omega)$ , which returns bond prices for which, as long as consumption for all agents is nonnegative and the default probability of the government is less than 1, the following market-clearing condition holds:

$$B_1 = \gamma b_1^L(B_1, \gamma, \omega) + (1 - \gamma) b_1^H(B_1, \gamma, \omega), \quad (19)$$

where  $B_1$  in the left-hand-side of this expression represents the public bonds supply, and the right-hand-side is the aggregate government bond demand.

As explained earlier, we analyze the government's problem following a backward induction strategy by studying first the default decision problem in the final period  $t = 1$ , followed by the optimal debt issuance choice at  $t = 0$ .

#### 4.2.1 Government Default Decision at $t = 1$

At  $t = 1$ , the government chooses to default or not by solving this optimization problem:

$$\max_{d \in \{0, 1\}} \{W_1^{d=0}(B_1, g_1, \gamma, \omega), W_1^{d=1}(g_1, \gamma, \omega)\}, \quad (20)$$

where  $W_1^{d=0}(B_1, g_1, \gamma, \omega)$  and  $W_1^{d=1}(B_1, g_1, \gamma, \omega)$  denote the values of the social welfare function at the beginning of period 1 in the case of repayment and default, respectively. Using the government budget constraint to substitute for  $\tau_1^{d=0}$  and  $\tau_1^{d=1}$ , the government's payoffs can be expressed as:

$$W_1^{d=0}(B_1, g_1, \gamma, \omega) = \omega u(\gamma - g_1 + b_1^L - B_1) + (1 - \omega) u(\gamma - g_1 + b_1^H - B_1) \quad (21)$$

and

$$W_1^{d=1}(g_1, \gamma, \omega) = u(\gamma(1 - \phi(g_1)) - g_1). \quad (22)$$

<sup>as</sup> This result is similar to the result in standard models of external default showing that rationing emerges at  $t$  for debt levels so high that the government would choose default at all possible income realizations in  $t + 1$ .

Combining these payoff functions, it follows that the government defaults if this condition holds:

$$\begin{aligned} & \omega \left[ u(\gamma - g_1 + \overbrace{(b_1^L - B_1)}^{\leq 0}) - u(\gamma(1 - \phi(g_1)) - g_1) \right] \\ & + (1 - \omega) \left[ u(\gamma - g_1 + \overbrace{(b_1^H - B_1)}^{\geq 0}) - u(\gamma(1 - \phi(g_1)) - g_1) \right] \leq 0 \end{aligned} \quad (23)$$

Notice that all agents forego  $g_1$  of their income to government absorption regardless of the default choice. Moreover, debt repayment reduces consumption and welfare of  $L$  types and rises them for  $H$  types, whereas default implies the same consumption and utility for both types of agents.

The distributional effects of a default are implicit in condition (23). Given that debt repayment affects the cash-in-hand for consumption of  $L$  and  $H$  types according to  $(b_1^L - B_1) \leq 0$  and  $(b_1^H - B_1) \geq 0$ , respectively, it follows that, for a given  $B_1$ , the payoff under repayment allocates (weakly) lower welfare to  $L$  agents and higher to  $H$  agents, and that the gap between the two is larger the larger is  $B_1$ . Moreover, since the default payoffs are the same for both types of agents, this is also true of the *difference* in welfare under repayment vs default: It is higher for  $H$  agents than for  $L$  agents and it gets larger as  $B_1$  rises. To induce default, however, it is necessary not only that  $L$  agents have a smaller difference in the payoffs of repayment vs default, but that the difference is negative (ie, they must attain lower welfare under repayment than under default), which requires  $B_1 > b_1^L + \gamma\phi(g_1)$ . This also implies that taxes under repayment need to be necessarily larger than under default, since  $\tau_1^{d=0} - \tau_1^{d=1} = B_1$ .

We can illustrate the distributional mechanism driving the default decision by comparing the utility levels associated with the consumption allocations of the default and repayment states with those that would be socially efficient. To this end, it is helpful to express the values of hypothetical optimal private debt holdings in period 1 as  $b_1^L = B_1 - \epsilon$  and  $b_1^H(\gamma) = B_1 + \frac{\gamma}{1-\gamma}\epsilon$ , for some  $\epsilon \in [0, B_1]$ . That is,  $\epsilon$  represents a given hypothetical decentralized allocation of debt holdings across agents.<sup>at</sup> Consumption allocations under repayment would therefore be  $c_1^L(\epsilon) = \gamma - g_1 - \epsilon$  and  $c_1^H(\gamma, \epsilon) = \gamma - g_1 + \frac{\gamma}{1-\gamma}\epsilon$ , so  $\epsilon$  also determines the decentralized consumption dispersion.

<sup>at</sup> We take  $\epsilon$  as given at this point because it helps us explain the intuition behind the distributional default incentives of the government, but  $\epsilon$  is an equilibrium outcome solved for later on. Also,  $\epsilon$  must be non-negative, otherwise  $H$  types would be the nonbondholders.

The government payoff under repayment can be rewritten as:

$$W^{d=0}(\epsilon, g_1, \gamma, \omega) = \omega u(\gamma - g_1 + \epsilon) + (1 - \omega) u\left(\gamma - g_1 + \frac{\gamma}{1 - \gamma} \epsilon\right).$$

The efficient dispersion of consumption that the social planner would choose is characterized by the value of  $\epsilon^{SP}$  that maximizes social welfare under repayment. In the particular case of  $\omega = \gamma$  (ie, when the government is utilitarian and uses welfare weights that match the wealth distribution),  $\epsilon^{SP}$  satisfies this first-order condition:

$$u'\left(\gamma - g_1 + \frac{\gamma}{1 - \gamma} \epsilon^{SP}\right) = u'(\gamma - g_1 - \epsilon^{SP}). \quad (24)$$

Hence, the efficient allocations are characterized by zero consumption dispersion, because equal marginal utilities imply  $c^{L,SP} = c^{H,SP} = \gamma - g_1$ , which is attained with  $\epsilon^{SP} = 0$ .

Continuing under the utilitarian government assumption ( $\omega = \gamma$ ), consider now the government's default decision when default is costless ( $\phi(g_1) = 0$ ). Given that the only policy instruments the government can use, other than the default decision, are nonstate contingent debt and lump-sum taxes, it is straightforward to show that default will always be optimal. This is because default supports the socially efficient allocations in the decentralized equilibrium (ie, it yields zero consumption dispersion with consumption levels  $c^L = c^H = \gamma - g_1$ ). This outcome is invariant to the values of  $B_1$ ,  $g_1$ ,  $\gamma$  and  $\epsilon$  (over their relevant ranges). This result also implies, however, that in this model a utilitarian government without default costs can never sustain debt.

The above scenario is depicted in Fig. 14, which plots the social welfare function under repayment as a function of  $\epsilon$  as the bell-shaped curve, and the social welfare under default (which is independent of  $\epsilon$ ), as the black dashed line. Clearly, the maximum welfare under repayment is attained when  $\epsilon = 0$  which is also the efficient amount of consumption dispersion  $\epsilon^{SP}$ . Moreover, since the relevant range of consumption dispersion is  $\epsilon > 0$ , welfare under repayment is decreasing in  $\epsilon$  over the relevant range.

These results can be summarized as follows:

**Result 1.** *If  $\phi(g_1) = 0$  for all  $g_1$  and  $\omega = \gamma$ , then for any  $\gamma \in (0, 1)$  and any  $(B_1, g_1)$ , the social value of repayment  $W^{d=0}(B_1, g_1, \gamma)$  is decreasing in  $\epsilon$  and attains its maximum at the socially efficient point  $\epsilon^{SP} = 0$  (ie, when welfare equals  $u(\gamma - g_1)$ ). Hence, default is always optimal for any given decentralized consumption dispersion  $\epsilon > 0$ .*

The outcome is very different when default is costly. With  $\phi(g_1) > 0$ , default still yields zero consumption dispersion, but at lower levels of consumption and therefore utility,

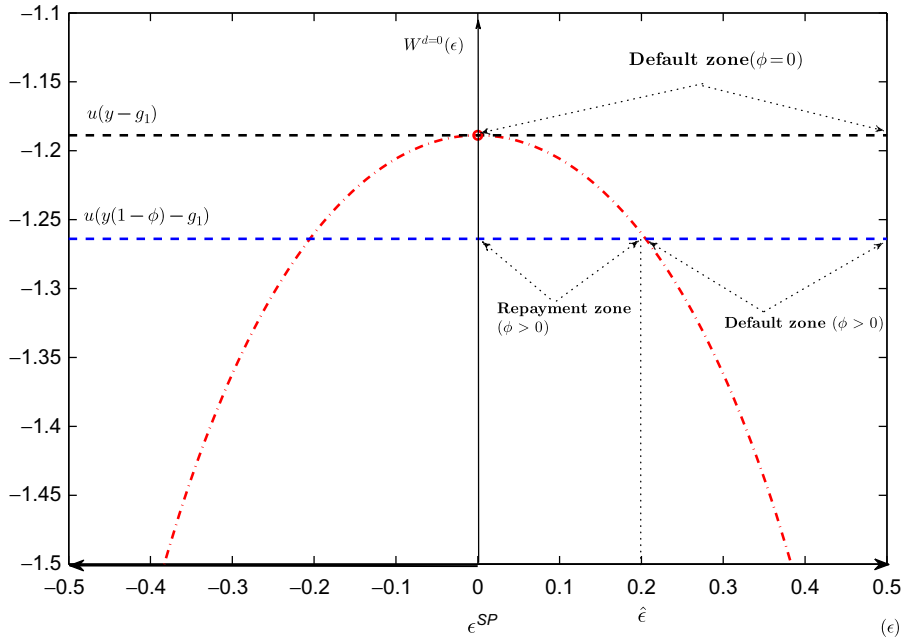


Fig. 14 Default decision and consumption dispersion.

since consumption allocations under default are  $c^L = c^H = (1 - \phi(g_1))\gamma - g_1$ . This does not alter the result that the social optimum is  $\epsilon^{SP} = 0$ , but what changes is that default can no longer support the socially efficient consumption allocations. Instead, there is now a threshold amount of consumption dispersion in the decentralized equilibrium,  $\hat{\epsilon}(\gamma)$ , which varies with  $\gamma$  and such that for  $\epsilon \geq \hat{\epsilon}(\gamma)$  default is again optimal, but for lower  $\epsilon$  repayment is now optimal. This is because when  $\epsilon$  is below the threshold, repayment produces a level of social welfare higher than under default.

Fig. 14 also illustrates this scenario. The default cost lowers the common level of utility of both types of agents, and hence of social welfare, in the default state (shown in the figure as the blue dashed line), and  $\hat{\epsilon}(\gamma)$  is determined where social welfare under repayment and under default intersect. If the decentralized consumption dispersion with the debt market functioning ( $\epsilon$ ) is between 0 and less than  $\hat{\epsilon}(\gamma)$  then it is optimal for the government to repay. Intuitively, if consumption dispersion is not too large, the government prefers to repay because the income cost imposed on agents to remove consumption dispersion under default is too large. Moreover, as  $\gamma$  rises the domain of  $W_1^{d=0}$  narrows, and thus  $\hat{\epsilon}(\gamma)$  falls and the interval of decentralized consumption dispersions that supports repayment narrows. This is natural because a higher  $\gamma$  causes the planner to weight more L-types in the social welfare function, which are agents with weakly lower utility in the repayment state.

These results can be summarized as follows:

**Result 2.** *If  $\phi(g_1) > 0$ , then for any  $\gamma \in (0, 1)$  and any  $(B_1, g_1)$ , there is a threshold value of consumption dispersion  $\hat{\epsilon}(\gamma)$  such that the payoffs of repayment and default are equal:  $W^{d=0}(B_1, g_1, \gamma) = u(\gamma(1 - \phi(g_1)) - g_1)$ . The government repays if  $\epsilon < \hat{\epsilon}(\gamma)$  and defaults otherwise. Moreover,  $\hat{\epsilon}(\gamma)$  is decreasing in  $\gamma$ .*

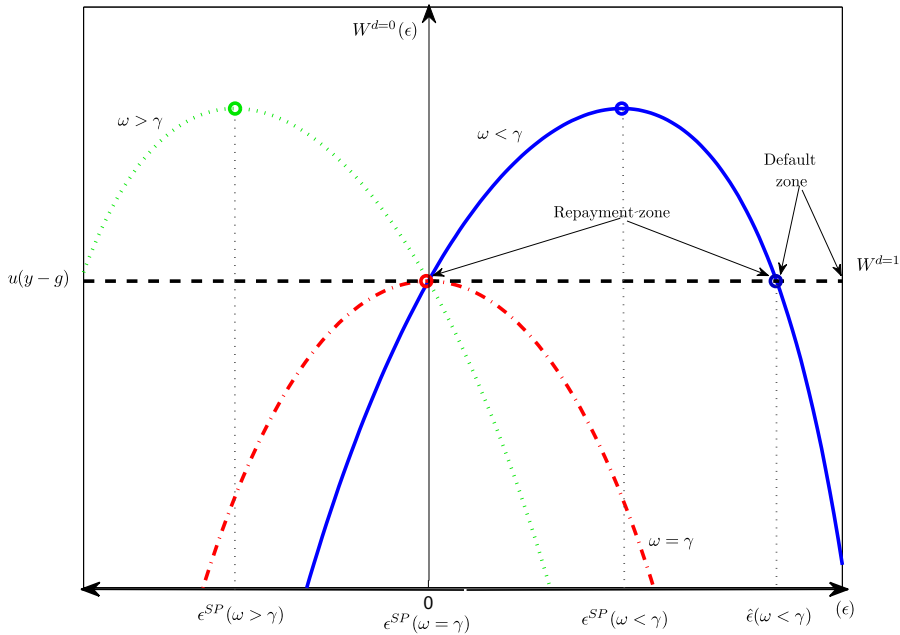
Introducing a bias in the welfare function of the government (relative to utilitarian social welfare) can result in repayment being optimal even without default costs, which provides for an alternative way to sustain debt subject to default risk. Assuming  $\phi(g_1) = 0$ , there are two possible scenarios depending on the relative size of  $\gamma$  and  $\omega$ . First, if  $\omega > \gamma$ , the planner again always chooses default as in the setup with  $\omega = \gamma$ . This is because for any  $\epsilon > 0$ , the decentralized consumption allocations feature  $c^H > c^L$ , while the planner's optimal consumption dispersion requires  $c^H \leq c^L$ , and hence  $\epsilon^{SP}$  cannot be implemented. Default brings the planner the closest it can get to the payoff associated with  $\epsilon^{SP}$  and hence it is always chosen.

In the second scenario  $\omega < \gamma$ , which means that the government's bias assigns more (less) weight to  $H$  ( $L$ ) types than the fraction of each type of agents that actually exists. In this case, the model can support equilibria with debt even without default costs. In particular, there is a threshold consumption dispersion  $\hat{\epsilon}$  such that default is optimal for  $\epsilon \geq \hat{\epsilon}$ , where  $\hat{\epsilon}$  is the value of  $\epsilon$  at which  $W_1^{d=0}(\epsilon, g_1, \gamma, \omega)$  and  $W_1^{d=1}(g_1)$  intersect. For  $\epsilon < \hat{\epsilon}$ , repayment is preferable because  $W_1^{d=0}(\epsilon, g_1, \gamma, \omega) > W_1^{d=0}(g_1)$ . Thus, without default costs, equilibria for which repayment is optimal require two conditions: (a) that the government's bias favors bond holders ( $\omega < \gamma$ ), and (b) that the debt holdings chosen by private agents do not produce consumption dispersion in excess of  $\hat{\epsilon}$ .

Fig. 15 illustrates the outcomes just described. This figure plots  $W_1^{d=0}(\epsilon, g_1, \gamma, \omega)$  for  $\omega \gtrless \gamma$ . The planner's default payoff and the values of  $\epsilon^{SP}$  for  $\omega \gtrless \gamma$  are also identified in the plot. The vertical intercept of  $W_1^{d=0}(\epsilon, g_1, \gamma, \omega)$  is always  $W_1^{d=1}(g_1)$  for any values of  $\omega$  and  $\gamma$ , because when  $\epsilon = 0$  there is zero consumption dispersion and that is also the outcome under default. In addition, the bell-shaped form of  $W_1^{d=0}(\epsilon, g_1, \gamma, \omega)$  follows from  $u'(\cdot) > 0, u''(\cdot) < 0$ .<sup>au</sup>

Take first the case with  $\omega > \gamma$ . In this case, the planner's payoff under repayment is the dotted bell curve. Here,  $\epsilon^{SP} < 0$ , because the optimality condition implies that the planner's optimal choice features  $c^L > c^H$ . Since default is the only instrument available to the government, however, these consumption allocations are not feasible, and by choosing

<sup>au</sup> Note in particular that  $\frac{\partial W_1^{d=0}(\epsilon, g_1, \gamma, \omega)}{\partial \epsilon} \gtrless 0 \iff \frac{u'(c^H(\epsilon))}{u'(c^L(\epsilon))} \gtrless \left(\frac{\omega}{\gamma}\right) \left(\frac{1-\gamma}{1-\omega}\right)$ . Hence, the planner's payoff is increasing (decreasing) at values of  $\epsilon$  that support sufficiently low (high) consumption dispersion so that  $\frac{u'(c^H(\epsilon))}{u'(c^L(\epsilon))}$  is above (below)  $\left(\frac{\omega}{\gamma}\right) \left(\frac{1-\gamma}{1-\omega}\right)$ .



**Fig. 15** Default decision with nonutilitarian planner ( $\phi = 0$ ).

default the government attains  $W^{d=1}$ , which is the highest feasible government payoff for any  $\epsilon \geq 0$ . In contrast, in the case with  $\omega = \gamma$ , for which the planner's payoff function is the dashed bell curve, the planner chooses  $\epsilon^{SP} = 0$ , and default attains exactly the same payoff, so default is chosen. In short, if  $\omega \geq \gamma$ , the government always defaults for any decentralized distribution of debt holdings represented by  $\epsilon > 0$ , and thus equilibria with debt cannot be supported.

When  $\omega < \gamma$ , the planner's payoff is the continuous curve. The intersection of the downward-sloping segment of  $W_1^{d=0}(\epsilon, g_1, \gamma, \omega)$  with  $W^{d=1}$  determines the default threshold  $\hat{\epsilon}$  such that default is optimal only in the *default zone* where  $\epsilon \geq \hat{\epsilon}$ . Default is still a second-best policy for the planner, because with it the planner cannot attain  $W^{d=0}(\epsilon^{SP})$ , it just gets the closest it can get. In contrast, the choice of repayment is preferable in the *repayment zone* where  $\epsilon < \hat{\epsilon}$ , because in this zone  $W_1^{d=0}(\epsilon, g_1, \gamma, \omega) > W^{d=1}(g_1)$ .

Adding default costs to this political bias setup ( $\phi(g_1) > 0$ ) makes it possible to support repayment equilibria even when  $\omega \geq \gamma$ . As Fig. 16 shows, with default costs there are threshold values of consumption dispersion,  $\hat{\epsilon}$ , separating repayment from default zones for  $\omega \leq \gamma$ .

It is also evident in Fig. 16 that the range of values of  $\epsilon$  for which repayment is chosen widens as  $\gamma$  rises relative to  $\omega$ . Thus, when default is costly, equilibria with repayment require only the condition that the debt holdings chosen by private agents, which are implicit in  $\epsilon$ , do not produce consumption dispersion larger than the value of  $\hat{\epsilon}$  associated

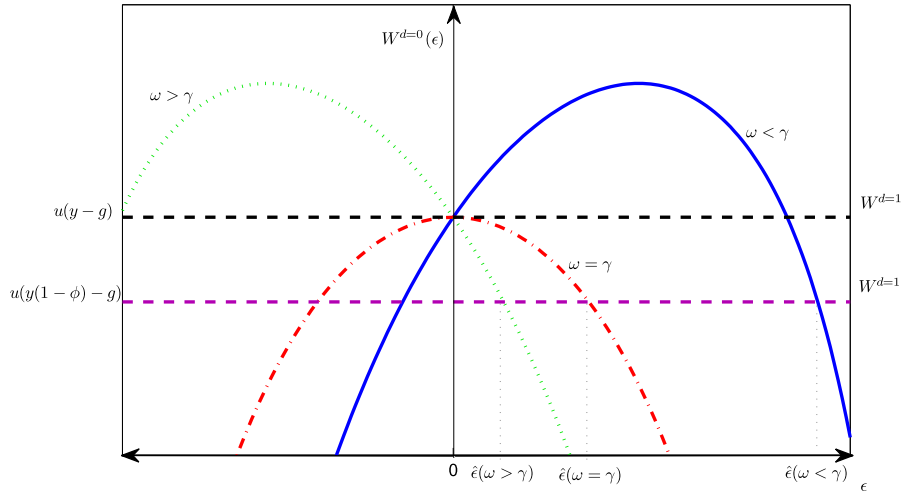


Fig. 16 Default decision with nonutilitarian planner when  $\phi(g_1) > 0$ .

with a given  $(\omega, \gamma)$  pair. Intuitively, the consumption of  $H$ -type agents must not exceed that of  $L$ -type agents by more than what  $\hat{\epsilon}$  allows, because otherwise default is optimal.

The fact that a government biased in favor of bond holders can find it optimally to repay may seem unsurprising. As we argue later, however, in fact governments with this bias can be an endogenous outcome of majority voting if the fraction of agents that are nonbondholders is sufficiently large. This occurs when these agents are liquidity constrained (ie, hitting the no-borrowing constraint), because in this case they prefer that the government favors bondholders so that it can sustain higher debt levels because public debt provides them with liquidity.

#### 4.2.2 Government Debt Issuance Decision at $t = 0$

We are now in a position to study how the government chooses the optimal amount of debt to issue in the initial period. These are the model's predicted sustainable debt levels ex ante, some of which will be optimally defaulted on ex post, depending on the realization of  $g_1$  in the second period. Both the government and the private sector are aware of this, so the debt levels that can be issued at equilibrium in the first period are traded at prices that can carry a default risk premium, which will be the case if for a given debt stock there are some values of  $g_1$  for which default is the optimal choice in the second period.

The government's optimization problem is easier to understand if we first illustrate how public debt serves as a tool for altering consumption dispersion across agents both within a period and across periods. In particular, consumption dispersion in each period and repayment state is given by these conditions:

$$\begin{aligned}
c_0^H - c_0^L &= \frac{1}{1-\gamma} [B_0 - q_0(B_1, \gamma, \omega) B_1], \\
c_1^{H, d=0} - c_1^{L, d=0} &= \frac{1}{1-\gamma} B_1, \\
c_1^{H, d=1} - c_1^{L, d=1} &= 0.
\end{aligned}$$

These expressions make it clear that, given  $B_0$ , issuing at least some debt ( $B_1 > 0$ ) reduces consumption dispersion at  $t = 0$  compared with no debt ( $B_1 = 0$ ), but increases it at  $t = 1$  if the government repays (ie,  $d = 0$ ). Moreover, the use of debt as tool for redistribution of consumption at  $t = 0$  is hampered by a Laffer curve relationship just like the distortionary taxes of the previous section. In this case, it takes the form of the debt Laffer curve familiar from the external default literature, which is defined by the mapping from an amount of debt issued  $B_1$  to the resources the government acquires with that amount of borrowing,  $q_0(B_1, \gamma, \omega) B_1$ . This mapping behaves like a Laffer curve because higher debt issuance carries a higher default risk, which reduces the price of the debt. Near zero debt the default risk is also zero so higher debt increases resources for the government, at very high debt near the region at which debt is unsustainable ex ante, higher debt reduces resources because the price falls proportionally much more than the debt rises, and in between we obtain the bell-shaped Laffer curve relationship. It follows then from this Laffer curve that, starting from  $B_1 = 0$ , consumption dispersion at  $t = 0$  first falls as  $B_1$  increases, but there is a critical positive value of  $B_1$  beyond which it becomes an increasing function of debt.

At  $t = 0$ , the government chooses its debt policy internalizing the above consumption dispersion effects, including the debt Laffer curve affecting date-0 dispersion, and their implications for social welfare. Formally, the government chooses  $B_1$  so as to maximize the “indirect” social welfare function:

$$W_0(\gamma, \omega) = \max_{B_1} \{ \omega v^L(B_1, \gamma, \omega) + (1 - \omega) v^H(B_1, \gamma, \omega) \}. \quad (25)$$

where  $v^L$  and  $v^H$  are the private agents’ value functions obtained from solving the problems defined in the Bellman equation (17) taking into account the government budget constraints and the equilibrium pricing function of bonds.

Focusing on the case with utilitarian government ( $\omega = \gamma$ ), we can gain some intuition about the solution of this maximization problem from its first-order condition (assuming that the relevant functions are differentiable):

$$u'(c_0^H) = u'(c_0^L) + \frac{\eta}{q_0(B_1, \gamma, \omega)\gamma} \{ \beta E_{g_1} [\Delta d \Delta W_1] + \gamma \mu^L \}$$



where

$$\begin{aligned}\eta &\equiv q_0(B_1, \gamma, \omega) / (q'_0(B_1, \gamma, \omega) B_1) < 0, \\ \Delta d &\equiv d(B_1 + \delta, g_1, \gamma) - d(B_1, g_1, \gamma) \geq 0, \quad \text{for } \delta > 0 \text{ small,} \\ \Delta W_1 &\equiv W_1^{d=1}(g_1, \gamma) - W_1^{d=0}(B_1, g_1, \gamma) \geq 0, \\ \mu^L &\equiv q_0(B_1, \gamma, \omega) u'(c_0^L) - \beta E_{g_1} [(1 - d^1) u'(c_1^L)] > 0.\end{aligned}$$

In these expressions,  $\eta$  is the price elasticity of the demand for government bonds,  $\Delta d \Delta W_1$  represents the marginal distributional benefit of a default, and  $\mu^L$  is the shadow value of the borrowing constraint when it binds for  $L$ -type agents.

If both types of agents could be unconstrained in their savings decisions, so that  $\mu_L = 0$ , and if there is no change in the risk of default (or assuming commitment to remove default risk entirely), so that  $E_{g_1}[\Delta d \Delta W_1] = 0$ , then the optimality condition simplifies to:

$$u'(c_0^H) = u'(c_0^L).$$

Hence, in this case the social planner would want to issue debt so as to equalize marginal utilities of consumption across agents at date 0, which requires simply setting  $B_1$  to satisfy  $q_0(B_1, \gamma, \omega) B_1 = B_0$ . If it is the case that  $L$ -types are constrained (ie,  $\mu_L > 0$ ), and still assuming no change in default risk or a government committed to repay, the optimality condition becomes:

$$u'(c_0^H) = u'(c_0^L) + \frac{\eta \mu^L}{q_0(B_1, \gamma, \omega)}.$$

Since  $\eta < 0$ , this result implies  $c_0^L < c_0^H$ , because  $u'(c_0^L) > u'(c_0^H)$ . Thus, even with unchanged default risk or no default risk at all, the government's debt choice sets  $B_1$  as needed to maintain an optimal, positive level of consumption dispersion, which is the one that supports an excess in marginal utility of  $L$ -type agents relative to  $H$ -type agents equal to  $\frac{\eta \mu^L}{q_0(B_1, \gamma, \omega)}$ . Moreover, since optimal consumption dispersion is positive,

we can also ascertain that  $B_0 > q_0(B_1, \gamma, \omega) B_1$ , which using the government budget constraint implies that the government runs a primary surplus at  $t = 0$ . The government borrows resources, but less than it would need in order to eliminate all consumption dispersion (which requires zero primary balance).

The intuition for the optimality of issuing debt can be presented in terms of tax smoothing and savings: Date-0 consumption dispersion without debt issuance would be  $B_0/(1 - \gamma)$ , but this is more dispersion than what the government finds optimal, because by choosing  $B_1 > 0$  the government provides tax smoothing (ie, reduces date-0 taxes) for everyone, which in particular eases the  $L$ -type agents credit constraint,

and provides also a desired vehicle of savings for  $H$  types. Thus, positive debt increases consumption of  $L$  types (since  $c_0^L = \gamma - g_0 - B_0 + q_0(B_1, \gamma, \omega)B_1$ ), and reduces consumption of  $H$  types (since  $c_0^H = \gamma - g_0 + \left(\frac{\gamma}{1-\gamma}\right)(B_0 - q_0(B_1, \gamma, \omega)B_1)$ ). But issuing debt (assuming repayment) also increases consumption dispersion at  $t = 1$ , since debt is then paid with higher taxes on all agents, while  $H$  agents collect also the debt repayment. Thus, the debt is being chosen optimally to trade off the social costs and benefits of reducing (increasing) date-0 consumption and increasing (reducing) date-1 consumption for agents who are bondholders (nonbondholders). In doing so, the government internalizes the debt Laffer curve and the fact that additional debt lowers the price of bonds and helps reduce  $\mu^L$ , which in turn reduces the government's optimal consumption dispersion.<sup>av</sup>

In the presence of default risk and if default risk changes near the optimal debt choice, the term  $E_{g_1}[\Delta d \Delta W_1]$  enters in the government's optimality condition with a positive sign, which means the optimal gap in the date-0 marginal utilities across agents widens even more. Hence, the government's optimal choice of consumption dispersion for  $t = 0$  is greater than without default risk, and the expected dispersion for  $t = 1$  is lower, because in some states of the world the government will choose to default and consumption dispersion would then drop to zero. This also suggests that the government chooses a lower value of  $B_1$  than in the absence of default risk, since date-0 consumptions are further apart. Moreover, the debt Laffer curve now plays a central role in the government's weakened incentives to borrow, because as default risk rises the price of bonds drops to zero faster and the resources available to reduce date-0 consumption dispersion peak at lower debt levels. In short, default risk reduces the government's ability to use nonstate-contingent debt in order to reduce consumption dispersion.

In summary, the more constrained the  $L$ -types agents are (higher  $\mu^L$ ) or the higher the expected distributional benefit of a default (higher  $E_{g_1}[\Delta d \Delta W_1]$ ), the larger the level of debt the government finds optimal to issue. Both of these mechanisms operate as pecuniary externalities: They matter only because the government debt choice can alter the equilibrium price of bonds which is taken as given by private agents.

For given values of  $\gamma$  and  $\omega$ , a *Competitive Equilibrium with Optimal Debt and Default Policies* is a pair of value functions  $v^i(B_1, \gamma, \omega)$  and decision rules  $b^i(B_1, \gamma, \omega)$  for  $i = L, H$ , a government bond pricing function  $q_0(B_1, \gamma, \omega)$  and a set of government policy functions  $\tau_0(B_1, \gamma, \omega)$ ,  $\tau_1^{d \in \{0,1\}}(B_1, g_1, \gamma, \omega)$ ,  $d(B_1, g_1, \gamma, \omega)$ ,  $B_1(\gamma, \omega)$  such that:

1. Given the pricing function and government policy functions,  $v^i(B_1, \gamma, \omega)$  and  $b^i(B_1, \gamma, \omega)$  solve the households' problem.
2.  $q_0(B_1, \gamma, \omega)$  satisfies the market-clearing condition of the bond market (equation (19)).
3. The government default decision  $d(B_1, g_1, \gamma, \omega)$  solves problem (20).

<sup>av</sup> Note, however, that without default risk the Laffer curve has less curvature than with default risk, because  $q_0^{ND}(B_1, \gamma) \geq q_0(B_1, \gamma)$ .

4. Taxes  $\tau_0(B_1, \gamma, \omega)$  and  $\tau_1^d(B_1, g_1, \gamma, \omega)$  are consistent with the government budget constraints.
5. The government debt policy  $B_1(\gamma, \omega)$  solves problem (25).

### 4.3 Quantitative Analysis

We study the quantitative predictions of the model using a calibration based on European data. Since the model is simple, the goal is not to match closely the observed dynamics of debt and risk premia in Europe, but to show that a reasonable set of parameter values can support an equilibrium in which sustainable debt subject to default risk exists.<sup>aw</sup> We also use this numerical analysis to study show the dispersion of initial wealth and the bias in government welfare affect sustainable debt.

#### 4.3.1 Calibration

The model is calibrated to annual frequency, and most of the parameter values are set to match moments computed using European data. The parameter values that need to be set are the subjective discount factor  $\beta$ , the coefficient of relative risk aversion  $\sigma$ , the moments of the stochastic process of government expenditures  $\{\mu_g, \rho_g, \sigma_g\}$ , the initial levels of government debt and expenditures  $(B_0, g_0)$ , the level of income  $\gamma$ , the initial wealth of  $L$ -type agents  $b_0^L$  and the default cost function  $\phi(g_1)$ . The calibrated parameter values are summarized in Table 14. We evaluate equilibrium outcomes for values of  $\gamma$  and  $\omega$  in the  $[0,1]$  interval. Data for the United States and Europe documented in D'Erasmus and Mendoza (2013) suggest that the empirically relevant range for  $\gamma$  is  $[0.55, 0.85]$ . Hence, when taking a stance on a particular value of  $\gamma$  is useful we use  $\gamma = 0.7$ , which is the mid point of the plausible range.

The preference parameters are set to standard values:  $\beta = 0.96$ ,  $\sigma = 1$ . We also assume for simplicity that  $L$ -types start with zero wealth,  $b_0^L = 0$ .<sup>ax</sup> This and the other calibration parameters result in savings plans such that  $L$ -type agents are credit constrained, and hence  $b_1^L = 0$ .

We estimate an AR(1) process for government expenditures-GDP ratio (in logs) for France, Germany, Greece, Ireland, Italy, Spain and Portugal and set  $\{\mu_g, \rho_g, \sigma_g\}$  to the cross-country averages of the corresponding estimates. This results in the following

<sup>aw</sup> We solve the model following a backward-recursive strategy analogous to the one used in the theoretical analysis. First, for each pair  $\{\gamma, \omega\}$  and taking as given  $B_1$ , we solve for the equilibrium price and default functions by iterating on  $\{d_1, q_0, b_1^L\}$ . Then, in the second stage we complete the solution of the equilibrium by finding the optimal choice of  $B_1$  that solves the government's date-0 optimization problem (25). As explained earlier, for given values of  $B_1$ ,  $\gamma$  and  $\omega$  an equilibrium with debt will not exist if either the government finds it optimal to default on  $B_1$  for all realizations of  $g_1$  or if at the given  $B_1$  the consumption of  $L$  types is nonpositive.

<sup>ax</sup>  $\sigma = 1$  and  $b_0^L = 0$  are also useful because under these assumptions we can obtain closed-form solutions and establish some results analytically.

**Table 14** Model parameters

Parameter		Value
Discount factor	$\beta$	0.96
Risk aversion	$\sigma$	1.00
Avg. Income	$\gamma$	0.79
Low household wealth	$b_0^L$	0.00
Avg. gov. consumption	$\mu_g$	0.18
Autocorrel. G	$\rho_g$	0.88
Std. dev. error	$\sigma_g$	0.017
Initial gov. debt	$B_0$	0.79
Output cost default	$\phi_0$	0.02

*Note:* Government expenditures, income, and debt values are derived using Eurostat data for France, Germany, Greece, Ireland, Italy, Spain, and Portugal.

values  $\mu_g = 0.1812$ ,  $\rho_g = 0.8802$  and  $\sigma_e = 0.017$ . We set  $g_0 = \mu_g$  and use the quadrature method proposed by [Tauchen \(1986\)](#) with 45 nodes in  $G_1 \equiv \{\underline{g}_1, \dots, \bar{g}_1\}$  to generate the realizations and transition probabilities of  $g_1$ .

Average income  $\gamma$  is calibrated such that the model's aggregate resource constraint is consistent with the data when GDP is normalized to one. This implies that the value of the agents' aggregate endowment must equal GDP net of fixed capital investment and net exports, since the latter two are not modeled. The average for the period 1970–2012 for the same set of countries used to estimate the  $g_1$  process implies  $\gamma = 0.7883$ .<sup>ay</sup>

We set the initial debt level  $B_0 = 0.79$  so that at the maximum observed level of inequality in the data,  $\gamma = 0.85$ , there is at least one feasible level of  $B_1$  when  $\omega = \gamma$ . We assume that the default cost takes the following form:  $\phi(g_1) = \phi_0 + (\bar{g} - g_1)/\gamma$ , where  $\bar{g}$  is calibrated to represent an “unusually large” realization of  $g_1$  set equal to the largest realization in the Markov process of government expenditures, which is in turn set equal to 3 standard deviations from the mean (in logs).<sup>az</sup>

We calibrate  $\phi_0$  to match an estimate of the observed frequency of *domestic* defaults. According to [Reinhart and Rogoff \(2011\)](#), historically, domestic defaults are about 1/4 as frequent as external defaults (68 domestic vs 250 external in their data since 1750). Since the probability of an external default has been estimated in the range of 3–5% (see, for example, [Arellano, 2008](#)), the probability of a domestic default is about 1%. The model is close to this default frequency on average when solved over the empirically relevant

<sup>ay</sup> Note also that under this calibration of  $\gamma$  and the Markov process of  $g_1$ , the gap  $\gamma - g_1$  is always positive, even for  $g_1 = \bar{g}_1$ , which in turn guarantees  $c_1^H > 0$  in all repayment states.

<sup>az</sup> This cost function shares a key feature of the default cost functions widely used in the external default literature to align default incentives so as to support higher debt ratios and trigger default during recessions (see [Arellano, 2008](#) and [Mendoza and Yue, 2012](#)): The default cost is an *increasing* function of disposable income ( $\gamma - g_1$ ). In addition, this formulation ensures that the agents' consumption during a default never goes above a given threshold.

range of  $\gamma$ 's ( $\gamma \in [0.55, 0.85]$ ) if we set  $\phi_0 = 0.02$ . Note, however, that the calibration of  $\phi_0$  and  $B_0$  to match their corresponding targets needs to be done jointly by repeatedly solving the model until both targets are well approximated.

#### 4.3.2 Utilitarian Government ( $\omega = \gamma$ )

We study first a set of results obtained under the assumption  $\omega = \gamma$ , because the utilitarian government is a natural benchmark. Since the default decision of the government derives from the agents' utility under the repayment and default alternatives at  $t = 1$ , it is useful to map the ordinal utility measures into cardinal measures by computing "individual welfare gains of default," which are standard consumption-equivalent values that equalize utility under default and repayment. Given the CRRA functional form, the individual welfare gains of default reduce simply to the percent changes in consumption across the default and no-default states of each agent at  $t = 1$ :

$$\alpha^i(B_1, g_1, \gamma) = \frac{c_1^{i,d=1}(B_1, g_1, \gamma)}{c_1^{i,d=0}(B_1, g_1, \gamma)} - 1 = \frac{(1 - \phi(g_1))\gamma - g_1}{\gamma - g_1 + b_1^i - B_1} - 1$$

A positive (negative) value of  $\alpha^i(B_1, g_1, \gamma)$  implies that agent  $i$  prefers government default (repayment) by an amount equivalent to an increase (cut) of  $\alpha^i(\cdot)$  percent in consumption. The individual welfare gains of default are aggregated using  $\gamma$  to obtain the utilitarian representation of the social welfare gain of default:

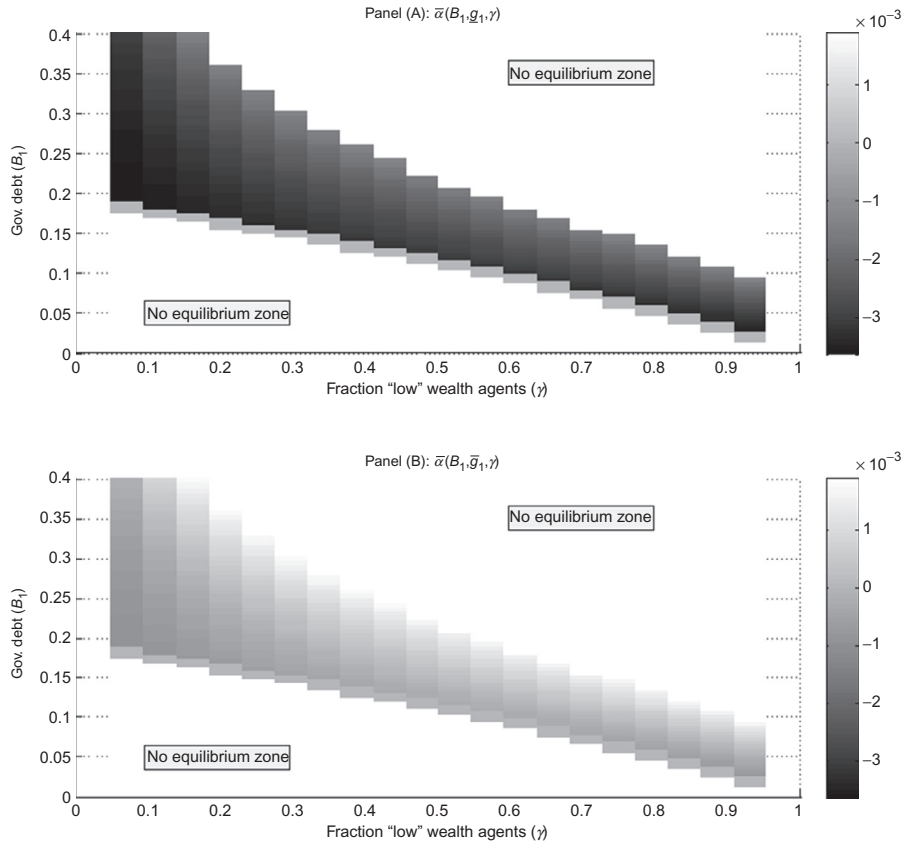
$$\bar{\alpha}(B_1, g_1, \gamma) = \gamma \alpha^L(B_1, g_1, \gamma) + (1 - \gamma) \alpha^H(B_1, g_1, \gamma).$$

A positive value indicates that default induces a social welfare gain and a negative value a loss.

Fig. 17 shows two intensity plots of the social welfare gain of default for the ranges of values of  $B_1$  and  $\gamma$  in the vertical and horizontal axes, respectively. Panel (A) is for a low value of government purchases,  $\bar{g}_1$ , set 3 standard deviations below  $\mu_g$ , and panel (B) is for a high value  $\bar{g}_1$  set 3 standard deviations above  $\mu_g$ . "No Equilibrium Zone", represent values of  $(B_1, \gamma)$  for which the debt market collapses and no equilibrium exists.<sup>ba</sup>

The area in which the social welfare gains of default are well defined in these intensity plots illustrates two of the key mechanisms driving the government's distributional incentives to default: First, fixing  $\gamma$ , the welfare gain of default is higher at higher levels of debt, or conversely the gain of repayment is lower. Second, keeping  $B_1$  constant, the welfare gain of default is also increasing in  $\gamma$  (ie, higher wealth concentration increases

<sup>ba</sup> Note that to determine if  $c_0^L \leq 0$  at some  $(B_1, \gamma)$  we also need  $q_0(B_1, \gamma)$ , since combining the budget constraints of the  $L$  types and the government yields  $c_0^L = \gamma - g_0 - B_0 + q_0 B_1$ . Hence, to evaluate this condition we take the given  $B_1$  and use the  $H$ -types Euler equation and the market clearing condition to solve for  $q_0(B_1, \gamma, \omega)$ , and then determine if  $\gamma - g_0 - B_0 + q_0 B_1 \leq 0$ , if this is true, then  $(B_1, \gamma)$  is in the lower no-equilibrium zone.



**Fig. 17** Social welfare gains of default  $\bar{\alpha}(B_1, g_1, \gamma)$ . *Note:* The intensity of the color or shading in these plots indicates the magnitude of the welfare gain according to the legend shown to the right of the plots. The regions shown in white and marked as “no equilibrium zone,” represent values of  $(B_1, \gamma)$  for which the debt market collapses and no equilibrium exists.

the welfare gain of default). This implies that lower levels of wealth dispersion are sufficient to trigger default at higher levels of debt.<sup>bb</sup> For example, for a debt ratio of 20% of GDP ( $B_1 = 0.20$ ) and  $g_1 = \bar{g}_1$ , social welfare is higher under repayment if  $0 \leq \gamma \leq 0.25$  but it becomes higher under default if  $0.25 < \gamma \leq 0.6$ , and for higher  $\gamma$  there is no equilibrium because the government prefers default not only for  $g_1 = \bar{g}_1$  but for all possible  $g_1$ . If instead the debt is 40% of GDP, then social welfare is higher under default for all the values of  $\gamma$  for which an equilibrium exists.

<sup>bb</sup> Note that the cross-sectional variance of initial debt holdings is given by  $Var(b) = B^2 \frac{\gamma}{1-\gamma}$  when  $b_0^L = 0$ .

This implies that the cross-sectional coefficient of variation is equal to  $CV(b) = \frac{\gamma}{1-\gamma}$ , which is increasing in  $\gamma$  for  $\gamma \leq 1/2$ .

The two panels in Fig. 17 differ in that panel (B) displays a well-defined transition from a region in which repayment is socially optimal ( $\bar{\alpha}(B_1, g_1, \gamma) < 0$ ) to one where default is optimal ( $\bar{\alpha}(B_1, g_1, \gamma) > 0$ ) but in panel (A) the social welfare gain of default is never positive, so repayment is always optimal. This reflects the fact that higher  $g_1$  also weakens the incentives to repay. In the “No Equilibrium Zone” in the upper right, there is no equilibrium because at the given  $\gamma$  the government chooses to default on the given  $B_1$  for all values of  $g_1$ . In the “No Equilibrium Zone” in the lower left, there is no equilibrium because the given  $(B_1, \gamma)$  would yield  $c_0^L \leq 0$ , and so the government would not supply that particular  $B_1$ .

Consider next the government’s default decision choice, which is driven by the sign of the social welfare gains of default. It is evident from Fig. 17 that the government defaults the higher  $g_1$  for given  $B_1$  and  $\gamma$ , the higher  $B_1$  for a given  $\gamma$  and  $g_1$ , or at higher  $\gamma$  at given  $B_1$  and  $g_1$ . It follows then that we can compute a threshold value of  $\gamma$  such that the government is indifferent between defaulting and repaying in period  $t = 1$  for a given  $(B_1, g_1)$ . These indifference thresholds ( $\hat{\gamma}(B_1, g_1)$ ) are plotted in Fig. 18 against debt levels ranging from 0 to 0.4 for three values of government expenditures  $\{\underline{g}_1, \mu_g, \bar{g}_1\}$ . For any given  $(B_1, g_1)$ , the government chooses to default if  $\gamma \geq \hat{\gamma}$ .

Fig. 18 shows that the default threshold is decreasing in  $B_1$ . Hence, the government tolerates higher debt ratios without defaulting only if wealth concentration is sufficiently low. Also, default thresholds are decreasing in  $g_1$ , because the government has stronger

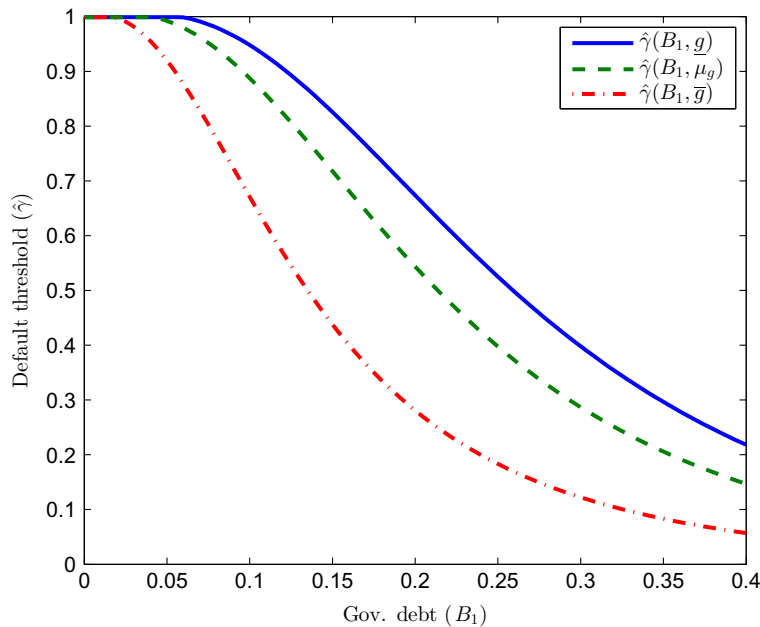


Fig. 18 Default threshold  $\hat{\gamma}(B_1, g_1)$ .

incentives to default when government expenditures are higher (ie, the threshold curves shift inward).<sup>bc</sup> This last feature of  $\hat{\gamma}$  is very important to determine equilibria with sustainable debt subject to default risk. If, for a given value of  $B_1$ ,  $\gamma$  is higher than the curve representing  $\hat{\gamma}$  for the lowest realization in the Markov process of  $g_1$  (which is also the value of  $\underline{g}_1$ ), the government defaults for sure and, as explained earlier, there is no sustainable debt at equilibrium. Alternatively, if for a given value of  $B_1$ ,  $\gamma$  is lower than the curve representing  $\hat{\gamma}$  for the highest realization of  $g_1$  (which is the value of  $\bar{g}_1$ ), the government repays for sure and debt would be issued effectively without default risk. Thus, for the model to support equilibria with sustainable debt subject to default risk, the optimal debt chosen by the government in the first period for a given  $\gamma$  must lie between these two extreme threshold curves. We show below that this is the case in this quantitative experiment.

Before showing those results, it is important to highlight three key properties of the bond pricing function. The quantitative results for this function, the details of which we omit to save space, reflect the properties discussed in the model analysis:

1. *The equilibrium price is decreasing in  $B_1$  for given  $\gamma$*  (the pricing functions shift downward as  $B_1$  rises). This follows from a standard demand-and-supply argument: For a given  $\gamma$ , as the government borrows more, the price at which the  $H$  types are willing to demand the additional debt falls and the interest rate rises.
2. *Default risk reduces the price of bonds below the risk-free price and thus induces a risk premium.* Intuitively, when there is no default risk (ie, for combinations of  $B_1$  and  $\gamma$  such that the probability of default is zero) both prices are identical. However, as the probability of default rises, agents demand a premium in order to clear the bond market.
3. *Bond prices are a nonmonotonic function of wealth dispersion:* When default risk is sufficiently low, bond prices are increasing in  $\gamma$ , but eventually they become a steep decreasing function of  $\gamma$ . Higher  $\gamma$  implies a more dispersed wealth distribution, so that  $H$ -type agents become a smaller fraction of the population, and hence they must demand a larger amount of debt per capita in order to clear the bond market (ie,  $b_1^H$  increases with  $\gamma$ ), which pushes bond prices up. While default risk is low this “demand composition effect” dominates and thus bond prices rise with  $\gamma$ , but as  $\gamma$  increases and default risk rises (since higher wealth dispersion strengthens default incentives), the growing risk premium becomes the dominating force (at about  $\gamma > 0.5$ ) and produces bond prices that fall sharply as  $\gamma$  increases.

Finally we examine the numerical solutions of the model’s full equilibrium with optimal debt and default policies. The key element of the solution is the sustainable debt, which is also the government’s optimal choice of debt issuance in the first period at the equilibrium price (ie, the optimal  $B_1$  that solves problem (25)). We show this sustainable debt as an equilibrium manifold (ie, as a plot of the sustainable debt obtained by

<sup>bc</sup>  $\hat{\gamma}$  approaches zero for  $B_1$  sufficiently large, but in Fig. 18  $B_1$  reaches 0.40 only for exposition purposes.



solving the model's equilibrium over a range of values of  $\gamma$ ). Given this sustainable debt, we can then use the functions that describe optimal debt demand plans of private agents in both periods, the government's default choice in period 1, bond prices, and default risk for *any* value of  $B_1$  to determine the corresponding *equilibrium* manifold values of all of the model's endogenous variables.

Fig. 19 shows the four main components of the equilibrium manifolds: Panel (A) plots the manifold of sustainable first-period debt issuance of the model with default risk,  $B_1^*(\gamma)$ , and also, for comparison, the debt in the case when the government is committed to repay so that debt is risk free,  $B_1^{RF}(\gamma)$ . Panel (B) shows equilibrium debt prices that correspond to the sustainable debt of the same two economies. Panel (C) shows the default spread (the difference in the inverses of the bond prices). Panel (D) shows the probability of default. Since in principle the government that has the option to default can still choose a debt level for which it could prefer to repay in all realizations of  $g_1$ ,

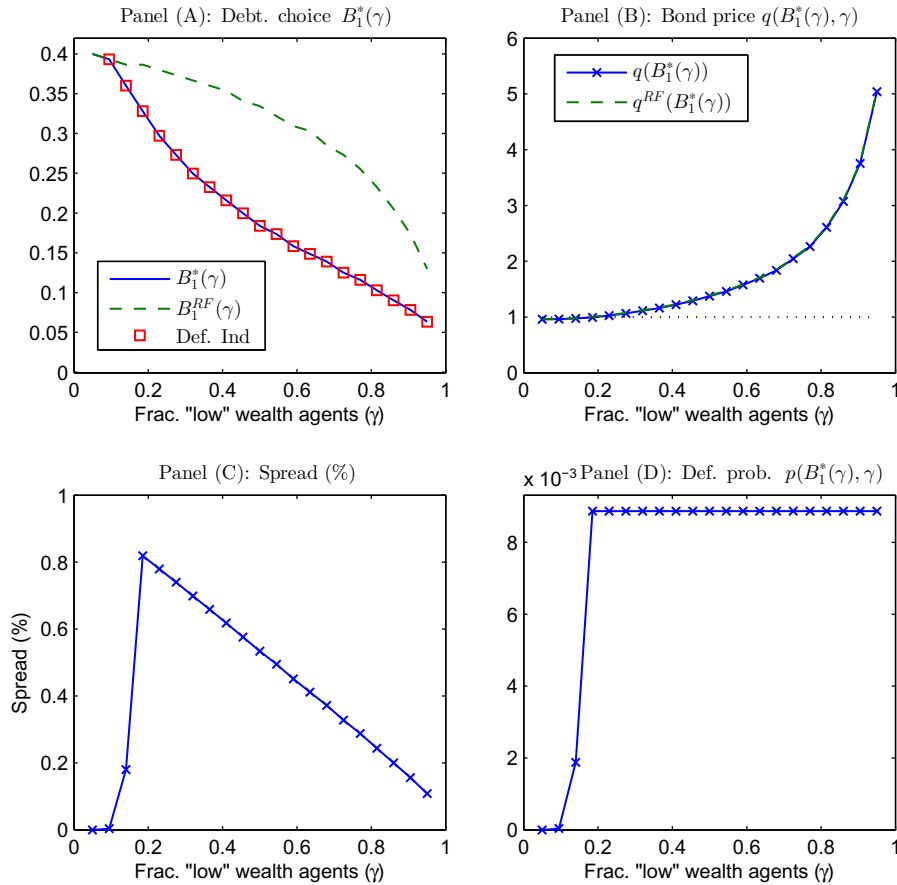


Fig. 19 Equilibrium manifolds.

we identify with a square in Panel (A) the equilibria in which  $B_1^*(\gamma)$  has a positive default probability. This is the case for all but the smallest value of gamma considered ( $\gamma = 0.05$ ), in which the government sets  $B_1^*(\gamma)$  at 40% of GDP with zero default probability.

Panel (A) shows that sustainable debt falls as  $\gamma$  increases in both the economy with default risk and the economy with a government committed to repay. This occurs because in both cases the government seeks to reallocate consumption across agents and across periods by altering the product  $q(B_1)B_1$  optimally, and in doing this it internalizes the response of bond prices to its debt choice. As  $\gamma$  rises, this response is influenced by stronger default incentives and a stronger demand composition effect. The latter dominates in this quantitative experiment, because panel (B) shows that the equilibrium bond prices always rise with  $\gamma$ . Hence, the government internalizes that as  $\gamma$  rises the demand composition effect strengthens demand for bonds, pushing bond prices higher, and as a result it can actually attain a higher  $q(B_1)B_1$  by choosing lower  $B_1$ . This is a standard Laffer curve argument: In the upward slopping segment of this curve, increasing debt increases the amount of resources the government acquires by borrowing in the first period.

In the range of empirically relevant values of  $\gamma$ , sustainable debt ratios range from 20% to 32% of GDP without default risk and from 8% to 15% with default risk. Since the median in the European data is 35%, these ratios are relatively low, but still they are notable given the simplicity of the two-period setup. In particular, the model lacks the stronger income- and tax-smoothing effects and the self-insurance incentives of a longer life horizon (see [Aiyagari and McGrattan, 1998](#)), and it has an upper bound on the optimal debt choice for  $\gamma = [0, 1]$  lower than  $B_0/(1 + \beta)$  (which is the upper bound as  $\gamma \rightarrow 0$  in the absence of default risk).

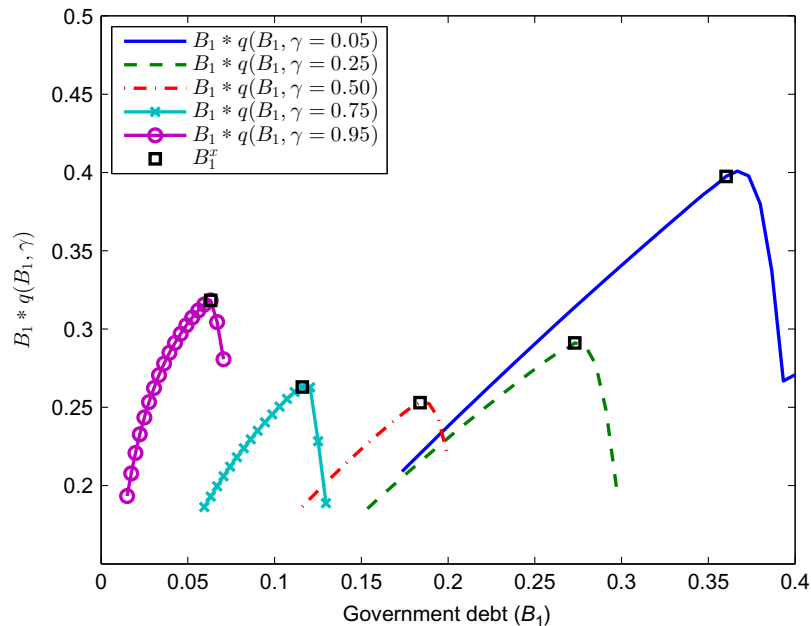
Panel (B) shows that bond prices of sustainable debt range from very low to very high as  $\gamma$  rises, including prices sharply above 1 that imply large negative real interest rates on public debt. In fact, as [D'Erasmus and Mendoza \(2013\)](#) explain, equilibrium bond prices are similar and increasing in  $\gamma$  with or without default risk, because at equilibrium the government chooses debt positions for which default risk is low (see panel (D)), and thus the demand composition effect that strengthens as  $\gamma$  rises dominates and yields bond prices increasing in  $\gamma$  and similar with or without default risk.<sup>bd</sup>

<sup>bd</sup> Everything else equal, our model predicts that higher income dispersion (either due to less progressive tax systems or underlying households' income or bond positions) results in higher spreads. In [D'Erasmus and Mendoza \(2013\)](#), we show that an economy with more progressive tax system results in lower spreads. The intuition is simple. The more the government can redistribute via means of taxation the lower the incentives to redistribute through a domestic default on the debt. The results in that paper show that incentives to default do not disappear but spreads decrease considerably. Also in [D'Erasmus and Mendoza \(2013\)](#), we present evidence of the nonlinear relationship between debt to income ratios and wealth inequality. Data limitations prevents us from extending this analysis to the relationship between spreads and income dispersion or the progressivity of the tax system.

Panels (C) and (D) show that, in contrast with standard models of external default, in this model the default spread is neither similar to the probability of default nor does it have a monotonic relationship with it.<sup>be</sup> Both the spread and the default probability start at zero for  $\gamma = 0.05$  because  $B_1^*(0.05)$  has zero default probability. As  $\gamma$  increases up to 0.2, both the spread and the default probability of the sustainable debt are similar in magnitude and increase together, but for  $\gamma > 0.2$  the spread falls with  $\gamma$  while the default probability remains unchanged around 0.9%. For  $\gamma = 0.95$  the probability of default is 9 times larger than the spread (0.9 vs 0.1%).

The role of the government's incentives to reallocate consumption across agents and across periods internalizing the response of bond prices when choosing debt can be illustrated further by examining the debt Laffer curve. Fig. 20 shows debt Laffer curves for five values of  $\gamma$  in the  $[0.05, 0.95]$  range.

In all but one case, the sustainable debt  $B_1^*(\gamma)$  (ie, the equilibrium debt chosen optimally by the government at the equilibrium price) is located at the maximum of the corresponding Laffer curve. In these cases, setting debt higher than at the maximum is



**Fig. 20** Debt Laffer curve. *Note:* Each curve is truncated at values of  $B_1$  in the horizontal axis that are either low enough for  $c_0^L \leq 0$  or high enough for default to be chosen for all realizations of  $g_1$ , because as noted before in these cases there is no equilibrium.

<sup>be</sup> In the standard models, the two are similar and a monotonic function of each other because of the arbitrage condition of a representative risk-neutral investor.

suboptimal because default risk reduces bond prices sharply, moving the government to the downward-sloping segment of the Laffer curve. Setting debt lower than the maximum is also suboptimal, because then default risk is low and extra borrowing generates more resources since bond prices change little, leaving the government in the upward-sloping segment region of the Laffer curve. Thus, if the optimal debt has a nontrivial probability of default, the government's debt choice exhausts its ability to raise resources by borrowing. The exception is the case with  $\gamma = 0.05$ , in which  $B_1^*(\gamma)$  has zero default probability. In this case, the government's optimal debt is to the left of the maximum of the Laffer curve, and thus the debt choice does not exhaust the government's ability to raise resources by borrowing. This also happens when the default probability is positive but negligible. For example, when  $\gamma = 0.15$  the default probability is close to zero and the optimal debt choice is again slightly to the left of the maximum of the corresponding Laffer curve.

#### 4.3.3 Biased Welfare Weights ( $\omega \neq \gamma$ )

The final experiment we conduct examines how the results change if we allow the weights of the government's payoff function to display a bias in favor of bondholders. Fig. 21 shows how the planner's welfare gain of default varies with  $\omega$  and  $\gamma$  for two different levels of government debt ( $B_{1,L} = 0.143$  and  $B_{1,H} = 0.185$ ). The no-equilibrium region, which exists for the same reasons as before, is shown in white.

In line with the previous discussion, within the region where the equilibrium is well-defined, the planner's value of default increases monotonically as  $\omega$  increases, keeping  $\gamma$  constant, and falls as actual wealth concentration ( $\gamma$ ) rises, keeping  $\omega$  constant. Because of this, the north-west and south-east corners in each of the panels present cases that are at very different positions on the preference-for-default spectrum. When  $\omega$  is low, even for very high values of  $\gamma$ , the government prefers to repay (north-west corner), because the government puts relatively small weight on  $L$ -type agents. On the contrary, when  $\omega$  is high, even for low levels of  $\gamma$ , a default is preferred. It is also interesting to note that as we move from Panel (A) to Panel (B), so that government debt raises, the set of  $\gamma$ 's and  $\omega$ 's such that the equilibrium exists or repayment is preferred (ie, a negative  $\bar{\alpha}(B_1, g_1, \gamma, \omega)$ ) expands. This is because as we increase the level of debt  $B_1$ , as long as the government does not choose to default for all  $g_1$ , the higher level of debt allows  $L$ -type agents to attain positive levels of consumption (since initial taxes are lower).

Panels (A)–(D) in Fig. 22 display the model's equilibrium outcomes for the sustainable debt chosen by the government in the first period and the associated equilibrium bond prices, spreads and default probabilities under three possible values of  $\omega$ , all plotted as functions of  $\gamma$ . It is important to note that along the blue curve of the utilitarian case both  $\omega$  and  $\gamma$  effectively vary together because they are always equal to each other, while in the other two plots  $\omega$  is fixed and  $\gamma$  varies. For this reason, the line corresponding to the  $\omega_L$

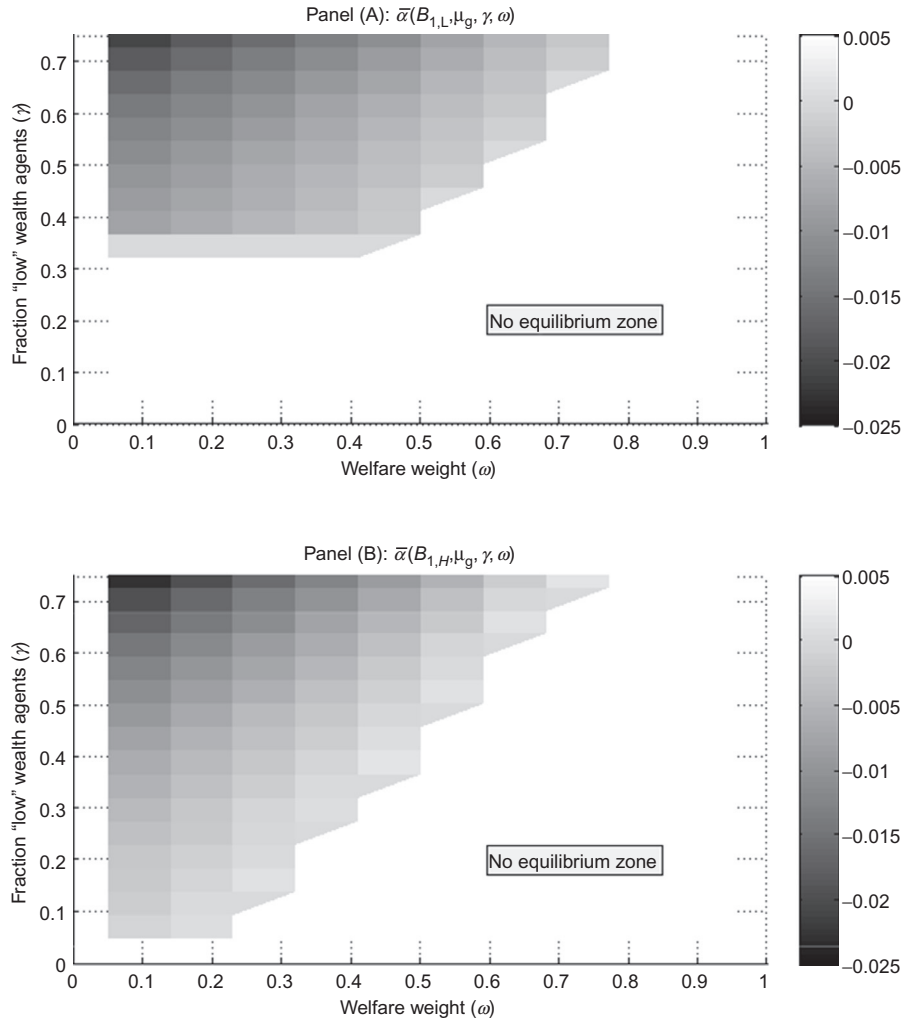
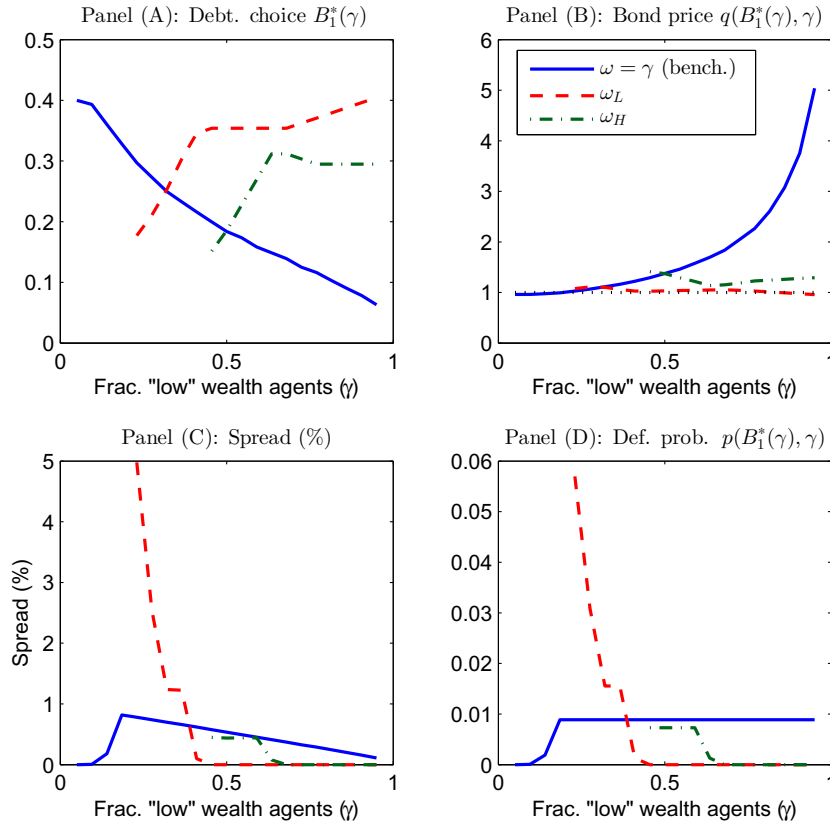


Fig. 21 Planner's welfare gain of default  $\bar{\alpha}(B_1, g_1, \gamma, \omega)$ .

case intersects the benchmark solution when  $\gamma = 0.32$ , and the one for  $\omega_H$  intersects the benchmark when  $\gamma = 0.50$ .

Fig. 22 shows that the optimal debt level is increasing in  $\gamma$ . This is because the incentives to default grow weaker and the repayment zone widens as  $\gamma$  increases for a fixed value of  $\omega$ . It is also interesting to note that in the  $\omega_L$  and  $\omega_H$  cases the equilibrium exists only for a small range of values of  $\gamma$  that are lower than  $\omega$ . Without default costs each curve would be truncated exactly where  $\gamma$  equals either  $\omega_H$  or  $\omega_L$ , but since these simulations retain the default costs used in the utilitarian case, there can still be equilibria with debt for some lower values of  $\gamma$  (as explained earlier).



**Fig. 22** Equilibrium manifolds with government bias at different values of  $\omega$ .

With the bias in favor of bondholders, the government is still aiming to optimize debt by focusing on the resources it can reallocate across periods and agents, which are still determined by the debt Laffer curve  $q_0(\cdot)B_1$ , and internalizing the response of bond prices to debt choices.<sup>bf</sup> This relationship, however, behaves very differently than in the benchmark model, because now *higher* sustainable debt is carried at increasing equilibrium bond prices, which leads the planner internalizing the price response to choose higher debt, whereas in the benchmark model *lower* debt was sustained at increasing equilibrium bond prices, which led the planner internalizing the price response to choose lower debt.<sup>bg</sup>

<sup>bf</sup> When choosing  $B_1$ , the government takes into account that higher debt increases disposable income for L-type agents in the initial period but it also implies higher taxes in the second period (as long as default is not optimal). Thus, the government is willing to take on more debt when  $\omega$  is lower.

<sup>bg</sup> Fig. 22 makes clear that with the government bias, the level of sustainable debt changes with the preferences of the government. Even though we do not model how these preferences arise, it is evident that two countries with the same fundamentals (ie, distribution of wealth and income) could end up with very different levels of sustainable debt depending on how household preferences are aggregated by the government in power.

The behavior of equilibrium bond prices (panel (B)) with either  $\omega_L = 0.32$  or  $\omega_H = 0.50$  differs markedly from the utilitarian case. In particular, the prices no longer display an increasing, convex shape, instead they are a relatively flat and nonmonotonic function of  $\gamma$ . This occurs because the higher supply of bonds that the government finds optimal to provide offsets the demand composition effect that increases individual demand for bonds as  $\gamma$  rises.

The domestic default approach to study sustainable debt adds important insights to those obtained from the empirical and structural approaches, both of which assumed repayment commitment. In particular, panel (A) of Fig. 19 shows that sustainable debt falls sharply once risk of default is present, even when it is very small, and that (if the government is utilitarian) sustainable debt falls sharply with the concentration of bond ownership, because of the strengthened incentive to use default as a tool for redistribution. Hence, estimates of sustainable debt based on models in which the government is assumed to be committed to repay are likely to be too optimistic. Intuitively, one can infer that in the structural model, a given increase in the initial debt would be harder to offset with higher primary balances if the interest rate at which those primary balances are discounted rises with higher debt because of default risk. Moreover, the representative-agent assumption is also likely to lead to optimistic estimates of sustainable debt, because representative-agents models abstract from the strong incentives to use debt default as a tool for redistribution across heterogeneous agents. These incentives are likely to be weaker than in the model in practice, because tax and transfer policies that we did not include in the model can be used for redistribution as well. But when these other instruments have been exhausted, and if inequality in bond holdings is sufficiently concentrated, the incentives to default as vehicle for redistribution are likely to be very strong.

A second important insight from this analysis is that sustainable debt is higher if the government's payoff function is biased in favor of bondholders, and can even exceed debt that is sustainable without default risk when the government has a utilitarian social welfare function. Furthermore, [D'Erasmus and Mendoza \(2013\)](#) show that nonbondholders may prefer equilibria where the government favors bondholders, instead of being utilitarian, because higher sustainable debt help relax their liquidity constraints. Hence, at sufficiently high levels of concentration of bond ownership, a biased government can sustain high debt and the biased government can be elected as a majority government.

The main caveat of this analysis is that, because it was based on a two-period model, it misses important endogenous costs of default that would be added to the model by introducing a longer life horizon. In this case, default costs due to the reduced ability to smooth taxation and consumption when the debt market closes, and due to the loss of access to the self-insurance vehicle and the associated tightening of liquidity constraints, can take up the role of the exogenous default costs and/or government bias for bondholders, enabling the model to improve its ability to account for key features of the data and sustain higher debt levels at nontrivial default premia. [D'Erasmus and Mendoza \(2014\)](#) examine a model with these features and study its quantitative implications.

## 5. CRITICAL ASSESSMENT AND OUTLOOK

We started this chapter by noting that the question of what is a sustainable public debt has always been paramount in the macroeconomics of fiscal policy. The question will remain paramount for years to come, as the precarious public debt and deficit positions of many advanced and emerging economies today will make it a central focus of both policy analysis and academic research. This chapter aimed to demonstrate the flaws that affect the classic, but still widely used, approach to analyze public debt sustainability, and to show how three approaches based on recent research can provide powerful alternative ways to tackle the question. Two of these approaches, the empirical approach and the structural approach, assume that the government is committed to repay its debt, and the third approach, the domestic default approach, assumes that the government cannot commit to repay. In this section, we reflect further on the limitations of each of these approaches and suggest directions for further research.

The empirical approach has been widely studied and is by now very well established. Its strengths are in that it can easily determine whether debt has been consistent with fiscal solvency in available time-series data via straightforward estimation of a fiscal reaction function, and in that analyzing the characteristics of this FRF it can shed light on the dynamics of adjustment of debt and the primary balance. Unfortunately, as we explained earlier, it is not helpful for comparing alternative fiscal policy strategies to maintain debt sustainability and/or cope with public debt crises in the future.

The structural approach showed how an explicit dynamic general equilibrium model can be used to compare alternative fiscal policy strategies aimed at maintaining fiscal solvency at different levels of observed outstanding debt. We used a variation of the work-horse two-country Neoclassical framework with exogenous, balanced growth in which endogenous capacity utilization and a limited tax allowance for capital depreciation allow the model to match a key feature of the data for fiscal sustainability analysis: The observed elasticity of the capital tax revenue. Yet, the model is also very limited inasmuch as it abstracts from other important features of the data. In particular, the model is purely “real,” and hence abstracts from the fact that public debt is largely nominal debt denominated in domestic currencies, and also abstracts from linkages between potentially important nominal rigidities, relative prices, and the evolution of government revenues and outlays.

The model used in the structural approach also has the drawbacks that it abstracts from heterogeneity in households and firms and assumes that agents are infinitely lived. Hence, while it takes into account important efficiency effects resulting from alternative fiscal policies, it cannot capture their distributional implications across agents and/or generations. The fiscal policy research on heterogeneous-agents and overlapping-generations models has shown that these distributional effects can be quite significant, and hence it is important to develop models of debt sustainability that incorporate them. For



instance, [Aiyagari \(1995\)](#) showed that reductions in capital taxes have adverse distributional consequences that can offset the efficiency gains emphasized in representative agent models. [Aiyagari and McGrattan \(1998\)](#) showed that public debt has social value because it acts as vehicle to provide liquidity (ie, relax borrowing constraints) of the agents at the low end of the wealth distribution, and [Birkeland and Prescott \(2006\)](#) provide a setup in which using debt to save for retirement dominates a tax-and-transfer system. [Imrohoroglu et al. \(2016\)](#) and [Braun and Joines \(2015\)](#) also show how sophisticated overlapping-generations models can be applied to study debt-sustainability issues, with a particular focus on the implications of the adverse demographics dynamics facing Japan.

Of the approaches to debt sustainability analysis reviewed here, the domestic default approach is the one that has been studied the least. We provided a very simple canonical model in which default on domestic debt can emerge as an optimal outcome for a government with incentives to redistribute across debt holders and nonholders, but clearly significant further research in this area is needed (in addition to the recent work by [D'Erasmus and Mendoza \(2014\)](#) and [Dovis et al. \(2014\)](#) that we cited).

There are also two other directions in which research on debt sustainability should go. First, to model the role of public debt in financial intermediation in general and in financial stabilization policies in particular. In terms of the former, domestic banking systems are often large holders of domestic public debt, so a domestic default of the kind the third approach we examined seeks to explain tends to materialize in terms of a redistribution that hurts the balance sheets of banks. A deeper question in a similar vein is why public debt is such a high-demand asset, or liquidity vehicle, in modern financial systems. Macro/finance research is looking into this questions, but introducing these considerations into debt sustainability analysis is still a pending task. Regarding crisis-management policies, the aftermath of the global financial crisis has been characterized by strong demand for public debt instruments driven by quantitative easing policies and by the new regulatory environment. This may account for the apparent paradox between the pessimistic fiscal prospects that the analysis of this chapter presents and the observation that we currently observe near-zero and even negative yields on the public debt of some advanced economies (ie, demand for public debt remains very strong despite the highly questionable capacity of governments to repay it through standard improvements of the primary fiscal balance). But to be certain we need a richer model of debt sustainability that incorporates both the long-term forces that drive the government's capacity to repay and short-term debt dynamics around a financial crisis in which demand for risk-free asset surges.

The second direction in which debt sustainability analysis needs to branch out is to develop tools to incorporate considerations of potential multiplicity of equilibria in public debt markets. The seminal work of [Calvo \(1988\)](#) showed how debt can move between two equilibria supported by self-fulfilling expectations. In one the debt is repaid because agents expect that the government will be able to access the debt market, and thus

maintain the efficiency losses of taxation small enough to indeed generate enough revenue to repay. In the other, the government defaults because agents expect that it will not be able to access the debt market and will be forced into highly distorting levels of taxation that indeed result in revenues that are insufficient to repay. The external default literature has explored models with this kind of equilibrium multiplicity extensively, as documented in the corresponding chapter of this handbook, and theoretical work applying these ideas to domestic debt crises is also available, but research to incorporate this mechanism into quantitative models of domestic debt sustainability is still needed.

## 6. CONCLUSIONS

What is a sustainable public debt? Assuming that the government is committed to repay, the answer is a debt that satisfies the intertemporal government budget constraint (ie, a debt that is equal to the present discounted value of the primary fiscal balance). In this chapter we showed that the traditional approach to debt sustainability analysis is flawed. This approach uses the steady-state government budget constraint to define sustainable debt as the annuity value of the primary balance, but it cannot establish if current or projected debt and primary balance dynamics are consistent with that debt level. We then discussed two approaches to study public debt sustainability under commitment to repay: First, an empirical approach, based on a linear fiscal reaction function, according to which a positive, conditional response of the primary balance to debt is sufficient to establish debt sustainability. Second, a structural approach based on a two-country variant of the workhorse Neoclassical dynamic general equilibrium model with an explicit fiscal sector. The model differs from the standard Neoclassical setup in that it introduces endogenous capacity utilization and a limited tax allowance for depreciation expenses in order to match the observed elasticity of the capital tax base to changes in capital taxes. In this setup, the initial debt that is sustainable is the one determined by the present value of primary balances evaluated using equilibrium allocations and prices.

Applications of these first two approaches to cross-country data produced key insights. With the empirical approach, we found in tests based on historical US data and cross-country panels that the sufficiency condition for public debt to be sustainable (the positive, conditional response of the primary balance to debt), cannot be rejected. We also found, however, clear evidence showing that the fiscal dynamics observed in the aftermath of the recent surge in debt in advanced economies represent a significant structural break in the estimated reaction functions. Primary deficits have been too large, and are projected to remain too large, relative to what the fiscal reaction functions predict, and they are also large compared with those observed in the aftermath previous episodes of large surges in debt.

The structural approach differs from the empirical approach in that it can be used to evaluate the positive and normative effects of alternative paths of fiscal adjustment to

attain debt sustainability, whereas the empirical approach is silent about these effects. We calibrated the model to the United States and European data and used it to quantify the effects of unilateral changes in capital and labor taxes, particularly their effects on sustainable debt. The results suggest key differences across Europe and the United States. For the United States, the results suggest that changes in capital taxes cannot make the observed increase in debt sustainable, while small increases in labor taxes could. For Europe, the model predicts that the capacity to use taxes to make higher debt ratios sustainable is nearly fully exhausted. Capital taxation is highly inefficient (in the decreasing segment of dynamic Laffer curves), so cuts in capital taxes would be needed to restore fiscal solvency. Labor taxes are near the peak of the dynamic Laffer curve, and even if increased to the maximum point they do not generate enough revenue to make the present value of the primary balance match the observed surge in debt. In addition, international externalities of capital income taxes were quantitatively large, which suggest that incentives for strategic interaction are nontrivial and could lead to a classic race-to-the-bottom in capital income taxation.

The results of the applications of the empirical and structural approaches paint a bleak picture of the prospects for fiscal adjustment in advanced economies to restore fiscal solvency and make the post-2008 surge in public debt ratios sustainable. In light of these findings, and with the ongoing turbulence in European sovereign debt markets and recurrent debt ceiling debates in the United States, we examined a third approach to debt sustainability that relaxes the assumption of a government committed to repay and allows for the risk of default on domestic public debt. In this environment, debt is sustainable when it is part of the equilibrium that includes the optimal debt issuance and default choices of the government. The government has incentives to default as a vehicle for redistribution across agents who are heterogeneous in wealth. Public debt is not sustainable in the absence of default costs or a political bias to weigh the welfare of bond holders by more than their share of the wealth distribution. This is the case because without these assumptions default is always the optimal choice that maximizes the social welfare function of a government who values the utility of all agents, and this is the case regardless of the present value of primary balances used to characterize sustainable debt under the other two approaches.

Quantitatively, this domestic default approach adds valuable insights to those obtained from the empirical and structural approaches without default risk. In particular, sustainable debt falls sharply once risk of default is present, even when it is very small, and it also falls sharply with wealth inequality, because of the strengthened incentive to use default as a tool for redistribution. Hence, estimates of sustainable debt based on models in which the government is assumed to be committed to repay are too optimistic. Moreover, the representative-agent assumption is also likely to lead to optimistic estimates of sustainable debt, because models in this class abstract from the strong incentives to use debt default as a tool for redistribution across heterogeneous agents. A second important insight from the

domestic default approach is that sustainable debt is higher if the government's payoff function weighs the welfare of bond holders more heavily than their share of the wealth distribution. In addition, it is possible that low-wealth agents may also prefer that the government weights high-wealth agents more heavily, instead of acting as a utilitarian government, because higher debt stocks help relax their liquidity constraints.

The three approaches reviewed in this chapter provide useful tools for conducting debt sustainability analysis. When applied to the current fiscal situation of advanced economies, all three suggest that substantial fiscal adjustment is still needed, is likely to entail substantial welfare costs, and is likely to continue to be challenged by potential default risk in domestic sovereign debt markets.

## APPENDIX: DETAILS ON MEASUREMENT OF EFFECTIVE TAX RATES

Effective tax rates have been widely used in a number of studies including Carey and Tchilinguirian (2000), Sorensen (2001), and recently by Trabandt and Uhlig (2011, 2012). The MRT methodology uses the wedge between reported pretax and post-tax macro estimates of consumption, labor income and capital income to estimate the effective tax rate levied on each of the three tax bases. This methodology has two main advantages. First, it provides a fairly simple approach to estimating effective tax rates at the macro level using readily available data, despite the complexity of the various credits and deductions of national tax codes. Second, these tax rates correspond directly to the tax rates in a wide class of representative-agent models with taxes on consumption and factor incomes, including the model proposed here. The main drawback of the MRT tax rates is that they are average, not marginal, tax rates, but because they are intended for use in representative-agent models, this disadvantage is less severe than it would be in a model with heterogeneous agents. Moreover Mendoza et al. (1994) show that existing estimates of aggregate marginal tax rates have a high time-series correlation with the MRT effective tax rates, and that both have similar cross-country rankings.

Following Trabandt and Uhlig (2011), we modify the MRT estimates of labor and capital taxes by adding supplemental wages (ie, employers' contributions to social security and private pension plans) to the tax base for personal income taxes. These data were not available at the time of the MRT 1994 calculations and, because this adjustment affects the calculation of the personal income tax rate, which is an initial step for the calculation of labor and capital income tax rates, it alters the estimates of both. In general, this adjustment makes the labor tax base bigger and therefore the labor tax rate smaller than the MRT original estimates.<sup>bh</sup>

<sup>bh</sup> Trabandt and Uhlig make a further adjustment to the MRT formulae by attributing some of the operating surplus of corporations and nonincorporated private enterprises to labor, with the argument that this represents a return to entrepreneurs rather than to capital. We do not make this modification because the data do not provide enough information to determine what fraction of the operating surplus should be allocated to labor.

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