



## The Laffer curve revisited

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### ABSTRACT

Laffer curves for the US, the EU-14 and individual European countries are compared, using a neoclassical growth model featuring “constant Frisch elasticity” (CFE) preferences. New tax rate data is provided. The US can maximally increase tax revenues by 30% with labor taxes and 6% with capital taxes. We obtain 8% and 1% for the EU-14. There, 54% of a labor tax cut and 79% of a capital tax cut are self-financing. The consumption tax Laffer curve does not peak. Endogenous growth and human capital accumulation affect the results quantitatively. Household heterogeneity may not be important, while transition matters greatly.

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### 1. Introduction

How far are we from the slippery slope? How do tax revenues and production adjust, if labor or capital income taxes are changed? To answer these questions, Laffer curves for labor and capital income taxation are characterized quantitatively for the US, the EU-14 aggregate economy (i.e. excluding Luxembourg) and individual European countries by comparing the balanced growth paths of a neoclassical growth model, as tax rates are varied. The government collects distortionary taxes on labor, capital and consumption and issues debt to finance government consumption, lump-sum transfers and debt repayments.

A preference specification is employed which is consistent with long-run growth and features a constant Frisch elasticity of labor supply, originally proposed by King and Rebelo (1999). We call these CFE (constant Frisch elasticity) preferences. A characterization and proof is provided as well as an exploration of the implications for the cross elasticity of consumption and labor as emphasized by Hall (2009). This is an additional and broadly useful contribution.

For the benchmark calibration with a Frisch elasticity of 1 and an intertemporal elasticity of substitution of 0.5, the US can increase tax revenues by 30% by raising labor taxes and 6% by raising capital income taxes, while the same numbers for the EU-14 are 8% and 1%. Furthermore the degree of self-financing of tax cuts is calculated and a sensitivity analysis for the parameters is provided. To provide this analysis requires values for the tax rates on labor, capital and consumption. Following Mendoza et al. (1994), new data for these tax rates in the US and individual EU-14 countries are calculated and provided for the years 1995–2007: these too should be useful beyond the question investigated in this paper.

In 1974 Arthur B. Laffer noted during a business dinner that “there are always two tax rates that yield the same revenues”, see Wanniski (1978). Subsequently, the incentive effects of tax cuts was given more prominence in political discussions and political practice. The present paper documents that there is a Laffer curve in standard neoclassical growth

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models with respect to both capital and labor income taxation. According to the quantitative results, Denmark and Sweden indeed are on the “wrong” side of the Laffer curve for capital income taxation.

Care needs to be taken in interpreting these results. Maximizing tax revenues is quite different from maximizing welfare. The higher the level of distortionary taxes in the model, the higher are the efficiency losses associated with taxation. If government consumption is not valued by households or constant, welfare losses increase with the level of taxation in the model. In an alternative model framework, [Braun and Uhlig \(2006\)](#) demonstrate that increasing taxes and wasting the resulting tax revenues may even improve welfare. If government consumption is valued by households and adjusts endogenously with the level of revenues, higher taxes might increase welfare, depending on the degree of valuation. An explicit welfare analysis is beyond the scope of this paper and not its point. Rather, the focus is on the impact on government tax receipt, as a question of considerable practical interest.

Following [Mankiw and Weinzierl \(2006\)](#), we pursue a dynamic scoring exercise. That is, it is analyzed by how much a tax cut is self-financing if incentive feedback effects are taken into account. The paper documents that for the US model 32% of a labor tax cut and 51% of a capital tax cut are self-financing in the steady state. In the EU-14 economy 54% of a labor tax cut and 79% of a capital tax cut are self-financing.

It is shown that the fiscal effect is indirect: by cutting capital income taxes, the biggest contribution to total tax receipts comes from an increase in labor income taxation. Moreover, lowering the capital income tax as well as raising the labor income tax results in higher tax revenue in both the US and the EU-14, i.e. in terms of a “Laffer hill”, both the US and the EU-14 are on the wrong side of the peak with respect to their capital tax rates. By contrast, the Laffer curve for consumption taxes does not have a peak and is increasing in the consumption tax throughout, converging to a positive finite level when consumption tax rates approach infinity. While the allocation depends on the joint tax wedge created by consumption and labor taxes, the Laffer curves do not. This turns out to be a matter of “accounting”: since tax revenues are used for transfers, they are consumption-taxed in turn.

We derive conditions under which household heterogeneity does not affect the results much. However, transition effects matter: a permanent surprise increase in capital income taxes always raises tax revenues for the benchmark calibration. Finally, endogenous growth and human capital accumulation locates the US and EU-14 close to the peak of the labor income tax Laffer curve. As labor taxes are increased, incentives to enjoy leisure are increased, which in turn decreases the steady state level of human capital or the growth rate of the economy: tax revenues fall as a result.

There is a considerable literature on this topic: the contribution of the present paper differs from the existing results in several dimensions. [Baxter and King \(1993\)](#) employ a neoclassical growth model with productive government capital to analyze the effects of fiscal policy. [Lindsey \(1987\)](#) has measured the response of taxpayers to the US tax cuts from 1982 to 1984 empirically, and has calculated the degree of self-financing. [Schmitt-Grohe and Uribe \(1997\)](#) show that there exists a Laffer curve in a neoclassical growth model, but focus on endogenous labor taxes to balance the budget, in contrast to the analysis here. [Ireland \(1994\)](#) shows that there exists a dynamic Laffer curve in an AK endogenous growth model framework, see also [Bruce and Turnovsky \(1999\)](#) and [Novales and Ruiz \(2002\)](#). In an overlapping generations framework, [Yanagawa and Uhlig \(1996\)](#) show that higher capital income taxes may lead to faster growth, in contrast to the conventional economic wisdom. [Flodén and Lindé \(2001\)](#) contains a Laffer curve analysis. [Jonsson and Klein \(2003\)](#) calculate the total welfare costs of distortionary taxes including inflation and find Sweden to be on the slippery slope side of the Laffer curve for several tax instruments.

The present paper is closely related to [Prescott \(2002, 2004\)](#), who raised the issue of the incentive effects of taxes by comparing the effects of labor taxes on labor supply for the US and European countries. That analysis is broadened here by including incentive effects of labor and capital income taxes in a general equilibrium framework with endogenous transfers. His work has been discussed by e.g. [Ljungqvist and Sargent \(2007\)](#) as well as [Alesina et al. \(2006\)](#).

Like [Baxter and King \(1993\)](#) or [McGrattan \(1994\)](#), it is assumed that government spending may be valuable only insofar as it provides utility separably from consumption and leisure.

The paper is organized as follows. We specify the model in [Section 2](#) and its parameterization in [Section 3](#). [Section 4](#) discusses the baseline results. The effects of endogenous growth and human capital accumulation, household heterogeneity and transition issues are considered in [Sections 5–7](#). Finally, [Section 8](#) concludes. The supplementary documentation to this paper provides proofs, material on the CFE preferences, analytical versions of the Laffer curves, details on the calibration, the tax rate tables, raw data, comparison of the model to the data and MATLAB programs that can be used to replicate the results of this paper.<sup>1</sup>

## 2. The model

Time is discrete,  $t = 0, 1, \dots, \infty$ . The representative household maximizes the discounted sum of life-time utility subject to an intertemporal budget constraint and a capital flow equation. Formally,

$$\max_{c_t, n_t, k_t, x_t, b_t} E_0 \sum_{t=0}^{\infty} \beta^t [u(c_t, n_t) + v(g_t)]$$

<sup>1</sup> MATLAB programs and data can be downloaded from the following URL: <https://sites.google.com/site/mathiastrabandt/home/downloads/LafferDataAndCode.zip>.

subject to

$$\begin{aligned} (1 + \tau_t^c)c_t + x_t + b_t &= (1 - \tau_t^n)w_t n_t + (1 - \tau_t^k)(d_t - \delta)k_{t-1} + \delta k_{t-1} + R_t^b b_{t-1} + s_t + \Pi_t + m_t \\ k_t &= (1 - \delta)k_{t-1} + x_t \end{aligned} \tag{1}$$

where  $c_t, n_t, k_t, x_t, b_t, m_t$  denote consumption, hours worked, capital, investment, government bonds and an exogenous stream of payments. The household takes government consumption  $g_t$ , which provides utility, as given. Further, the household receives wages  $w_t$ , dividends  $d_t$ , profits  $\Pi_t$  from the firm and asset payments  $m_t$ . Moreover, the household obtains interest earnings  $R_t^b$  and lump-sum transfers  $s_t$  from the government. The household has to pay consumption taxes  $\tau_t^c$ , labor income taxes  $\tau_t^n$  and capital income taxes  $\tau_t^k$ . Note that capital income taxes are levied on dividends net-of-depreciation as in Prescott (2002, 2004) and in line with Mendoza et al. (1994).

The payments  $m_t$  are income from an exogenous asset or “tree”. We allow  $m_t$  to be negative and thereby allow the asset to be a liability. This feature captures a negative or positive trade balance, equating  $m_t$  to net imports, and introduces international trade in a minimalist way. In the balanced growth path equilibria, this model is therefore consistent with an open-economy interpretation with source-based capital income taxation, where the rest of the world grows at the same rate and features households with the same time preferences. The trade balance influences the reaction of steady state labor to tax changes and therefore the shape of the Laffer curve. It is beyond the scope of this paper to provide a genuine open economy analysis.

The representative firm maximizes profits

$$\max_{k_{t-1}, n_t} y_t - d_t k_{t-1} - w_t n_t \tag{2}$$

with the Cobb–Douglas production technology,  $y_t = \zeta^t k_{t-1}^\theta n_t^{1-\theta}$ , where  $\zeta^t$  denotes the trend of total factor productivity. The government faces the budget constraint,

$$g_t + s_t + R_t^b b_{t-1} = b_t + T_t \tag{3}$$

where government tax revenues are given by

$$T_t = \tau_t^c c_t + \tau_t^n w_t n_t + \tau_t^k (d_t - \delta) k_{t-1} \tag{4}$$

It is the goal to analyze how the equilibrium shifts, as tax rates are shifted. More generally, the tax rates may be interpreted as wedges as in Chari et al. (2007), and some of the results in this paper carry over to that more general interpretation. What is special to the tax rate interpretation and crucial to the analysis in this paper, however, is the link between tax receipts and transfers (or government spending) via the government budget constraint.

The paper focuses on the comparison of balanced growth paths. It is assumed that  $m_t = \psi^t \bar{m}$  where  $\psi$  is the growth factor of aggregate output. A key assumption is that government debt as well as government spending do not deviate from their balanced growth paths, i.e.  $b_{t-1} = \psi^t \bar{b}$  and  $g_t = \psi^t \bar{g}$ . When tax rates are shifted, government transfers adjust according to the government budget constraint (3), rewritten as  $s_t = \psi^t \bar{b} (\psi - R_t^b) + T_t - \psi^t \bar{g}$ . As an alternative, transfers are kept on the balanced growth path and government spending is adjusted instead.

### 2.1. The constant Frisch elasticity (CFE) preferences

A crucial parameter in the analysis will be the Frisch elasticity of labor supply,  $\varphi = (dn/dw)w/n|_{\bar{u}_c}$ . In order to understand the role of this elasticity most cleanly, it is natural to focus on preferences which feature a constant Frisch elasticity, regardless of the level of consumption or labor. Moreover, these preferences need to be consistent with balanced growth. We shall call preferences with these features “constant Frisch elasticity” preferences or CFE preferences. The following result has essentially been stated in King and Rebelo (1999), Eq. (6.7) as well Shimer (2009), but without a proof. A proof is provided in Section 2.2.

**Proposition 1.** *Suppose preferences are separable across time with a twice continuously differentiable felicity function  $u(c, n)$ , which is strictly increasing and concave in  $c$  and  $-n$ , discounted a constant rate  $\beta$ , consistent with long-run growth and feature a constant Frisch elasticity of labor supply  $\varphi$ , and suppose that there is an interior solution to the first-order condition. Then, the preferences feature a constant intertemporal elasticity of substitution  $1/\eta > 0$  and are given by*

$$u(c, n) = \log(c) - \kappa n^{1+1/\varphi} \tag{5}$$

if  $\eta = 1$  and by

$$u(c, n) = \frac{1}{1-\eta} (c^{1-\eta} (1-\kappa(1-\eta)n^{1+1/\varphi})^\eta - 1) \tag{6}$$

if  $\eta > 0, \eta \neq 1$ , where  $\kappa > 0$ , up to affine transformations. Conversely, this felicity function has the properties stated above.

Hall (2009) has recently emphasized the importance of the Frisch demand for consumption  $c = c(\lambda, w)$  and the Frisch labor supply  $n = n(\lambda, w)$ , resulting from the usual first-order conditions and the Lagrange multiplier  $\lambda$  on the budget constraint, see (11) and (12). His work has focussed attention in particular on the cross-elasticity between consumption and wages. That elasticity is generally not constant for CFE preferences. In the supplementary documentation, it is

shown that

$$\text{cross-elasticity of consumption w.r.t. wages} = (1 + \varphi) \left( 1 - \frac{1}{\eta} \right) (\alpha \bar{c}/\bar{y})^{-1} \tag{7}$$

in the model along the balanced growth path, with  $\alpha$  given in (17). The cross-elasticity is positive, iff  $\eta > 1$ . This cross-elasticity is calculated to be 0.4 for the US and 0.3 for the EU-14 for the benchmark calibration  $\varphi = 1, \eta = 2$ . This is in line with Hall (2009).

As an alternative, the paper also uses the Cobb–Douglas preference specification

$$u(c_t, n_t) = \sigma \log(c_t) + (1 - \sigma) \log(1 - n_t) \tag{8}$$

as it is an important and widely used benchmark, see e.g. Cooley and Prescott (1995). Here, the Frisch elasticity is given by  $1/n_t - 1$  and therefore decreases with increasing labor supply.

### 2.2. Proof of Proposition 1

**Proof.** King et al. (2001) have shown that consistency with long-run growth implies that the preferences feature a constant intertemporal elasticity of substitution  $1/\eta > 0$  and are of the form

$$u(c, n) = \log(c) - \nu(n) \tag{9}$$

if  $\eta = 1$  and

$$u(c, n) = \frac{1}{1 - \eta} (c^{1 - \eta} \nu(n) - 1) \tag{10}$$

where  $\nu(n)$  is increasing (decreasing) in  $n$  iff  $\eta > 1$  ( $\eta < 1$ ). We concentrate on the second equation. Interpret  $w$  to be the net-of-the-tax-wedge wage, i.e.  $w = ((1 - \tau^n)/(1 + \tau^c))\tilde{w}$ , where  $\tilde{w}$  is the gross wage and where  $\tau^n$  and  $\tau^c$  are the (constant) tax rates on labor income and consumption. Taking the first-order conditions with respect to a budget constraint,

$$c + \dots = wn + \dots$$

the following two first-order conditions are obtained:

$$\lambda = c^{-\eta} \nu(n), \tag{11}$$

$$-(1 - \eta)\lambda w = c^{1 - \eta} \nu'(n). \tag{12}$$

Use (11) to eliminate  $c^{1 - \eta}$  in (12), resulting in

$$-\frac{1 - \eta}{\eta} \lambda^{1/\eta} w = \frac{1}{\eta} \nu'(n) (\nu(n))^{1/\eta - 1} = \frac{d}{dn} (\nu(n))^{1/\eta}. \tag{13}$$

The constant elasticity  $\varphi$  of labor with respect to wages implies that  $n$  is positively proportional to  $w^\varphi$ , for  $\lambda$  constant.<sup>2</sup> Write this relationship and the constant of proportionality conveniently as  $w = \xi_1 \eta \lambda^{-1/\eta} (1 + \frac{1}{\varphi}) n^{1/\varphi}$  for some  $\xi_1 > 0$ , which may depend on  $\lambda$ . Substitute this equation into (13). With  $\lambda$  constant, integrate the resulting equation to obtain

$$\xi_0 - \xi_1 (1 - \eta) n^{1/\varphi + 1} = \nu(n)^{1/\eta} \tag{14}$$

for some integrating constant  $\xi_0$ . Note that  $\xi_0 > 0$  in order to assure that the left-hand side is positive for  $n=0$ , as demanded by the right-hand side. Furthermore, as  $\nu(n)$  cannot be a function of  $\lambda$ , the same must be true of  $\xi_0$  and  $\xi_1$ . Up to a positive affine transformation of the preferences, one can therefore choose  $\xi_0 = 1$  and  $\xi_1 = \kappa$  for some  $\kappa > 0$  wlog. Extending the proof to the case  $\eta = 1$  is straightforward.  $\square$

### 2.3. Equilibrium

In equilibrium the household chooses plans to maximize its utility, the firm solves its maximization problem and the government sets policies that satisfy its budget constraint. In what follows, key balanced growth relationships of the model that are necessary for computing Laffer curves are summarized. Except for hours worked, interest rates and taxes all other variables grow at a constant rate  $\psi = \xi^{1/(1 - \theta)}$ . For CFE preferences, the balanced growth after-tax return on any asset is  $\bar{R} = \psi^n / \beta$ . It is assumed throughout that  $\xi \geq 1$  and that parameters are such that  $\bar{R} > 1$ , but  $\beta$  is not necessarily restricted to be less than one. Let  $\bar{k}/\bar{y}$  denote the balanced growth path value of the capital–output ratio  $k_{t-1}/y_t$ . In the model, it is given by

$$\bar{k}/\bar{y} = \left( \frac{\bar{R} - 1}{\theta(1 - \tau^k)} + \frac{\delta}{\theta} \right)^{-1}. \tag{15}$$

<sup>2</sup> The authors are grateful to Robert Shimer, who pointed out this simplification of the proof.

Labor productivity and the before-tax wage level are given by

$$\frac{y_t}{\bar{n}} = \psi^t k/y^{\theta/(1-\theta)} \quad \text{and} \quad w_t = (1-\theta) \frac{y_t}{\bar{n}}.$$

This provides the familiar result that the balanced growth capital–output ratio and before-tax wages only depend on policy through the capital income tax  $\tau^k$ , decreasing monotonically, and depend on preference parameters only via  $\bar{R}$ . It also implies that the tax receipts from capital taxation and labor taxation relative to output are given by these tax rates times a relative-to-output tax base which only depends on the capital income tax rate.

It remains to solve for the level of equilibrium labor. Let  $\bar{c}/\bar{y}$  denote the balanced growth path ratio  $c_t/y_t$ . With the CFE preference specification and along the balanced growth path, the first-order conditions of the household and the firm imply

$$(\eta \kappa \bar{n}^{1+1/\varphi})^{-1} + 1 - \frac{1}{\eta} = \alpha \bar{c}/\bar{y} \tag{16}$$

where

$$\alpha = \left( \frac{1 + \tau^c}{1 - \tau^n} \right) \left( \frac{1 + \frac{1}{\varphi}}{1 - \theta} \right) \tag{17}$$

depends on tax rates, the labor share and the Frisch elasticity of labor supply.

#### 2.4. Characterizing s-Laffer curves

For the benchmark s-Laffer curves, transfers  $\bar{s}$  are varied and government spending  $\bar{g}$  is fixed. The feasibility constraint implies

$$\bar{c}/\bar{y} = \chi + \gamma \frac{1}{\bar{n}} \tag{18}$$

where  $\chi = 1 - (\psi - 1 + \delta) \bar{k}/\bar{y}$  and  $\gamma = (\bar{m} - \bar{g}) \bar{k}/\bar{y}^{-\theta/(1-\theta)}$ . Substituting Eq. (18) into (16) therefore yields a one-dimensional nonlinear equation in  $\bar{n}$ , which can be solved numerically, given values for preference parameters, production parameters, tax rates and the levels of  $\bar{b}$ ,  $\bar{g}$  and  $\bar{m}$ .

**Proposition 2.** Assume that  $\bar{g} \geq \bar{m}$ . Then, the solution for  $\bar{n}$  is unique. It is decreasing in  $\tau^c$  or  $\tau^n$ , with  $\tau^k, \bar{b}, \bar{g}$  fixed.

The proof follows in a straightforward manner from examining the equations above. In particular, for constant  $\tau^k$  and  $\tau^c$ , there is a tradeoff as  $\tau^n$  increases: while equilibrium labor and thus the labor tax base decrease, the fraction taxed from that tax base increases. This tradeoff gives rise to the Laffer curve.

Similarly, and in the special case  $\bar{g} = \bar{m}$ ,  $\bar{n}$  falls with  $\tau^k$ , creating the same Laffer curve tradeoff for capital income taxation. Generally, the tradeoff for  $\tau^k$  appears to be hard to sign and we shall rely on numerical calculations instead.

#### 2.5. Characterizing g-Laffer curves

For the alternative g-Laffer curves, fix transfers  $\bar{s}$  and vary spending  $\bar{g}$ . Rewrite the budget constraint of the household as

$$\bar{c}/\bar{y} = \frac{\tilde{\chi}}{1 + \tau^c} + \frac{\tilde{\gamma}}{(1 + \tau^c) \bar{n}} \tag{19}$$

where  $\tilde{\chi} = 1 - (\psi - 1 + \delta) \bar{k}/\bar{y} - \tau^n (1 - \theta) - \tau^k (\theta - \delta) \bar{k}/\bar{y}$  and  $\tilde{\gamma} = (\bar{b}(\bar{R} - \psi) + \bar{s} + \bar{m}) \bar{k}/\bar{y}^{-\theta/(1-\theta)}$  can be calculated, given values for preference parameters, production parameters, tax rates and the levels of  $\bar{b}$ ,  $\bar{s}$  and  $\bar{m}$ . Note that  $\tilde{\chi}$  and  $\tilde{\gamma}$  do not depend on  $\tau^c$ .

To see the difference to the case of fixing  $\bar{g}$ , consider a simpler one-period model without capital and the budget constraint

$$(1 + \tau^c)c = (1 - \tau^n)wn + s. \tag{20}$$

Maximizing growth-consistent preferences, i.e.  $u(c,n) = (1/(1-\eta))(c^{1-\eta}v(n)-1)$  subject to this budget constraint, one obtains

$$(\eta - 1) \frac{v(n)}{nv'(n)} = 1 + \frac{s}{(1 - \tau^n)wn}. \tag{21}$$

If transfers  $s$  do not change with  $\tau^c$ , then consumption taxes do not change labor supply. Moreover, if transfers are zero,  $s=0$ , labor taxes do not have an impact either. In both cases, the substitution effect and the income effect exactly cancel just as they do for an increase in total factor productivity. This insight generalizes to the model at hand, albeit with some modification.

**Proposition 3.** Fix  $\bar{s}$ , and instead adapt  $\bar{g}$ , as the tax revenues change across balanced growth equilibria.

1. There is no impact of consumption tax rates  $\tau^c$  on equilibrium labor. As a consequence, tax revenues always increase with increased consumption taxes.
2. Suppose that  $0 = \bar{b}(\bar{R} - \psi) + \bar{s} + \bar{m}$ . Furthermore, suppose that labor taxes and capital taxes are jointly changed, so that  $\tau^n = \tau^k(1 - (\delta/\theta)k/y)$  where the capital–income ratio depends on  $\tau_k$  per (15). Equivalently, suppose that all income from labor and capital is taxed at the rate  $\tau_n$  without a deduction for depreciation. Then there is no change of equilibrium labor.

**Proof.** For the claim regarding consumption taxes, note that the terms  $(1 + \tau_c)$  for  $\bar{c}/y$  in (19) cancel with the corresponding term in  $\alpha$  in Eq. (16). For the claim regarding  $\tau_k$  and  $\tau_n$ , note that  $\tau^n = \tau^k(1 - (\delta/\theta)k/y)$  together with (15) implies

$$\bar{R} - 1 = (1 - \tau^k) \left( \frac{\theta}{k/y} - \delta \right) = (1 - \tau^n) \frac{\theta}{k/y} - \delta.$$

Then either by rewriting the budget constraint with an income tax  $\tau_n$  and calculating the consumption–output ratio or with  $\tilde{\chi} = (1 - \tau^n)(1 - \theta(\psi - 1 + \delta)/(\bar{R} - 1 + \delta))$  as well as  $\hat{y} = 0$ , one obtains that the right-hand side in Eq. (16) and therefore also  $\bar{n}$  remain constant, as tax rates are changed.  $\square$

The above discussion highlights in particular the importance of tax-unaffected income  $\bar{b}(\bar{R} - \psi) + \bar{s} + \bar{m}$  on equilibrium labor. It also highlights an important reason for including the trade balance in this analysis.

Given  $\bar{n}$ , it is then straightforward to calculate total tax revenue as well as government spending. Conversely, provided with an equilibrium value for  $\bar{n}$ , one can use Eq. (16) combined with Eq. (18) to find the value of the preference parameter  $\kappa$ , supporting this equilibrium. A similar calculation obtains for the Cobb–Douglas preference specification.

The supplementary documentation to this paper provides analytical characterizations and expressions for Laffer curves. The partial derivatives of total revenues are reasonably tractable. It is recommended to use a software capable of symbolic mathematics for further symbolic manipulations or numerical evaluations.

## 2.6. Consumption taxes

We calculate the slope of the  $s$ -consumption-tax Laffer curve and find that it approaches zero, as  $\tau_c \rightarrow \infty$ : the somewhat tedious details shall be left out here. Initially, this may be a surprising contrast to the calculations below showing a single-peaked  $s$ -Laffer curves in labor taxes: since the tradeoff between consumption and labor is determined by the wedge

$$\zeta = \frac{1 - \tau^n}{1 + \tau^c},$$

one might have expected these two Laffer curves to map into each other with some suitable transformation of the abscissa. However, while the allocation is a function of the tax wedge only, this is not the case for the tax revenues as given by the Laffer curves. This can perhaps best be appreciated in the simplest case of a one-period model, where agents have preferences given by  $\log(c) - n$ , facing the budget constraint (20) with wages  $w$  held constant throughout and with transfers  $s$  equal to tax receipts in equilibrium. It is easy to see that labor is equal to the tax wedge,  $n = \zeta = (1 - \tau^n)/(1 + \tau^c)$ , and that  $c = wn$ : so, consumption taxes and labor taxes have the same equilibrium tax base. The two Laffer curves are given by

$$L(x) = (\tau_c + \tau_n) \frac{1 - \tau^n}{1 + \tau^c} w$$

where  $x = \tau_c$  or  $x = \tau_n$  and they cannot be written in terms of just the tax wedge and wages alone. As a further simplification, assume  $w = 1$  and consider setting one of the two tax rates to zero: in that case, one achieves the same labor supply  $n = \zeta$  for  $\tau_n = 1 - \zeta$  and  $\tau_c = 0$  as well as for  $\tau_n = 0$  and  $\tau_c = 1/\zeta$ . For the first case, i.e. when varying labor taxes, the tax revenues are  $\zeta(1 - \zeta)$ , and have a peak at  $\zeta = n = 0.5$ . The tax revenues are  $1 - \zeta$  in the second case of varying consumption taxes, and are increasing to one, as the tax wedge  $\zeta$ , labor supply and therefore available resources fall to zero. Transfers approach one, but they are treated as income before consumption taxes: when the household attempts to consume this transfer income, it has to pay taxes approaching 100%, so that it is indeed left only with the resources originally produced.

This result is due to the tax treatment of transfer income, and one may wish to view this as a matter of “accounting”. Indeed, matters change, if the transfers were to be paid in kind, not in cash or if the agent did not have to pay consumption taxes on them. In that case, the Laffer curve would only depend on the tax wedge and wages, and would be given by  $L(\zeta) = (1 - \zeta)wn(\zeta)$ . In the model with capital and net imports, one would have to likewise exclude all other sources of income from consumption taxes along with the transfers, in order to have the Laffer curves in consumption taxes coincide with the Laffer curve in labor taxes, when written as a function of the tax wedge.

### 3. Calibration and parameterization

The model is calibrated to annual post-war data of the US and EU-14 economy. An overview of the calibration is provided in Tables 1 and 2.

We use data from the AMECO database of the European Commission, the OECD database, the Groningen Growth and Development Centre and Conference Board database and the BEA NIPA database. Mendoza et al. (1994) calculate average effective tax rates from national product and income accounts for the US. This paper follows their methodology to calculate tax rates from 1995 to 2007 for the US and 14 of the EU-15 countries, excluding Luxembourg for data availability reasons. The results largely agree with Carey and Rabesona (2004), who have likewise calculated tax rates from 1975 to 2000. The supplementary documentation to this paper provides the calculated panel of tax rates for labor, capital and consumption, details on the required tax rate calculations, the data used, details on the calibration and further discussion.

The empirical measure of government debt for the US as well as the EU-14 area provided by the AMECO database is nominal general government consolidated gross debt (excessive deficit procedure, based on ESA 1995) which is divided by nominal GDP. For the US the gross debt to GDP ratio is 63% in the sample. As an alternative, we also used 40%, as this is the ratio of government debt held by the public to GDP in the sample: none of the quantitative results change noticeably.

Most of the preference parameters are standard. Parameters are set such that the household chooses  $\bar{n} = 0.25$  in the US baseline calibration. This is consistent with evidence on hours worked per person aged 15–64 for the US. See the supplementary documentation for details.

For the intertemporal elasticity of substitution, a general consensus is followed for it to be close to 0.5 and therefore  $\eta = 2$  is set as a benchmark choice. The specific value of the Frisch labor supply elasticity is of central importance for the shape of the Laffer curve. In the case of the alternative Cobb–Douglas preferences the Frisch elasticity is given by  $(1 - \bar{n})/\bar{n}$  and equals 3 when  $\bar{n} = 0.25$ . This value is in line with e.g. Cooley and Prescott (1995) and Prescott (2002, 2004, 2006), while a value close to 1 as in Kimball and Shapiro (2008) may be closer to the current consensus view.

**Table 1**

Part 1 of the baseline calibration for the US and EU-14 benchmark model. All numbers are expressed in percent.

Variable	US	EU-14	Description	Restriction
$\tau^n$	28	41	Labor tax rate	Data
$\tau^k$	36	33	Capital tax rate	Data
$\tau^c$	5	17	Consumption tax rate	Data
$\bar{b}/\bar{y}$	63	65	Annual government debt to GDP	Data
$\bar{g}/\bar{y}$	18	23	Gov.consumption + invest. to GDP	Data
$\psi$	2	2	Annual balanced growth rate	Data
$\bar{R}-1$	4	4	Annual real interest rate	Data
$\bar{m}/\bar{y}$	4	-1	Net imports to GDP	Data
<i>Implied</i>				
$\bar{s}/\bar{y}$	8	15	Government transfers to GDP	
$\frac{\bar{b}/\bar{y}(\bar{R}-\psi)}{\bar{s}/\bar{y} + \bar{m}/\bar{y}}$	12	16	Untaxed income to GDP	

**Table 2**

Part 2 of the baseline calibration for the US and EU-14 benchmark model. IES denotes intertemporal elasticity of substitution. CFE refers to constant Frisch elasticity preferences.  $\bar{n}_{US}$  denotes balanced growth labor in the US which is set to 25% of total time.

Parameter	US	EU-14	Description	Restriction
$\theta$	0.38	0.38	Capital share in production	Data
$\delta$	0.07	0.07	Depreciation rate of capital	Data
<i>CFE preferences (Benchmark)</i>				
$\eta$	2	2	Inverse of IES	Data
$\varphi$	1	1	Frisch labor supply elasticity	Data
$\kappa$	3.46	3.46	Weight of labor	$\bar{n}_{US} = 0.25$
<i>CFE preferences (Alternative)</i>				
$\eta$	1	1	Inverse of IES	Data
$\varphi$	3	3	Frisch labor supply elasticity	Data
$\kappa$	3.38	3.38	Weight of labor	$\bar{n}_{US} = 0.25$
<i>Cobb–Douglas preferences</i>				
$\sigma$	0.32	0.32	Weight of consumption	$\bar{n}_{US} = 0.25$

**Table 3**

Individual country calibration of the benchmark model. Country codes: Germany (GER), France (FRA), Italy (ITA), United Kingdom (GBR), Austria (AUT), Belgium (BEL), Denmark (DNK), Finland (FIN), Greece (GRE), Ireland (IRL), Netherlands (NET), Portugal (PRT), Spain (ESP) and Sweden (SWE). See Table 1 for abbreviations of variables. All numbers are expressed in percent.

	$\bar{\tau}^n$	$\bar{\tau}^k$	$\bar{\tau}^c$	$\bar{b}/\bar{y}$	$\bar{m}/\bar{y}$	$\bar{g}/\bar{y}$	$\bar{s}/\bar{y}$ (Implied)
USA	28	36	5	63	4	18	8
EU-14	41	33	17	65	-1	23	15
GER	41	23	15	62	-3	21	15
FRA	46	35	18	60	-1	27	15
ITA	47	34	15	110	-2	21	19
GBR	28	46	16	44	2	21	13
AUT	50	24	20	65	-3	20	23
BEL	49	42	17	107	-4	24	21
DNK	47	51	35	50	-4	28	27
FIN	49	31	27	46	-8	24	22
GRE	41	16	15	100	10	20	15
IRL	27	21	26	43	-13	19	11
NET	44	29	19	58	-6	27	12
PRT	31	23	21	57	8	23	11
ESP	36	30	14	54	3	21	13
SWE	56	41	26	58	-7	30	21

Therefore  $\eta = 2$  and  $\varphi = 1$  are used as the benchmark calibration for the CFE preferences. For comparison  $\eta = 1$  and  $\varphi = 3$  for CFE preferences as well as a Cobb–Douglas specification are used. See the supplementary documentation for a further discussion about the details of the calibration choices.

### 3.1. EU-14 model and individual EU countries

As a benchmark, all other parameters are kept as in the US model, i.e. the parameters characterizing the growth rate as well as production and preferences. As a result, the differences between the US and the EU-14 are calculated as arising solely from differences in fiscal policy, see Table 3 for the country specific tax rates and GDP ratios. This corresponds to Prescott (2002, 2004) who argues that differences in hours worked between the US and Europe are due to different levels of labor income taxes.

In the supplementary documentation, we provide a comparison of predicted versus actual data for three key values: equilibrium labor and the capital- and consumption to GDP ratio. Discrepancies remain. While these are surely due to a variety of reasons, in particular e.g. institutional differences in the implementation of the welfare state, see e.g. Rogerson (2007) or Pissarides and Ngai (2009), variation in parameters across countries may be one of the causes. For example, Blanchard (2004) as well as Alesina et al. (2006) argue that differences in preferences as well as labor market regulations and union policies rather than different fiscal policies are key to understanding why hours worked have fallen in Europe compared to the US. To obtain further insight and to provide a benchmark, parameters are varied across countries in order to obtain a perfect fit to observations for these three key values plus also the investment to GDP ratio. Then these parameters are examined whether they are in a “plausible range”, compared to the US calibration. Finally, it is investigated how far the results for the impacts of fiscal policy are affected. It will turn out that the effect is modest, so that the conclusions may be viewed as fairly robust.

More precisely, averages of the observations on  $x_t/y_t$ ,  $k_{t-1}/y_t$ ,  $n_t$ ,  $c_t/y_t$ ,  $g_t/y_t$ ,  $m_t/y_t$  and tax rates as well as a common choice for  $\psi, \varphi, \eta$  are used to solve the equilibrium relationships  $x_t/k_{t-1} = \psi - 1 + \delta$  for  $\delta$ , (15) for  $\theta$ , (16) for  $\kappa$  and aggregate feasibility for a measurement error, which is interpreted as mismeasured government consumption (as this will not affect the allocation otherwise), keeping  $g/y$ ,  $m/y$  and the three tax rates calibrated as in the baseline calculations.

Table 4 provides the list of resulting parameters. Note that a larger value for  $\kappa$  is needed and thereby a greater preference for leisure in the EU-14 (in addition to the observed higher labor tax rates) in order to account for the lower equilibrium labor in Europe. Some of the implications are perhaps unconventional, however, and if so, this may indicate that alternative reasons are the source for the cross-country variations. For example, while Ireland is calculated to have one of the highest preferences for leisure, Greece appears to have one of the lowest.

## 4. Results

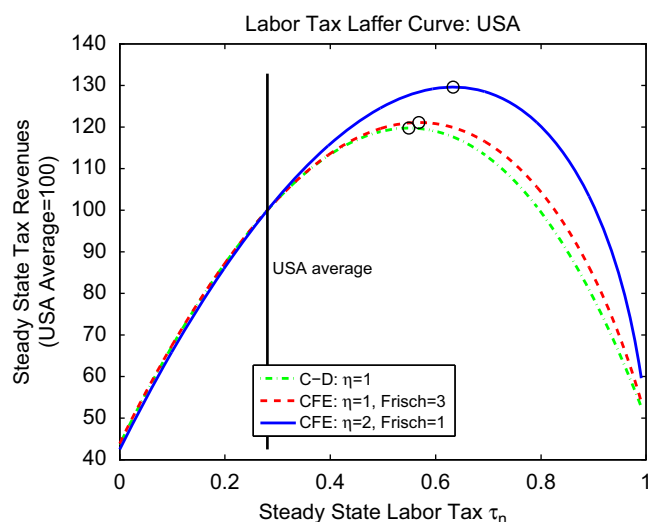
As a first check on the model, the measured and the model-implied sources of tax revenue are compared, relative to GDP. The precise numbers are available in the supplementary documentation. Due to the allocational distortions caused by the taxes, there is no a priori reason that these numbers should coincide. While the models overstate the taxes collected from labor income in the EU-14, they provide the correct numbers for revenue from capital income taxation, indicating that the methodology of Mendoza–Razin–Tesar is reasonably capable of delivering the appropriate tax burden on capital



**Table 4**

Parameter variations for individual countries that match observed data and benchmark model predictions for labor and capital-, investment- and consumption to GDP. Note that the individual country calibration displayed in Table 3 is imposed.  $\bar{g}_{ME}/\bar{y}$  denotes a measurement error on government consumption to GDP (expressed in percent). CFE preferences with  $\varphi = 1$  (Frisch elasticity of labor supply) and  $\eta = 2$  (inverse intertemporal elasticity of substitution) are assumed. See Table 2 for abbreviations of parameters.

	$\theta$	$\delta$	$\kappa$	$\bar{g}_{ME}/\bar{y}$
USA	0.35	0.083	3.619	0.4
EU-14	0.38	0.070	4.595	-1.7
GER	0.37	0.067	5.179	-0.2
FRA	0.41	0.069	5.176	0.4
ITA	0.39	0.070	5.028	0.4
GBR	0.36	0.064	4.385	0.5
AUT	0.39	0.071	3.985	0.6
BEL	0.39	0.084	5.136	0.5
DNK	0.40	0.092	3.266	0.7
FIN	0.34	0.070	3.935	1.4
GRE	0.40	0.061	3.364	-0.5
IRL	0.36	0.086	5.662	0.6
NET	0.38	0.077	5.797	0.1
PRT	0.39	0.098	3.391	0.5
ESP	0.42	0.085	5.169	0.3
SWE	0.36	0.048	2.992	0.4



**Fig. 1.** The US Laffer curve for labor taxes. Shown are steady state (balanced growth path) total tax revenues when labor taxes are varied between 0% and 100%. All other taxes and parameters are held constant. Total tax revenues at the US average labor tax rate are normalized to 100. Benchmark model results are provided for CFE (constant Frisch elasticity) preferences with a unit Frisch elasticity of labor supply and an inverse intertemporal elasticity of substitution,  $\eta = 2$ . For comparison, results are also provided for a different parameterization of CFE preferences as well as for Cobb–Douglas (C–D) preferences.

income, despite the difficulties of taxing capital income in practice. Further, hours worked are overstated while total capital is understated for the EU-14 by the model. With the parameter variation in Table 4, the model will match the data perfectly by construction. This applies similarly to individual countries. Generally, the numbers are roughly correct in terms of the order of magnitude, though, so we shall proceed with the analysis.

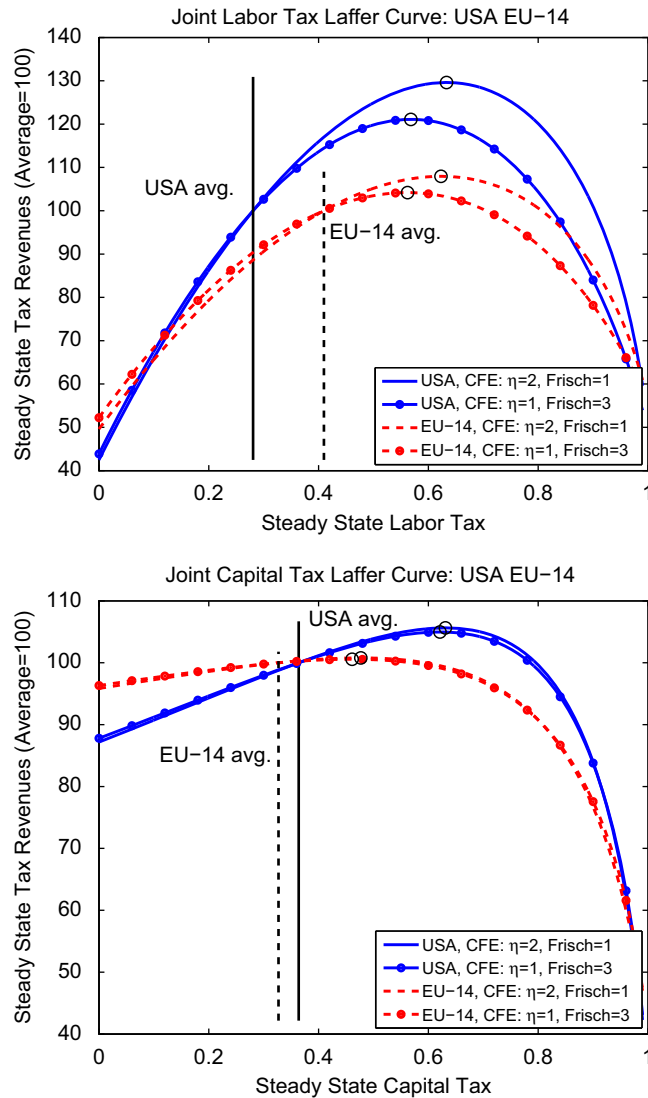
#### 4.1. Labor tax Laffer curves

The Laffer curve for labor income taxation in the US is shown in Fig. 1. In this experiment, labor taxes are varied between 0% and 100% and all other taxes, parameters and paths for government spending  $g$ , debt  $b$  and net imports  $m$  are held constant. Note that the CFE and Cobb–Douglas preferences coincide closely, if the intertemporal elasticity of substitution  $1/\eta$  and the Frisch elasticity of labor supply  $\varphi$  are the same at the benchmark steady state. Therefore, CFE preferences are close enough to the Cobb–Douglas specification, if  $\eta = 1$ , and provide a growth-consistent generalization, if  $\eta \neq 1$ .

**Table 5**

Labor tax Laffer curves: degree of self-financing, maximal tax rate, maximal additional tax revenues. Shown are results for the US and the EU-14, and the sensitivity of the results to changes in the CFE preference parameters  $\varphi$  (Frisch elasticity of labor supply) and  $\eta$  (inverse intertemporal elasticity of substitution) in the benchmark model. All results are expressed in percent.

Parameters	Percent self-financing		Maximal labor tax rate $\tau^l$		Max. additional tax revenue	
	US	EU-14	US	EU-14	US	EU-14
$\varphi = 1, \eta = 2$	32	54	63	62	30	8
$\varphi = 3, \eta = 1$	38	65	57	56	21	4
$\varphi = 3, \eta = 2$	49	78	52	51	14	2
$\varphi = 1, \eta = 2$	32	54	63	62	30	8
$\varphi = 0.5, \eta = 2$	21	37	72	71	47	17
$\varphi = 1, \eta = 2$	32	54	63	62	30	8
$\varphi = 1, \eta = 1$	27	47	65	65	35	10
$\varphi = 1, \eta = 0.5$	20	37	69	68	43	15



**Fig. 2.** Comparing the US and the EU-14 labor and capital tax Laffer curves. Shown are steady state (balanced growth path) total tax revenues when labor taxes (upper panel) or capital taxes (lower panel) are varied between 0% and 100%. All other taxes and parameters are held constant. Total tax revenues at the average tax rates are normalized to 100. Benchmark model results are provided for CFE (constant Frisch elasticity) preferences with a unit Frisch elasticity of labor supply and an inverse intertemporal elasticity of substitution,  $\eta = 2$ . For comparison, results are also provided for a different parameterization of CFE preferences.

For marginal rather than dramatic tax changes, the slope of the Laffer curve near the current data calibration is of interest. The slope is related to the degree of self-financing of a tax cut, defined as the ratio of additional tax revenues due to general equilibrium incentive effects and the lost tax revenues at constant economic choices. More formally and precisely, the degree of self-financing of a labor tax cut is calculated per

$$\text{self-financing rate} = 1 - \frac{1}{w_t \bar{n}} \frac{\partial T_t(\tau^n, \tau^k, \tau^c)}{\partial \tau^n} \approx 1 - \frac{1}{w_t \bar{n}} \frac{T_t(\tau^n + \epsilon, \tau^k, \tau^c) - T_t(\tau^n - \epsilon, \tau^k, \tau^c)}{2\epsilon}$$

where  $T(\tau^n, \tau^k, \tau^c)$  is the function of tax revenues across balanced growth equilibria for different tax rates, and constant paths for government spending  $g$ , debt  $b$  and net imports  $m$ . This self-financing rate is a constant along the balanced growth path, i.e. does not depend on  $t$ . The degree of self-financing of a capital tax cut can be calculated similarly.

These self-financing rates are calculated numerically as indicated by the second expression, with  $\epsilon$  set to 0.01 (and tax rates expressed as fractions). If there were no endogenous change of the allocation due to a tax change, the loss in tax revenue due to a one percentage point reduction in the tax rate would be  $w_t \bar{n}$ , and the self-financing rate would calculate to 0. At the peak of the Laffer curve, the tax revenue would not change at all, and the self-financing rate would be 100%. Indeed, the self-financing rate would become larger than 100% beyond the peak of the Laffer curve.

For labor taxes, Table 5 provides results for the self-financing rate as well as for the location of the peak of the Laffer curve for the benchmark calibration of the CFE preference parameters, as well as a sensitivity analysis. The peak of the Laffer curve shifts up and to the right, as  $\eta$  and  $\varphi$  are decreased. The dependence on  $\eta$  arises due to the nonseparability of preferences in consumption and leisure. Capital adjusts as labor adjusts across the balanced growth paths. See also the supplementary documentation for a graphical representation of this sensitivity analysis.

Table 5 also provides results for the EU-14: there is considerably less scope for additional financing of government revenue in Europe from raising labor taxes. For the preferred benchmark calibration with a Frisch elasticity of 1 and an intertemporal elasticity of substitution of 0.5, it is found that the US and the EU-14 are located on the left side of their Laffer curves, but while the US can increase tax revenues by 30% by raising labor taxes, the EU-14 can raise only an additional 8%.

To gain further insight, the upper panel of Fig. 2 compares the US and the EU Laffer curve, benchmarking both Laffer curves to 100% at the average tax rates.

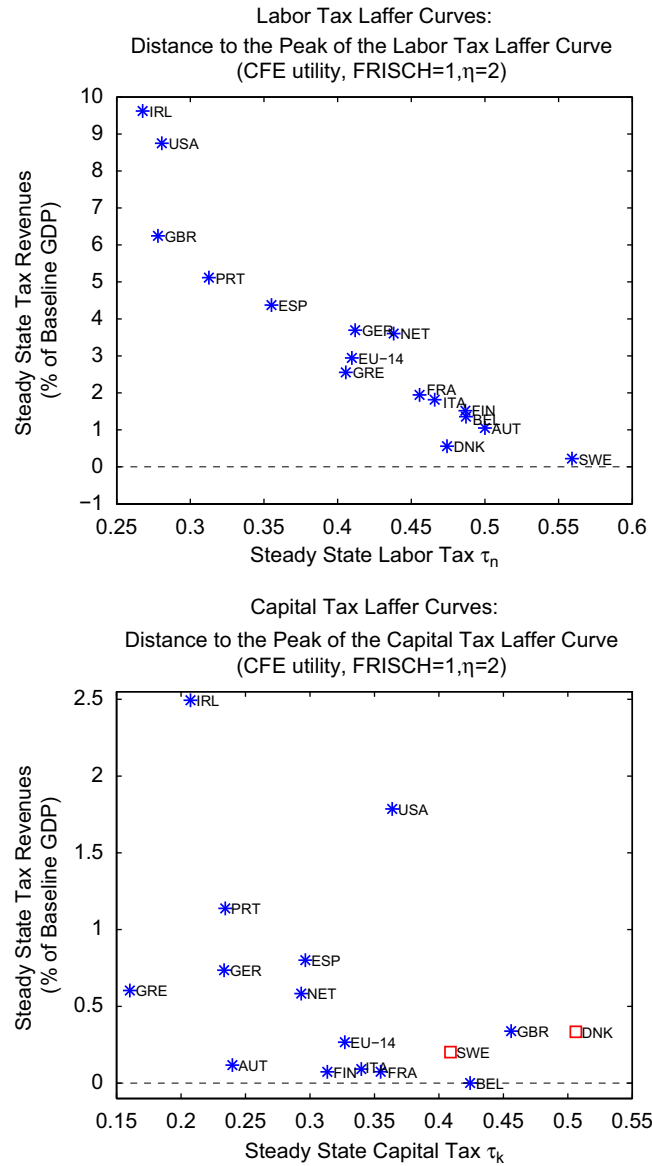
Table 6 as well as the top panel of Fig. 3 provide insight into the degree of self-financing as well as the location of the Laffer curve peak for individual countries, when varying them according to Table 4. The results for keeping parameters the same across countries are very similar.

It matters for the thought experiment here that the additional tax revenues are spent on transfers, and not on other government spending. For the latter, the substitution effect is mitigated by an income effect on labor: as a result the Laffer curve becomes steeper with a peak to the right and above the peak coming from a “labor tax for transfer” Laffer curve, see Fig. 4.

**Table 6**

Labor tax Laffer curves across countries for CFE preferences with  $\varphi = 1$  (Frisch elasticity of labor supply) and  $\eta = 2$  (inverse intertemporal elasticity of substitution): degree of self-financing, maximal tax rate, maximal additional tax revenues. Shown are results for keeping the same parameters for all countries and for varying the parameters so as to obtain observed labor and investment-, capital- and consumption to GDP ratio in the benchmark model, see Tables 3 and 4. All numbers are expressed in percent.

Parameters	Percent self-financing		Maximal labor tax rate $\tau^n$		Max. additional tax revenue	
	Same	Varied	Same	Varied	Same	Varied
USA	32	30	63	64	30	33
EU-14	54	55	62	61	8	7
GER	50	51	64	64	10	10
FRA	62	62	63	63	5	5
ITA	63	62	62	62	4	4
GBR	42	42	59	59	17	17
AUT	71	70	61	62	2	2
BEL	69	68	61	62	3	3
DNK	83	79	55	57	1	1
FIN	70	68	62	63	3	3
GRE	54	55	60	59	7	7
IRL	35	34	68	69	30	32
NET	53	53	67	67	9	9
PRT	45	44	59	60	14	15
ESP	46	46	62	62	13	13
SWE	83	86	63	61	1	0

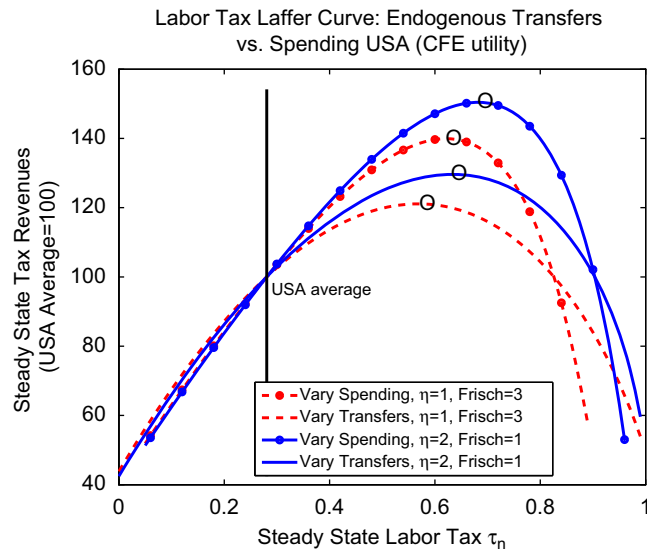


**Fig. 3.** Distances to the peak of the labor tax (upper panel) and capital tax (lower panel) Laffer curves across countries. The x-axes depict the observed tax rates (averages over time). The y-axes show the additional steady state (balanced growth path) tax revenues in percent of baseline GDP that would arise when a country moves to the peak of the Laffer curve. Stars denote countries that are to the left of the peak. Squares denote countries that are to the right of the peak. Benchmark model results are provided for CFE (constant Frisch elasticity) preferences with a unit Frisch elasticity of labor supply and an inverse intertemporal elasticity of substitution,  $\eta = 2$ . Tax rates, spending and parameters are varied across countries as provided in Tables 3 and 4.

4.2. Capital tax Laffer curves

The lower panel of Fig. 2 shows the Laffer curve for capital income taxation in the US, comparing it to the EU-14 and for two different parameter configurations, benchmarking both Laffer curves to 100% at the average capital tax rates. Numerical results are in Table 7. The figure already shows that the capital income tax Laffer curve is surprisingly invariant to variations of the CFE parameters. A more detailed comparison figure is available in the supplementary documentation to this paper. For the preferred benchmark calibration with a Frisch elasticity of 1 and an intertemporal elasticity of substitution of 0.5, we find that the US and the EU-14 are located on the left side of their Laffer curves, but the scope for raising tax revenues by raising capital income taxes are small: they are bound by 6% in the US and by 1% in the EU-14.

The cross-country comparison is in the lower panel of Fig. 3 and in Table 8. Several countries, e.g. Denmark and Sweden, show a degree of self-financing in excess of 100%: these countries are on the “slippery side” of the Laffer curve and can actually improve their budgetary situation by cutting capital taxes, according to the calculations. As one can see, the additional revenues that can be obtained from an increased capital income taxation are small, once the economy has



**Fig. 4.** Labor tax Laffer curve US: spending versus transfers. Shown are steady state (balanced growth path) total tax revenues when labor taxes are varied between 0% and 100% and either government transfers or government consumption adjust endogenously to balance the government budget. All other taxes and parameters are held constant. Total tax revenues at the US average labor tax rate are normalized to 100. Benchmark model results are provided for CFE (constant Frisch elasticity) preferences with a unit Frisch elasticity of labor supply and an inverse intertemporal elasticity of substitution,  $\eta = 2$ . For comparison, results are also provided for a different parameterization of CFE preferences.

**Table 7**

Capital tax Laffer curves: degree of self-financing, maximal tax rate, maximal additional tax revenues. Shown are results for the US and the EU-14, and the sensitivity of the results to changes in the CFE preference parameters  $\varphi$  (Frisch elasticity of labor supply) and  $\eta$  (inverse intertemporal elasticity of substitution) in the benchmark model. All results are expressed in percent.

Parameters	Percent self-financing		Maximal capital tax rate $\tau^k$		Max. additional tax revenue	
	US	EU-14	US	EU-14	US	EU-14
$\varphi = 1, \eta = 2$	51	79	63	48	6	1
$\varphi = 3, \eta = 1$	55	82	62	46	5	1
$\varphi = 3, \eta = 2$	60	87	60	44	4	0
$\varphi = 1, \eta = 2$	51	79	63	48	6	1
$\varphi = 0.5, \eta = 2$	45	73	64	50	7	1
$\varphi = 1, \eta = 2$	51	79	63	48	6	1
$\varphi = 1, \eta = 1$	48	77	64	49	6	1
$\varphi = 1, \eta = 0.5$	45	73	64	50	7	1

converged to the new balanced growth path. The key for capital income are transitional issues and the taxation of initially given capital: this issue is examined in Section 7.

It is instructive to investigate, why the capital Laffer curve is so flat e.g. in Europe. Fig. 5 shows a decomposition of the overall Laffer curve into its pieces: the reaction of the three tax bases and the resulting tax receipts. The labor tax base is falling throughout: as the incentives to accumulate capital are deteriorating, less capital is provided along the balanced growth equilibrium, and therefore wages fall. The capital tax revenue keeps rising quite far, though. Indeed, even the capital tax base  $(\theta - \delta k/y)\bar{y}$  keeps rising, as the decline in  $k/y$  numerically dominates the effect of the decline in  $\bar{y}$ . An important lesson to take away is therefore this: if one is interested in examining the revenue consequences of increased capital taxation, it is actually the consequence for labor tax revenues which is the “first-order” item to watch. This decomposition and insight shows the importance of keeping the general equilibrium repercussions in mind when changing taxes.

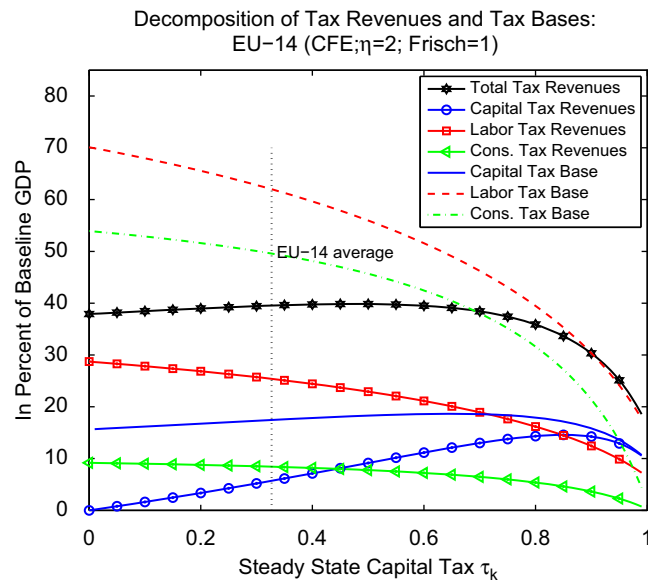
Table 9 summarizes the range of results of the sensitivity analysis both for labor taxes as well as capital taxes for the US and the EU-14 in the benchmark model.

Furthermore, one may be interested in the combined budgetary effect of changing labor and capital income taxation. This gets closer to the literature of Ramsey optimal taxation, to which this paper does not seek to make a contribution. But Fig. 6, providing the contour lines of a “Laffer hill”, nonetheless may provide some useful insights. As one compares balanced growth paths, it turns out that revenue is maximized when raising labor taxes but lowering capital taxes: the peak of the hill is in the lower right hand side corner of that figure. Indeed, many countries are on the “wrong” side of the “Laffer hill”, i.e. do not feature its peak in the northeast corner of that plot.

**Table 8**

Capital tax Laffer curves across countries for CFE preferences with  $\varphi = 1$  (Frisch elasticity of labor supply) and  $\eta = 2$  (inverse intertemporal elasticity of substitution): degree of self-financing, maximal tax rate, maximal additional tax revenues. Shown are results for keeping the same parameters for all countries and for varying the parameters so as to obtain observed labor and investment-, capital- and consumption to GDP ratio in the benchmark model, see Tables 3 and 4. All numbers are expressed in percent.

Parameters	Percent self-financing		Maximal capital tax rate $\tau^k$		Max. additional tax revenue	
	Same	Varied	Same	Varied	Same	Varied
USA	51	46	63	68	6	7
EU-14	79	80	48	47	1	1
GER	70	71	49	49	2	2
FRA	88	89	44	43	0	0
ITA	88	88	42	42	0	0
GBR	73	73	57	58	1	1
AUT	88	88	35	35	0	0
BEL	103	98	40	43	0	0
DNK	137	126	30	35	1	1
FIN	92	90	38	40	0	0
GRE	73	74	42	39	2	2
IRL	50	48	62	67	8	8
NET	75	74	50	52	1	1
PRT	65	61	50	55	3	3
ESP	68	67	52	53	2	2
SWE	109	116	33	29	0	0



**Fig. 5.** Decomposing capital taxes: EU-14. Shown are steady state (balanced growth path) total tax revenues, individual tax revenues and individual tax bases when capital taxes are varied between 0% and 100%. All other taxes and parameters are held constant. All numbers are expressed in percent of baseline GDP. Benchmark model results are provided for CFE (constant Frisch elasticity) preferences with a unit Frisch elasticity of labor supply and an inverse intertemporal elasticity of substitution,  $\eta = 2$ .

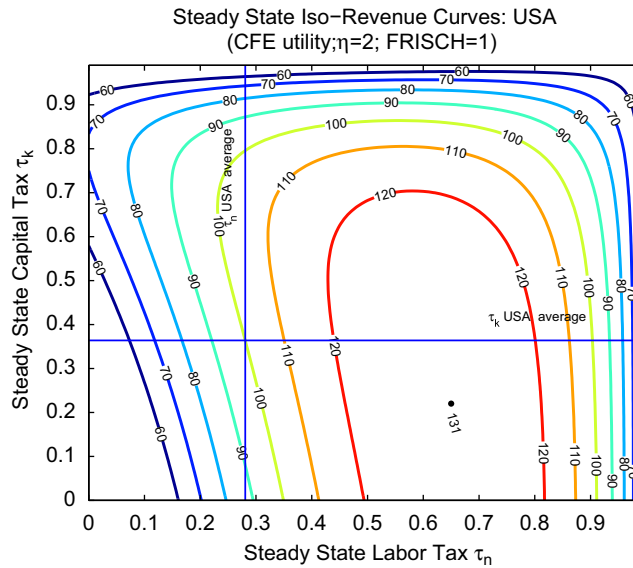
## 5. Endogenous growth and human capital accumulation

In the analysis, the comparison of long-run steady states has been emphasized. The macroeconomic literature on long-run phenomena generally emphasizes the importance of endogenous growth, see e.g. the textbook treatments of Jones (2001), Barro and Martin (2003) or Acemoglu (2008). While a variety of engines of growth have been analyzed, the accumulation of human capital appears to be particularly relevant for the analysis. In that case, labor income taxation actually amounts to the taxation of a capital stock, and this may potentially have a considerable effects on the results. While it is beyond the scope of this paper to analyze the many interesting possibilities, some insight into the issue can be obtained from the following specification incorporating learning-by-doing as well as schooling, following Lucas (1988) and Uzawa (1965). While first-generation endogenous growth models have stressed the endogeneity of the overall long-run

**Table 9**

Range of results for the parameter variations considered in the benchmark model, i.e. no human capital accumulation, no transition dynamics, no heterogeneity. All numbers are expressed in percent.

	US	EU-14
<i>Maximal additional tax revenues</i>		
Labor taxes	14–47	2–17
Capital taxes	4–7	0–1
<i>Maximizing tax rate</i>		
Labor taxes	52–72	51–71
Capital taxes	60–64	44–50
<i>Percent self-financing of a tax cut</i>		
Labor taxes	20–49	37–78
Capital taxes	45–60	73–87



**Fig. 6.** The “Laffer hill” for the US. Shown are steady state (balanced growth path) total tax revenues when capital taxes and labor taxes are varied between 0% and 100%. Consumption taxes and other parameters are held constant. Contour lines depict different levels of tax revenues. Total tax revenues at the average tax rates are normalized to 100. Benchmark model results are provided for CFE (constant Frisch elasticity) preferences with a unit Frisch elasticity of labor supply and an inverse intertemporal elasticity of substitution,  $\eta = 2$ .

growth rate, second-generation growth models have stressed potentially large level effects, without affecting the long-run growth rate. We shall provide an analysis, encompassing both possibilities.

Consider the following modification to the baseline model. Assume that human capital can be accumulated by both learning-by-doing as well as schooling. The agent splits total non-leisure time  $n_t$  into work-place labor  $q_t n_t$  and schooling time  $(1 - q_t)n_t$ , where  $0 \leq q_t \leq 1$ . Agents accumulate human capital according to

$$h_t = (Aq_t n_t + B(1 - q_t)n_t)^\omega h_{t-1}^{1-\Omega} + (1 - \delta_h)h_{t-1} \tag{22}$$

where  $A \geq 0$  and  $B > A$  parameterize the effectiveness of learning-by-doing and schooling respectively and where  $0 < \delta_h \leq 1$  is the depreciation rate of human capital. Furthermore, let  $\Omega = 0$  for the “first-generation” version and  $\Omega = \omega$  for the “second-generation” version of the model. For the “first-generation” version of the model, production is given by  $y_t = k_{t-1}^\theta (h_{t-1} q_t n_t)^{1-\theta}$  while it is given by  $y_t = \xi^t k_{t-1}^\theta (h_{t-1} q_t n_t)^{1-\theta}$  for the “second-generation” version. Note that non-leisure time  $n_t$  is multiplied by human capital  $h_{t-1}$  and the fraction  $q_t$  devoted to work-place labor. For both versions, wages are paid per unit of labor and human capital, i.e. with  $w_t = (1 - \theta)y_t / h_{t-1} q_t n_t$  so that the after-tax labor income is given by  $(1 - \tau_t^n)w_t h_{t-1} q_t n_t$ .

Consider the problem of a representative household. Let  $\lambda_t$  be the Lagrange multiplier for the budget constraint and let  $\mu_t$  be the Lagrange multiplier on the human accumulation constraint (22).

### 5.1. Analysis of “second-generation” case

We shall analyze the “second-generation” case first, as the algebra is somewhat simpler. Note that  $\mu_t = \bar{\mu}\psi^{(1-\eta)t}$  grows with the product of  $\lambda_t = \bar{\lambda}\psi^{-\eta t}$  and  $w_t = \bar{w}\psi^t$ , where  $\psi = \xi^{1/(1-\theta)}$ . The first-order condition with respect to human capital

along a balanced growth path can be written as

$$\bar{\mu} = \frac{(1-\tau^n)\bar{w}\bar{n}}{(\psi^{1-\eta}/\beta)-1+\omega\delta_h}\bar{\lambda}. \quad (23)$$

This equation has an intuitive appeal. Essentially, the shadow value of an extra unit of human capital corresponds to the discounted sum of the additional after-tax wage payments that it generates for the agent. Further, along a balanced growth path

$$\bar{h} = \delta_h^{-1/\omega}(B+(A-B)\bar{q})\bar{n}. \quad (24)$$

The first-order condition with respect to labor along the balanced growth path yields  $\bar{u}_n = (1-\tau^n)\bar{w}\bar{h}\bar{\lambda} + \omega\delta_h\bar{\mu}\bar{h}/\bar{n}$ , where the first term is as in the benchmark model, except for the additional factor  $\bar{h}$ , and the second term due to the consideration of accumulating human capital. With  $\bar{w}\bar{h}\bar{q}\bar{n} = (1-\theta)\bar{y}$  and in close similarity to (16), this implies

$$(\eta\kappa\bar{n}^{1+1/\varphi})^{-1} + 1 - \frac{1}{\eta} = \alpha''\bar{c}/\bar{y}, \quad (25)$$

where

$$\alpha'' = \left(\frac{1+\tau^c}{1-\tau^n}\right) \left(\frac{1+\frac{1}{\varphi}}{1-\theta}\right) \mathcal{G}'' \quad \text{with } \mathcal{G}'' = \frac{(\psi^{1-\eta}/\beta)-1+\omega\delta_h}{(\psi^{1-\eta}/\beta)-1+2\omega\delta_h}. \quad (26)$$

The Kuhn–Tucker condition for the split  $q_t$  along the balanced growth path yields  $\bar{q} = \min\{1; (B/(B-A))\mathcal{G}''\}$  after some algebra, and is independent of tax rates. As a check on the calculations, note that  $\alpha'' = \alpha$ , if  $\omega = 0$ , as indeed should be the case. For small values of  $\omega$ , the “correction” to  $\alpha$  is small too. Perhaps more importantly, note that  $\kappa$  in (16) as well as (25) should be calibrated so as to yield  $\bar{q}\bar{n}_{US} = 0.25$ . In particular, if  $\eta = 1$  and noting that the split  $\bar{q}$  of non-leisure time devoted to work–place labor remains constant, a proportional change in  $\alpha$  just leads to a similar proportional change in  $\kappa$ .

The key impact of taxation then lies in the impact of the level of human capital, per Eq. (24): all other equations remain essentially unchanged. Heuristically, as e.g. labor taxes are increased, non-leisure time is decreased, which in turn leads to a decrease in human capital. This in turn leads to a loss in tax revenue, compared to the benchmark case of no-human-capital accumulation. Put differently, the taxation of labor does not impact some intertemporal trade-off directly, as it appears to be the case for capital taxation, but rather “indirectly” via a level effect, as human capital is proportional to non-leisure time along the balanced growth path.

## 5.2. Analysis of “first-generation” case

The analysis of the “first-generation” case is rather similar. Along the balanced growth path

$$\frac{h_{t+1}}{h_t} \equiv (B+(A-B)\bar{q})^\omega \bar{n}^\omega + 1 - \delta_h = \psi, \quad (27)$$

where this equation now determines the economic growth rate  $\psi$ . Note that  $h_{t-1} = \psi^t \bar{h}$ , where we normalize  $\bar{h} = 1$ . Wages per unit of human capital do not grow, so that  $\mu_t = \bar{\mu}\psi^{-\eta t}$  grows with  $\lambda_t = \bar{\lambda}\psi^{-\eta t}$ , where  $\psi$  is now given by (27). The first-order condition with respect to human capital along a balanced growth path can be written as

$$\bar{\mu} = \frac{(1-\tau^n)\bar{w}\bar{n}}{\bar{R}-\psi}\bar{\lambda} \quad (28)$$

where  $\bar{R} = \psi^\eta/\beta$  as before, except that  $\psi$  is given per (27). The first-order condition with respect to labor along the balanced growth path yields  $\bar{u}_n = (1-\tau^n)\bar{w}\bar{\lambda}(1+\omega(\psi-1+\delta_h)/(\bar{R}-\psi))$ . In close similarity to (16) and (25), this implies

$$(\eta\kappa\bar{n}^{1+1/\varphi})^{-1} + 1 - \frac{1}{\eta} = \alpha'\bar{c}/\bar{y}, \quad (29)$$

where

$$\alpha' = \left(\frac{1+\tau^c}{1-\tau^n}\right) \left(\frac{1+\frac{1}{\varphi}}{1-\theta}\right) \mathcal{G}' \quad \text{with } \mathcal{G}' = \frac{\bar{R}-\psi}{\bar{R}-\psi+\omega(\psi-1+\delta_h)}. \quad (30)$$

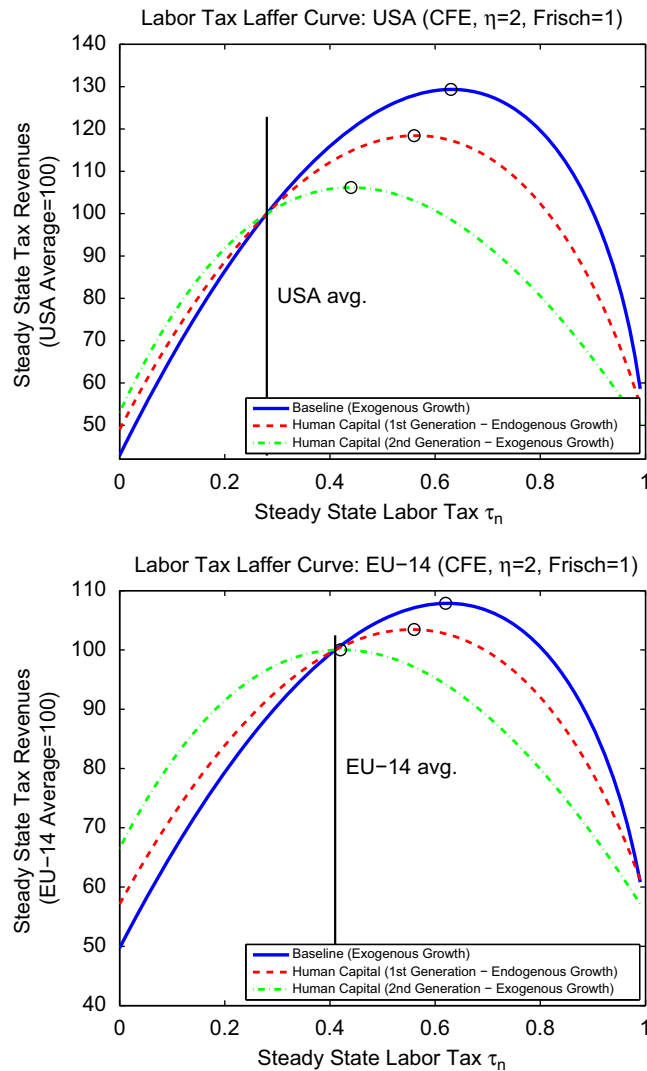
The first-order condition for the work–school split yields  $\bar{q} = \min\{1; (B/(B-A))\mathcal{G}'\}$ . One therefore reaches almost the same conclusions as in the “second-generation” formulation above, but there is a minor and a major difference. The minor difference concerns the last factor in (30) compared to the last factor in (26): they are numerically different. In the case that  $\eta = 1$ , and due to the necessity to calibrate  $\kappa$ , this does not make a difference. The major difference is the impact of labor supply on the endogenous growth rate per (27). For example, as the labor tax rate is changed, this leads to changes in labor supply, thereby to changes in the growth rate, the steady state return  $\bar{R}$ , and therefore to changes in the capital–output ratio per Eq. (15) and the consumption–output ratio, influencing in turn the coefficients in the equation for  $\bar{n}$  and



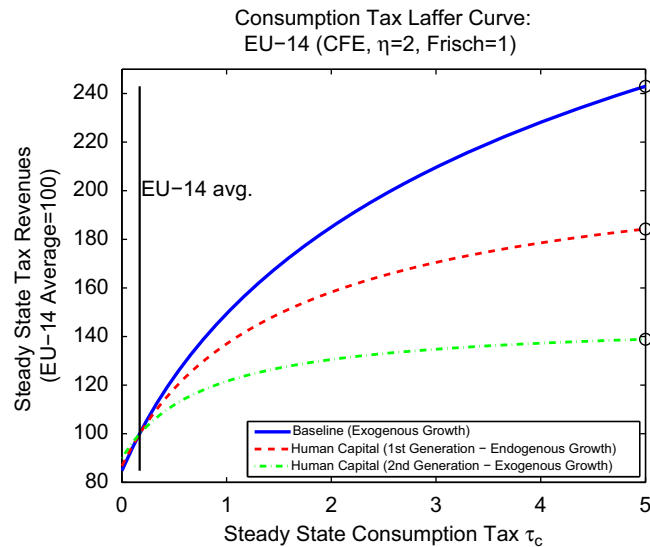
the solution for  $\bar{q}$ . This is a fixed point problem, which requires different algebra and additional analysis. While it may be of some interest to solve these equations and investigate the resulting numerical changes, it appears rather evident that the impact will be quantitatively small. First, the effect is truly indirect: except for the impact on the steady state return  $\bar{R}$  (and the numerical difference in the last factor of (30) vs (26), the analysis is exactly as above in the “second-generation” case. Second and empirically, little evidence has been found that taxation impacts on the long-run growth rate, see Levine and Renelt (1992). Thus, a sufficiently rich and appropriately calibrated extension of this “first-generation” version should feature at most a modest impact on the long-run growth rate in order to be in line with the available empirical evidence.

### 5.3. Quantitative implications of human capital

We examine the quantitative implications of human capital accumulation for the Laffer curves. To do so, the same calibration strategy for the initial steady state is applied as before, except assuming now  $\bar{q}_{US} = 0.25$ . Further,  $\omega = 0.5$  and  $\delta_h = \delta$  is set for simplicity.  $A$  is set such that initial  $\bar{q}_{US} = 0.8$ . In the first-generation model,  $B$  is set to imply an initial growth rate  $\psi_{US} = 1.02$ . In the second-generation model  $B$  is set to have  $h_{US} = 1$  initially. The top panel of Fig. 7 depicts the labor tax Laffer curve for the US with and without human capital accumulation. It turns out that the peak moves to the left



**Fig. 7.** Labor tax Laffer curves: the impact of endogenous human capital accumulation. Shown are steady state (balanced growth path) total tax revenues when labor taxes are varied between 0% and 100% in the US (upper panel) and EU-14 (lower panel). All other taxes and parameters are held constant. Total tax revenues at the average tax rates are normalized to 100. Three cases are examined. First, the benchmark model with exogenous growth. Second, the benchmark model with a first-generation version of endogenous human capital accumulation that gives rise to endogenous growth. Third, the benchmark model with a second-generation version of endogenous human capital accumulation that features exogenous growth. All results are provided for CFE (constant Frisch elasticity) preferences with a unit Frisch elasticity of labor supply and an inverse intertemporal elasticity of substitution,  $\eta = 2$ .



**Fig. 8.** Consumption tax Laffer curve in the EU-14: the impact of endogenous human capital accumulation. Shown are steady state (balanced growth path) total tax revenues when consumption taxes are varied between 0% and 500%. All other taxes and parameters are held constant. Total tax revenues at the EU-14 average consumption tax rate are normalized to 100. Three cases are examined. First, the benchmark model with exogenous growth. Second, the benchmark model with a first-generation version of endogenous human capital accumulation that gives rise to endogenous growth. Third, the benchmark model with a second-generation version of endogenous human capital accumulation that features exogenous growth. All results are provided for CFE (constant Frisch elasticity) preferences with a unit Frisch elasticity of labor supply and an inverse intertemporal elasticity of substitution,  $\eta = 2$ .

and the Laffer curve as such shifts down once human capital accumulation is accounted for. The second-generation model predicts larger deviations from the baseline model without human capital accumulation, than the first-generation version. Furthermore, while the second-generation version is rather insensitive to  $\eta$ , this is not so for the first-generation model. Indeed, for  $\eta = 1$ , the labor tax Laffer curve for the first-generation version actually exceeds the baseline version, and the peak moves to the right. Examination of the results for the first-generation version with  $\eta = 2$  reveals that raising labor taxes results in a modest fall of real interest rates, inducing households to substantially shift the fraction of non-leisure time away from work-place labor towards schooling, thereby accelerating human capital accumulation. Since this effect works only through the shift of long-term interest rates, we judge it to be implausibly large and lead us to favor the results from the second-generation version over the first-generation specification. The lower part of Fig. 7 also recalculates the labor tax Laffer curve for the EU-14 parameterization. Importantly and interestingly, the EU-14 is literally at the peak, given the second-generation version.

Fig. 8 compares the impact of human capital accumulation on consumption taxes: for illustration, consumption tax rates up to the surely unreasonably high level of 500% are shown. As explained at the end of Section 2.6, the allocation depends on the joint tax wedge created by consumption and labor taxes, while the Laffer curves do not: since tax revenues are used for transfers, which are then consumption-taxed in turn: as a result, the consumption tax Laffer curve keeps rising throughout. However, the human capital accumulation now has a rather dramatic effect on the scale of the Laffer curve: the higher tax wedge leads to lower human capital or less growth, and therefore, resources are lost overall. By contrast, the capital tax Laffer curves move little, when incorporating human capital accumulation in the model: their graphs are available in the supplementary documentation to this paper.

These results show that human capital accumulation is likely to have an important impact on tax revenues and the Laffer curve, especially for labor income taxes: for  $\eta = 2$  as well as other reasonable parameters, current labor tax rates appear to be considerably closer to the peak.

## 6. Heterogeneity and marginal tax rates

So far, a model with a representative agent, facing an affine-linear tax schedule has been considered. How much will the analysis be affected if agent heterogeneity and nonlinear tax schedules are incorporated? A full, quantitative analysis requires detailed knowledge about the distributions of incomes from various sources, tax receipts, labor supply elasticities and so forth. While desirable, this is beyond the scope of this paper. However, some insights can be provided, when imposing additional and appealing restrictions.

We shall consider two extensions of the baseline model to investigate this issue. For both, replace the assumption of the representative household with a population of heterogeneous and exogenously given human capital  $h$ . The aggregate distribution function for human capital  $h \geq 0$  shall be denoted with  $H$  and the normalization  $1 = \int hH(dh)$  shall be assumed. For other variables, the subscript  $h$  shall be used to denote the dependence on  $h$ . Variables without  $h$ -subscript

denote economy-wide averages. These averages shall normally be calculated per integrating across the population, with exceptions as noted. In particular, let  $\bar{n}$  denote the human-capital weighted average of individual labor supplies,  $\bar{n} = \int h\bar{n}_h H(dh)$  as this is the aggregate labor supply of relevance for the production function. Wages are paid per unit of time and unit of human capital, so that an agent of type  $h$  receives labor income  $w_t h n_{h,t}$  in period  $t$ , before paying labor income taxes.

6.1. Marginal tax rates depending on agent type

As a first extension, suppose that the agent “type”  $h$  is known to the government, and that the government sets a marginal labor income tax rate  $\tau_h^n$ , which differs across agent types. Thus, the after-tax labor income is  $(1 - \tau_h^n)w_t h n_{h,t}$ . The first-order conditions for consumption and labor are now changed, compared to the benchmark model. Detrend all variables appropriately to  $t=1$ . The first-order condition with respect to labor is  $\bar{u}_{n,h} = (1 - \tau_h^n)\bar{w}h\bar{\lambda}_h$  where it is useful to denote the additional factor  $h$ , compared to the benchmark model. Replacing  $(1 + \tau^c)\bar{\lambda}_h$  with  $\bar{u}_{c,h}$ , one obtains a version of Eq. (16):

$$(\eta\kappa\bar{n}_h^{1+1/\varphi})^{-1} + 1 - \frac{1}{\eta} = \alpha_h \frac{\bar{n}}{\bar{y}} \frac{\bar{c}_h}{h\bar{n}_h} \tag{31}$$

where  $\alpha_h$  is given by

$$\alpha_h = \left( \frac{1 + \tau^c}{1 - \tau_h^n} \right) \left( \frac{1 + \frac{1}{\varphi}}{1 - \theta} \right). \tag{32}$$

This model already features considerable complexity, and can be enriched even further, when also considering heterogeneity in wealth and transfers. The analysis simplifies considerably with the following high-level assumption however. Let  $z_h = \bar{c}_h / (1 - \tau_h^n)\bar{w}h\bar{n}_h$  be the ratio of consumption to after-tax labor income for an agent of type  $h$ , given tax rates.

**Assumption A.1.** Assume that the ratio  $z_h$  of consumption to after-tax labor income is constant across the population,  $z_h \equiv z$ , regardless of tax rates. I.e. the ratio  $z$  may change in the aggregate, as tax rates are changed, but not on the individual level.

This assumption is regarded as a benchmark and point of orientation for a richer analysis. The assumption is immediately appealing in a model without capital income and without transfers: in fact, there it must hold by construction. It is still appealing in the richer model here, if the distribution of wealth and transfers is “in line” with after-tax labor income. The assumption is appealing if all labor tax net factors  $(1 - \tau_h^n)$  change by a common factor, but not, if e.g. some  $\tau_h^n$  are changed, whereas others are not. While it may be interesting to derive specifications on primitives, which deliver Assumption A.1 as a result, rather than as assumption, we shall proceed without doing so.

The assumption directly implies that  $\bar{n}_h$  is constant across the population, given tax rates:  $\bar{n}_h \equiv \bar{n}$ . As another exception from the aggregation-per-integration rule, denote with  $\tau^n$  the human-capital weighted average of the individual labor income tax rates,

$$\tau^n = \int \tau_h^n h H(dh). \tag{33}$$

Indeed, this is the tax rate that is implicitly calculated in the empirical results in Section 4, as tax receipts are aggregated  $\tau_h^n h \bar{n}_h$  and not tax rates  $\tau_h^n$  across the population. Per integration of  $c_h = z((1 - \tau_h^n)\bar{w}h\bar{n}_h)$ , it is easy to see that  $\bar{c} = (1 - \tau^n)\bar{n}$ . With that, Eqs. (31) and (32) turn into Eq. (16), and the analysis therefore proceeds as there.

**Proposition 4.** *With Assumption A.1, the Laffer curves remain unchanged.*

An interesting alternative benchmark is provided by the following assumption, distinguishing between transfer receivers and tax payers, and replacing Assumption A.1:

**Assumption A.2.** Assume that the human capital distribution is constant between  $h_1 < h_2$ , i.e.  $\lim_{h > h_1, h \rightarrow h_1} H(h) = H(h_2)$ . For some range of taxes, assume that agents with  $h \leq h_1$  either choose not to work,  $\bar{n}_h = 0$ , or cannot generate labor income  $h=0$ , but are the receivers of all transfers.

In that case, one immediately gets

**Proposition 5.** *Impose Assumption A.2. Then, for the range of taxes of that assumption, the Laffer curves coincide with the Laffer curves obtained in the benchmark model for  $s=0$  and all additional revenues spent on  $g$ .*

From the perspective of the tax paying agents, the transfers to the transfer-receiving-only part of the population has the same allocational consequences as general government spending.

## 6.2. Marginal tax rates depending on net income

A second extension draws on [Heathcote et al. \(2010\)](#). These authors have recently pointed out that it may be reasonable to model the increase in the marginal tax rates as a constant elasticity of net income. To make their assumption consistent with the long-run growth economy here and to furthermore keep the analysis simple, suppose that net labor income is given by

$$(1-\tau^n)w\bar{n}^{1-v}(h\bar{n}_h)^v \quad (34)$$

for some general proportionality factor  $(1-\tau^n)w\bar{n}^{1-v}$  and some elasticity parameter  $v$ : [Heathcote et al. \(2010\)](#) estimate  $v = 0.74$ . The actual tax rate paid is therefore  $\tau_h^n = 1 - (1-\tau^n)\bar{n}^{1-v}(h\bar{n}_h)^{v-1} \rightarrow 1$  for  $h\bar{n}_h \rightarrow \infty$  and is actually negative for sufficiently small values of  $h\bar{n}_h$ , implying a subsidy. With (34) and in contrast to the first extension, the agent takes into account the effect of changing marginal tax rates, as she is changing labor supply. Similar to the first extension, the first-order conditions imply

$$(\eta\kappa\bar{n}_h^{1+1/\varphi})^{-1} + 1 - \frac{1}{\eta} = \frac{1}{v} \alpha \frac{\bar{n}}{\bar{y}} \frac{\bar{c}_h}{\bar{n}^{1-v}(h\bar{n}_h)^v} \quad (35)$$

with  $\alpha$  as in (17). There are a few differences between (31) and (35): the most crucial one may be the extra factor  $1/v$  on the right hand side of the latter.

To say more requires additional assumptions. Let  $z_h = \bar{c}_h / ((1-\tau^n)w\bar{n}^{1-v}(h\bar{n}_h)^v)$  be the ratio of consumption to after-tax labor income for an agent of type  $h$ , given tax rates. As argued above, we shall proceed with [Assumption A.1](#), that this ratio is independent of  $h$ , but may depend on aggregate conditions. Again, the labor supply will then be independent of  $h$ , i.e.  $\bar{n}_h \equiv \bar{n}$ , where the latter may change with aggregate conditions. Per integration, one finds that  $\bar{n}$  satisfies

$$(\eta\kappa\bar{n}^{1+1/\varphi})^{-1} + 1 - \frac{1}{\eta} = \frac{1}{v} \alpha \frac{\bar{c}}{\bar{y}} \quad (36)$$

with  $\alpha$  as in (17). The difference to the benchmark model (16) is the additional factor  $1/v$  on the right hand side. Similar to the human capital accumulation calculations of [Section 5](#), note that  $\kappa$  should be calibrated, so that  $\bar{n}_{US} = 0.25$  solves the steady state equations. In particular, for  $\eta = 1$ , the additional factor  $1/v$  will just result in multiplication of the previous value for  $\kappa$  with  $v$ , with the remaining analysis unchanged.

**Proposition 6.** *With Assumption A.1, with  $\eta = 1$  and with  $\kappa$  calibrated to US data, the Laffer curves in  $\tau^k, \tau^n, \tau^c$  remain unchanged.*

For  $\eta \neq 1$ , the constant  $1 - 1/\eta$  in (36) will result in some changes from the additional factor  $1/v$ , but they remain small, if  $\eta$  is near unity and  $\kappa$  is calibrated to US data. Finally, (36) now allows the analysis of changes in the progressivity parameter  $v$  of the tax code and its impact on tax revenues.

## 7. Transition

So far, only long-run steady states have been compared. The question arises, how the results may change, if one considers the transition from one steady state to the next. Indeed, if e.g. the capital stock falls towards the new steady state, when taxes are raised, there will be a transitory “windfall” of tax receipts during that transition, compared to the eventual steady state. This windfall can potentially be large.

Investigating that issue requires additional assumptions about the dynamics. It is assumed that it is costly to adjust capital, in dependence of the investment-to-capital ratio: note that this did not matter for the steady state considerations up to now. Replacing Eq. (1), we assume

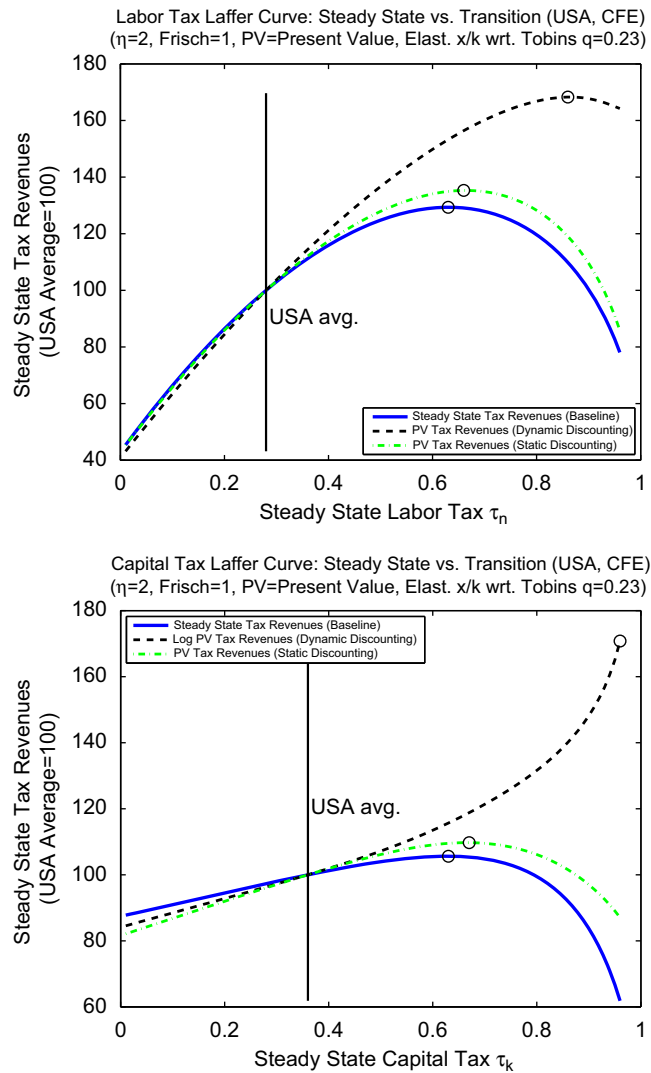
$$k_t = (1-\delta)k_{t-1} + \left[ 1 - \phi\left(\frac{x_t}{k_{t-1}}\right) \frac{k_{t-1}}{x_t} \right] x_t \quad (37)$$

where  $\phi(x_t/k_{t-1})$  is a convex function with  $\phi(\varpi) = \phi'(\varpi) = 0$  and  $\phi''(\varpi) \geq 0$  where  $\varpi = \psi - 1 + \delta$ . It is assumed to take the iso-elastic form  $\phi(x_t/k_{t-1}) = \frac{1}{2} [e^{\sqrt{1/\gamma\varpi}(x_t/k_{t-1}-\varpi)} + e^{-\sqrt{1/\gamma\varpi}(x_t/k_{t-1}-\varpi)} - 2]$ , where  $\gamma$  is chosen to imply an elasticity of the investment to capital ratio with respect to Tobin's  $q$  of 0.23 as in [Jermann \(1998\)](#). Finally, capital adjustment costs can be deducted from the capital tax bill as in [House and Shapiro \(2006\)](#). The quantitative results, however, do not hinge critically on this assumption.

A transition from the current “status quo” steady state to the new steady state is assumed, by supposing that some tax rate is permanently changed to its new, long-run value and allow transfers and/or government spending to adjust during the transition. Transition paths between the current and new steady state are calculated using a standard two point boundary solution algorithm. Then, net the present value of tax revenues is calculated along the entire transition path. Discounting is done by using the period-by-period real interest rate (dynamic discounting). As an alternative, the constant (balanced growth) real interest rate (static discounting) is used.

The results for the US calibration, at  $\eta = 2$  and  $\varphi = 1$ , are in the upper part of Fig. 9 for the labor tax Laffer curve. The figure compares the transition results to the original steady state comparison. The peak of the labor tax Laffer curve shifts to the right and up. This result is easy to understand: as the labor tax rate is increased, this will eventually decrease labor input and therefore decrease the capital stock. Along the transition, the capital stock is “too high”, producing additional tax revenue beyond the steady state calculations. Further, the figure shows that using the period-by-period real interest rate (dynamic discounting) or the constant balanced growth real interest rate (static discounting) makes a difference. However, the most appropriate discounting is likely the one that takes the full transition of the real interest rates into account since that is the interest rate at which the government borrows. Overall, the change of results due to the explicit incorporation of transition dynamics appears to be modest enough that much of the steady state comparison analysis is still valid. Notice, in particular, that the slope of the labor tax Laffer curve around the original tax rate has not changed much, so that the local degree of self-financing of a labor tax cut remains largely the same.

The results are rather dramatically different for the capital income tax Laffer curve in the bottom part of Fig. 9, however. While the steady state comparison indicates a very flat Laffer curve, the transition Laffer curve keeps rising, generating substantial additional tax revenues, even for very high capital income tax rates. The results are surprising only at first



**Fig. 9.** Steady state vs transition Laffer curves for labor taxes (upper panel) and capital taxes (lower panel). Two cases are examined. First, steady state (balanced growth path) total tax revenues are depicted when taxes are varied between 0% and 100%. Second, due to a transition from the average US tax rate to a new steady state tax rate on the interval 0–100%, present value total tax revenues are calculated. Discounting is done either by the period-by-period real interest rate (dynamic discounting) or by the constant (balanced growth) real interest rate (static discounting). Total tax revenues at the US average labor tax rate are normalized to 100. All results are provided for CFE (constant Frisch elasticity) preferences with a unit Frisch elasticity of labor supply and an inverse intertemporal elasticity of substitution,  $\eta = 2$ . The elasticity of the investment–capital ratio with respect to Tobin’s  $q$  is set to 0.23 as in Jermann (1998).

glance, however. One way to gain some intuition here is to realize that a sudden and large increase of capital income taxes induces a sizable fall of the real return on capital. Since it is the period-by-period real interest rate that is used for discounting, the present value of government tax revenue shoots up.

In addition, a sudden and surprising increase in the capital income tax contains a large initial wealth tax. A sudden, one-time wealth tax is not distortionary and can indeed raise substantial revenue. As a piece of practical policy advice, there may nonetheless be good reasons to rely on the steady state comparison rather than this transition path. Surprise tax increases are rare in practice. With sufficient delay, the distortionary effect on future capital accumulation can quickly outweigh the gains, that would be obtained for an immediate surprise rise, see e.g. Trabandt (2007). Furthermore, a delayed, but substantial raise in capital income taxes is likely to lead to large efforts of hiding tax returns, to tax evasions and to capital flight, rather than increases in tax receipts. These considerations have been absent from the analysis above, and it would be important to include them in future research on this issue.

## 8. Conclusion

Laffer curves for labor and capital income taxation have been characterized quantitatively for the US, the EU-14 and individual European countries by comparing the balanced growth paths of a neoclassical growth model featuring “constant Frisch elasticity” (CFE) preferences. For benchmark parameters, it is shown that the US can increase tax revenues by 30% by raising labor taxes and by 6% by raising capital income taxes. For the EU-14 economy 8% and 1% are obtained. A dynamic scoring analysis shows that 54% of a labor tax cut and 79% of a capital tax cut are self-financing in the EU-14. By contrast and due to “accounting”, the Laffer curve for consumption taxes does not have a peak and is increasing in the consumption tax throughout, converging to a positive finite level when consumption tax rates approach infinity. Conditions are derived under which household heterogeneity does not matter much for the results. However, transition effects matter: a permanent surprise increase in capital income taxes always raises tax revenues for the benchmark calibration. Finally, endogenous growth and human capital accumulation locates the US and EU-14 close to the peak of the labor income tax Laffer curve.

We therefore conclude that there rarely is a free lunch due to tax cuts. However, a substantial fraction of the lunch will be paid for by the efficiency gains in the economy due to tax cuts. Transitions matter.

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version at doi:[10.1016/j.jmoneco.2011.07.003](https://doi.org/10.1016/j.jmoneco.2011.07.003).

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