How Far Are We From The Slippery Slope? The Laffer Curve Revisited*

Mathias Trabandt†
Sveriges Riksbank
and
Harald Uhlig‡
University of Chicago, NBER and CEPR

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†Address: Mathias Trabandt, Sveriges Riksbank, Research Division, Brunkebergstorg 11, SE-103 37 Stockholm, Sweden, Tel. +46-(0)-8-787-0438, email: mathias.trabandt@riksbank.se.

‡Address: Harald Uhlig, Department of Economics, University of Chicago, 1126 East 59th Street, Chicago, IL 60637, U.S.A, email: huhlig@uchicago.edu

Abstract

How does the behavior of households and firms in the US compared to the EU-15 adjust if fiscal policy changes taxes? We answer this question quantitatively with a neoclassical growth model with CFE preferences, i.e. preferences which are consistent with long-run growth and feature a constant Frisch elasticity of labor supply. We characterize the resulting Laffer curves for labor taxation and capital income taxation quantitatively. While the US and the EU-15 are located on the left side of these Laffer curves, the EU-15 is closer to the slippery slopes and has moved closer from 1975 to 2000. The US can increase tax revenues by 40 to 52% by raising labor taxes but only 6% by raising capital income taxes, while the same numbers for EU-15 are 5% to 12% and 1% respectively. We show that 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-15, i.e. in terms of a "Laffer hill", both the US and the EU-15 are on the wrong side of the peak with respect to their capital tax rates. We calculate that some countries such as Denmark and Sweden are on the wrong side of the Laffer curve with respect to capital income taxation alone, i.e. would collect additional government revenue by cutting these taxes. A dynamic scoring analysis shows that two fifth of a labor tax cut and four fifth of a capital tax cut are self-financing in the EU-15, albeit at potentially large transitory costs to the government budget.

Key words: Laffer curve, incentives, dynamic scoring, US and EU-15 economy

JEL Classification: E0, E60, H0

	US	EU
Potential additional tax revenues (in %):		
labor taxes	40% .. 52%	5% .. 12%
capital taxes	5% .. 6%	0% .. 1%
Maximizing tax rate (in %) :		
labor taxes	60% .. 68%	52% .. 61%
capital taxes	59%	42%
Percent self-financing of a tax cut (CFE, $\eta = 2, \varphi = 1$):		
labor taxes	16 %	42 %
capital taxes	46 %	82 %

Table 1: *Some key quantitative results.*

"The supply-side economists...have delivered the largest genuinely free lunch I have seen in 25 years in this business, and I believe we would have a better society if we followed their advice."

Robert E. Lucas (1990)

1 Introduction

How does the behavior of households and firms in the US compared to the EU-15 adjust if fiscal policy changes taxes? We answer this question quantitatively with a closed-economy neoclassical growth model with a representative household, featuring long-run growth consistent preferences with a constant Frisch elasticity of labor supply. Holding preferences fixed, we compare the results across the US and the EU-15 for labor taxes as well as capital income taxes. Further, we examine how incentives have changed over time by analyzing how the economies have shifted over time on their Laffer curves. Finally, we calculate the degree of self-financing of tax cuts in steady state as well as dynamically. Table 1 provides a short summary of some of our main quantitative results.

The neoclassical growth model exhibits an inverted U-shape relationship between taxes and tax revenues, i.e. it features a Laffer curve. The Laffer curve provides us with a framework to think about the incentive effects of tax changes and the degree of self-financing of tax cuts.

In 1974 Arthur B. Laffer noted during a business dinner that "there are always two tax rates that yield the same revenues".[1] In the 1980's, some supply-side economists conjectured that the US were on the right hand or slippery slope side of the Laffer curve and that therefore tax cuts would increase tax revenues. More generally, the incentive effects of tax cuts was given more prominence in political discussions and political practice.

The goal of this paper is a quantitative assessment of the positions of the US and EU-15 economies on their respective Laffer curves by employing a simple closed-economy calibrated neoclassical growth model.

In this paper, we investigate the shape of the Laffer curve, employing a closed-economy neoclassical growth model with a representative household. The government collects distortionary taxes on labor, capital and consumption and issues debt to finance government consumption, lump-sum transfers and debt repayments. We calibrate key parameters to the US economy as well as to the EU-15 economic area.

We focus on the intertemporal elasticity of substitution as well as the Frisch elasticity of labor supply as key parameters of the preference specification. We focus on preferences which are consistent with long-run growth and feature constant Frisch elasticity. We call them CFE preferences. As an alternative, we also employ Cobb-Douglas preferences in consumption and leisure.

For a 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-15 are located on the left side of their Laffer curves, but the EU-15 economy being much closer to the slippery slopes than the US. We show that the US has moved closer to the peak for labor taxes while it has hardly shifted relative to the peak for capital taxes. By contrast, the EU-15 has moved considerably closer to the peak for both - labor and capital taxes.

We calculate the degree of self-financing for a capital tax cut in the US to be about one half and to be about 80 percent in the EU-15. We show 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. We show that 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-15, i.e. in terms of a "Laffer hill", both the US and the EU-15 are on the wrong side

[1] see Wanniski (1978).

of the peak with respect to their capital tax rates.

An individual country analysis for the EU-15 area reveals that a number of individual EU-15 countries are close to the slippery slopes of their Laffer curves with respect to labor income taxation and in some cases are on the slippery side with respect to capital income taxation. For example, Sweden and Denmark can collect additional tax revenue in the long term by cutting capital income taxes.

Following Mankiw and Weinzierl (2005), we pursue a dynamic scoring exercise. That is, we analyze by how much a tax cut is self-financing if we take incentive feedback effects into account. We find that for the US model 16% of a labor tax cut and 46% of a capital tax cut are self-financing in the steady state. In the EU-15 economy 42% of a labor tax cut and 82% of a capital tax cut are self-financing. These effects take time, however. The degree of self-financing after one year are 14% and 5% for labor and capital taxes in the US, and 35% and 10% for labor and capital taxes in the EU 15. Thus there are substantial transitory costs in terms of tax revenues for cutting taxes.

The paper is organized as follows. After discussing the related literature next, we specify the model in section 3. Section 4 discusses our results. Finally, section 5 concludes that eventually there is a cheap lunch - in terms of government revenue - from cutting taxes, in particular from cutting capital income taxes.

2 Discussion of Related Literature

Baxter and King (1993) were one of the first authors who analyzed the effects fiscal policy a dynamic general equilibrium neoclassical growth model with productive government capital. The authors analyze the effects of temporary and permanent changes of exogenous government purchases. Garcia-Mila, Marcet, and Ventura (2001) study the welfare impacts of alternative tax schemes on labor and capital in a neoclassical growth model with heterogenous agents and demonstrate that there exists a static Laffer curve. In contrast to the above papers, our work features a representative agent framework with endogenous government purchases. 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, with their results debated in Bruce and Turnovsky (1999), Novales and Ruiz (2002) and Agell and Persson (2001). 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.

The model in Floden and Linde (2001) contains a Laffer curve and the authors report that for labor taxes the US is located on the left side whereas Sweden is on the slippery slope side of the Laffer curve. Jonsson and Klein (2003) analyze the welfare costs of distortionary taxation including inflation in the US and Sweden. The authors analyze the welfare effects of moving from the distorted equilibrium to the undistorted equilibrium taking costs of transition into account. Jonsson and Klein (2003) analyze the welfare costs of stochastic fluctuations. The authors find that the total welfare costs of distortionary taxes including inflation are five times higher in Sweden compared to the US. Based on their model, Jonsson and Klein (2003) report that Sweden is on the slippery slope side of the Laffer curve for several tax instruments while the US is on the left hand side. Our results are in line with these findings, with a sharper focus on the location and quantitative importance of the Laffer curve with respect to labor and capital income taxes.

Our paper is 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. Focussing on the labor market equilibrium, he argues that the incentive effects of labor taxes imply that Europeans work less than their US counterpart. We broaden that analysis here by including incentive effects of labor and capital income taxes in a general equilibrium framework with endogenous government consumption.

Ljungqvist and Sargent (2006) argue that the model of Prescott (2002, 2004) has difficulties in explaining the observed employment outcome as soon as government benefits are taken into account. Blanchard (2004) as well as Alesina, Glaeser, and Sacerdote (2005) argue that changes in preferences respectively labor market regulations and union policies rather than different fiscal policies are the driving forces for the observation that hours worked have fallen in Europe compared to the US. They argue that preferences in Europe have shifted over time towards more leisure and thus lower hours worked. By contrast to these alternative explanations for the differences in hours worked between the US and Europe, the present paper employs a model similar to Prescott (2002, 2004) and analyzes the incentive effects of changes in taxation by investigating the Laffer curve.

Lindsey (1987) has measured the response of taxpayers to the US tax cuts from 1982 to 1984 empirically. He reports that one-sixth up to one-quarter of the tax cuts were self-financing and finds that total income tax revenues would have been maximized at a total tax rate of about 40 percent. In contrast to Lindsey (1987) and based on the balanced growth comparisons in a neoclassical growth framework employed here, we argue that the peak of the Laffer curve occurs at higher tax rates and a higher degrees of self-financing of tax cuts.

Mankiw and Weinzierl (2005) pursue a dynamic scoring exercise in a neoclassical growth model for the US economy. Similar to the measure of self-financing in Lindsey (1987), dynamic scoring accounts for the feedback effect from lower taxes to growth via increased incentives to participate on the markets. Mankiw and Weinzierl (2005) find that in the US half of a capital tax cut is self-financing compared to a static scoring exercise. Leeper and Yang (2005) argue that Mankiw and Weinzierl's result that static scoring overestimates the revenue loss hinges on the assumption that lump-sum transfers adjust to balance the government budget. In particular, Leeper and Yang (2005) show that a bond-financed tax cut can have adverse effects on growth. Interestingly, they show that when the government consumption to GDP ratio is adjusted to rising debt in response to a labor tax cut then static scoring underestimates the revenue loss as opposed to Mankiw and Weinzierl.

The model at hand features endogenous government consumption. Second, we calculate the dynamic scoring effect for the EU-15 economic area and compare it to the US economy. Finally, in our experiments government debt is fixed and the level of government consumption adjusts. We find that static scoring overestimates the revenue loss for labor and capital tax cuts and thereby confirm Mankiw and Weinzierl (2005).

We assume that the government collects distortionary taxes on labor, capital and consumption and issues debt to finance government consumption, lump-sum transfers and debt repayments. We model the US and the EU-15 economy each as a closed economy. This assumption implies that input factor markets for labor and capital are internationally independent. Labor immobility between the US and the EU-15 is probably a good approximation. For capital the closed economy assumption can be motivated by either the Feldstein and Horioka (1980) observation that domestic saving and investment are highly correlated or by interpreting the model in the light of ownership-based taxation instead of source-based taxation. In both cases changes in fiscal policy will have only minor cross border effects. For explicit tax policy in open economies, see e.g Mendoza and Tesar (1998) or Kim and Kim (2004) and the references therein.

Like Christiano and Eichenbaum (1992), Baxter and King (1993), McGrattan (1994), Lansing (1998), Cassou and Lansing (2006), Klein, Krusell, and Rios-Rull (2004) as well as Trabandt (2006), we assume that government spending may be valuable only insofar as it provides utility separably from consumption and leisure.

3 The Model

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

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

s.t.

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

where c_t, n_t, k_t, x_t, b_t denote consumption, hours worked, capital, investment and government bonds. The household takes government consumption g_t, which provides utility, as given. Further, the household receives wages w_t, dividends d_t and profits Π_t from the firm. 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 τ_t^c, labor income taxes τ_t^n and capital income taxes τ_t^k. Note that capital income taxes are levied on dividends net-of-depreciation as in Prescott (2002, 2004) and in line with Mendoza, Razin, and Tesar (1994).

The representative firm maximizes its profits subject to a Cobb-Douglas production technology,

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

s.t.

$$y_t = \xi^t k_{t-1}^{\theta} n_t^{1-\theta} \tag{2}$$

where ξ^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 T_t are

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

Our goal is to analyze how the equilibrium shifts, as tax rates are shifted. For most of the paper, we focus on comparisons of balanced growth paths. We also have reasons to calculate the dynamic impact of a tax change: we shall then assume that the three tax rates on labor, capital and consumption follow exogenous AR(1) processes. Our key assumption is that government debt as well as transfers do not deviate from their balanced growth pathes, i.e.

$$b_{t-1} = \psi^t \bar{b} \tag{5}$$

and

$$s_t = \psi^t \bar{s} \forall t \geq 0 \tag{6}$$

When tax rates are shifted, government spending adjusts according to the government budget constraint (3), rewritten as

$$g_t = \psi^t \bar{b}(\psi - R_t^b) + T_t - \psi^t \bar{s}. \tag{7}$$

As an alternative, we shall also consider keeping government spending on the balanced growth path and adjusting transfers instead.

3.1 The Constant Frisch Elasticity (CFE) preferences

It is a priori plausible, that the intertemporal elasticity of substitution as well as the Frisch elasticity of labor supply are key properties of the preferences for the analysis at hand.

As a benchmark, it is reasonable to assume that preferences are separable, consistent with long-run growth (i.e. consistent with a constant labor supply as wages and consumption grow at the same rate) and feature a constant Frisch elasticity,

$$\varphi = \frac{dn}{dw}\frac{w}{n}|_{\bar{U}_c} \tag{8}$$

The following result has been stated without proof in Shimer (2008), and there may exist earlier references.

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 β, consistent with long-run growth and feature a constant Frisch elasticity of labor supply φ, 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*

$$u(c,n) = \log(c) - \kappa n^{1+\frac{1}{\varphi}} \tag{9}$$

if $\eta = 1$ and by

$$u(c,n) = \frac{1}{1-\eta}\left(c^{1-\eta}\left(1-\kappa(1-\eta)n^{1+\frac{1}{\varphi}}\right)^{\eta} - 1\right) \tag{10}$$

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

Proof: *It is well known 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*

$$u(c,n) = \log(c) - v(n) \tag{11}$$

if $\eta = 1$ and

$$u(c,n) = \frac{1}{1-\eta}\left(c^{1-\eta}v(n) - 1\right) \tag{12}$$

We concentrate on the second equation. Taking the first order conditions with respect to a budget constraint

$$c + \ldots = wn + \ldots$$

we obtain the two first order conditions

$$\lambda = c^{-\eta} v(n) \tag{13}$$

$$\lambda w = c^{1-\eta} v'(n) \tag{14}$$

By the implicit function theorem, there are differentiable functions $c(w)$ *and* $n(w)$ *solving these two equations at* $\lambda \equiv \bar{\lambda}$ *locally around an interior solution. Implicit differentiation yields*

$$c'(w) = \frac{1}{\eta} \frac{v'(n)c}{v(n)} n'(w) \tag{15}$$

$$0 = -\lambda + (1-\eta) c^{-\eta} v'(n) c'(w) + c^{1-\eta} v''(n) n'(w) \tag{16}$$

Substituting (15) into (16), dividing by (14) and rearranging yields the differential equation

$$\frac{1}{\varphi} = \frac{n}{n'(w)w} = \frac{1-\eta}{\eta} \frac{v'(n)n}{v(n)} + \frac{v''(n)n}{v'(n)} \tag{17}$$

Define $x = \log n$ *and* $f(x) = logv(e^x)$. *Imposing* φ *to be constant, the differential equation can then be rewritten as*

$$\frac{1}{\varphi} = \frac{1-\eta}{\eta} f'(x) + \frac{f''(x)}{f'(x)} + f'(x) - 1 \tag{18}$$

Define $h(x) = 1/f'(x)$ *and rewrite the differential equation as*

$$0 = \frac{1}{\eta} - (1 + \frac{1}{\varphi}) h(x) - h'(x) \tag{19}$$

This is a linear differential equation, which has the set of solutions

$$h(x) = \xi_1 e^{-(1+\frac{1}{\varphi})x} + (1 + \frac{1}{\varphi}) \frac{1}{\eta} \tag{20}$$

parameterized by $\xi_1 \in \mathbf{R}$. *Use this to solve for* $f(x)$ *and finally* $v(n)$ *as*

$$v(n) = \xi_2 \left(\xi_1 + \frac{1}{\eta} n^{(1+\frac{1}{\varphi})} \right)^{\eta} \tag{21}$$

for some $\xi_2 > 0$. *Rescaling* $v(n)$, *one may choose the constants* ξ_1 *and* ξ_2 *so that* $v(n)$ *takes the form*

$$v(n) = \left(1 - \kappa(1-\eta) n^{(1+\frac{1}{\varphi})} \right)^{\eta} \tag{22}$$

where it is now easy to see that $\kappa > 0$ in order to assure that $u(c, n)$ is decreasing in n. It is straightforward to show concavity in c and $-n$. Extending the proof to the case $\eta = 1$ is straightforward to. $\bullet$

As an alternative, we also use a standard Cobb-Douglas utility function,

$$U_{c-d}(c_t, n_t) = \frac{(c_t^\alpha (1-n_t)^{1-\alpha})^{1-\eta} - 1}{1-\eta}$$

as in Cooley and Prescott (1995), Chari, Christiano, and Kehoe (1995) or Uhlig (2004).

3.2 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. Except for hours worked, interest rates and taxes all other variables grow at a constant rate $\psi = \xi^{\frac{1}{1-\theta}}$. In order to obtain a stationary solution, we detrend all non-stationary variables by the balanced growth factor ψ^t. For the dynamics, we log-linearize the equations around the balanced growth path and use Uhlig (1999) to solve the model.

For the CFE preference specification and along the balanced growth path, the first-order conditions of the household and the firm imply

$$\left(\eta\kappa\bar{n}^{1+\frac{1}{\varphi}}\right)^{-1} + 1 - \frac{1}{\eta} = \alpha\frac{\bar{c}}{\bar{y}} \tag{23}$$

where

$$\alpha = \frac{1+\tau^c}{1-\tau^n}\frac{1+\frac{1}{\varphi}}{1-\theta} \tag{24}$$

depends on tax rates, the labor share and the Frisch elasticity of labor supply. The budget constraint of the household implies

$$\frac{\bar{c}}{\bar{y}} = \chi + \nu\frac{1}{\bar{n}} \tag{25}$$

where

$$
\begin{aligned}
\chi &= \frac{1}{1+\tau^c}\left(1-(\psi-1+\delta)\left(\frac{\bar{k}}{\bar{y}}\right)-\tau^n(1-\theta)-\tau^k\left(\theta-\delta\left(\frac{\bar{k}}{\bar{y}}\right)\right)\right) \\
\nu &= \frac{\bar{b}(\bar{R}-\psi)+\bar{s}}{1+\tau^c}\left(\frac{\bar{n}}{\bar{y}}\right)
\end{aligned}
$$

can be calculated, given values for preference parameters, production parameters, tax rates and the levels of $\bar{b}$, $\bar{s}$. Substituting equation (25) into (23) therefore yields a one-dimensional nonlinear equation in $\bar{n}$, which can be solved numerically. 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 this equation to find the value of the preference parameter κ, supporting this equilibrium. A similar calculation obtains for the Cobb-Douglas preference specification.

3.3 Calibration and Parameterization

We calibrate the model to post-war data of the US and EU-15 economy. For data on tax rates, we use the methodology employed by Mendoza, Razin, and Tesar (1994), who calculate average tax rates from national product and income accounts. Following the same methodology, Carey and Rabesona (2002) have recalculated effective average tax rates on labor, capital and consumption from 1975 to 2000. We are grateful to these authors to share their data with us. We take a conservative stand here and use the part of their work where the effective tax rates are based on the original Mendoza, Razin, and Tesar (1994) methodology. However, our results do not change much when using their new methodology. Figure 1 shows the time series we have used. For the bulk of our analysis, we focus on the average of these tax rates over the time span shown.

Using this methodology necessarily fails to capture fully the detailed nuances and features of the tax law and the inherent incentives. Nonetheless, five arguments may be made for why we use effective average tax rates instead of marginal tax rates for the calibration of the model. First, we are not aware of a comparable and coherent empirical methodology that could be used to calculate marginal labor, capital and consumption tax rates for the US and 15 European countries for a time span of the last 25 years. By contrast, Mendoza, Razin, and Tesar (1994) and Carey and Rabesona (2002) calculate effective average tax rates for labor, capital and consumption for our countries of interest.

Variable	US	EU-15	Description	Restriction
$\bar{\tau}^n$	0.26	0.38	Labor tax	Data
$\bar{\tau}^k$	0.37	0.34	Capital tax	Data
$\bar{\tau}^c$	0.05	0.17	Consumption tax	Data
$\bar{s}/\bar{y}$	0.11	0.19	Gov. transf. to GDP	Data
$\psi\bar{b}/\bar{y}$	0.61×4	0.53×4	Gov. debt to GDP	Data
ψ	1.0075	1.0075	Bal. growth factor	Data
$\bar{R}$	1.015	1.015	Real interest rate	Data

Table 2: Baseline calibration, part 1

There is some data available from the NBER for marginal tax rates on the federal and state level, see figure 5. While there are some differences to the Carey-Rabesona data at higher frequencies, the averages - which are relevant for the exercise at hand - are close.

Second, if any we probably make an error on side of caution since effective average tax rates can be seen as as representing a lower bound of statutory marginal tax rates. Third, marginal tax rates differ all across income scales. In order to properly account for this, a heterogenous agent economy is needed. This might be a useful next step but may fog up key issues analyzed in this paper initially. Fourth, statutory marginal tax rates are often different from realized marginal tax rates due to a variety of tax deductions etc. So that potentially, the effective tax rates computed and used here may reflect realized marginal tax rates more accurately than statutory marginal tax rates in legal tax codes. Fifth, using effective tax rates following the methodology of Mendoza, Razin, and Tesar (1994) facilitates comparison to previous studies that also use these tax rates as e.g. Mendoza and Tesar (1998) and many others. Nonetheless, a further analysis taking these points into account in detail is a useful next step on the research agenda.

All other data we use for the calibration comes from the AMECO database of the European Commission.[2] Although our data comes on an annual basis, time is taken to be quarters in our calibration.[3]

An overview of the calibration is provided in tables 2 and 3.

[2]The database is available online at $http://ec.europa.eu/economy\_finance/indicators/annual\_macro\_economic\_database/ameco\_en.htm$

[3]Note, however, that the chosen time unit is not important for the shape of the Laffer curve. In other words, we have checked that all our results remain the same if we had assumed the time unit to be a year.

Var.	US	EU-15	Description	Restriction
θ	0.36	0.36	Capital share on prod.	Data
δ	0.015	0.015	Depr. rate of capital	Data
η	2	2	inverse of IES	consensus(?)
φ	1	1	Frisch elasticity	consensus(?)
κ	3.42	3.42	weight of labor	$\bar{n}_{us} = 0.25$
η	1	1	inverse of IES	alternative
φ	3	3	Frisch elasticity	alternative
κ	3.36	3.36	weight of labor	$\bar{n}_{us} = 0.25$
α	0.321	0.321	Cons. weight in C-D	$\bar{n}_{us} = 0.25$

Table 3: Baseline calibration, part 2

3.3.1 US Model

In line with the above data on tax rates we set $\bar{\tau}^n = 0.26$, $\bar{\tau}^k = 0.37$ and $\bar{\tau}^c = 0.05$. Further, we set $\bar{b}$ such that it matches the mean annual debt to GDP ratio in the data of 61%[4]. Hence, in our quarterly stationarized model we impose $\psi\frac{\bar{b}}{\bar{y}} = 0.61 \times 4$. Further, we set $\bar{s}$ such that $\frac{\bar{s}}{\bar{y}} = 0.11$ which corresponds to the "implicit" government transfer to GDP ratio in the data.[5] See figure 1 for plots of the time series we use for the calibration of the above variables. The exogenous balanced growth factor ψ is set to 1.0075 which corresponds to the mean annual growth rate of real US GDP of roughly 3%. Further, we set the capital share $\theta = 0.36$ as in Kydland and Prescott (1982). In line with Stokey and Rebelo (1995) and Mendoza and Tesar (1998) we set $\delta = 0.015$ which implies an annual rate of depreciation of 6%.

3.3.2 Parameterizing Preferences

In line with Mendoza and Tesar (1998) and King and Rebelo (1999) we set $\bar{R} = 1.015$ which implies a 6% real interest rate per year. Depending on preferences this implies a

[4]Our empirical measure of government debt for the US as well as the EU-15 area provided by the AMECO database is nominal general government consolidated gross debt (excessive deficit procedure, based on ESA 1995) which we divide by nominal GDP. Figure 1 shows the resulting time series. Finally, averaging over time yields the above number for the debt to GDP ratio.

[5]Since there is no model-consistent data available for government transfers, we calculate "implicit" government transfers that are consistent with our government budget constraint. From the steady state representation of equation (3) total government expenditures are equal to $\bar{g} + (\bar{R}^b - \psi)\bar{b} + \bar{s}$. Since data is available for total gov. expenditures, gov. consumption and net interest payments we can easily back out government transfers.

discount factor $\beta \in [0.9915, 0.9926]$.

We set parameters 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.[6]

Empirical estimates of the intertemporal elasticity vary considerably. Hall (1988) estimates it to be close to zero. Recently, Gruber (2006) provides an excellent survey on estimates in the literature. Further, he estimates the intertemporal elasticity to be two. Cooley and Prescott (1995) and King and Rebelo (1999) use an intertemporal elasticity equal to one. The general current consensus seems to be that the intertemporal elasticity of substitution is closer to 0.5, which we shall use for our baseline calibration, but also investigating a value equal to unity as an alternative, and impose it for the Cobb-Douglas preference specification.

The specific value of the Frisch labor supply elasticity is of central importance for the shape of the Laffer curve. In the case of our alternative Cobb-Douglas preferences the Frisch elasticity is already pinned down by the other parameters $\frac{1-\bar{n}}{\bar{n}} \frac{1-\alpha(1-\eta)}{\eta}$ and equals 3 in our baseline calibration for an intertemporal elasticity of substitution equal to unity. This value is in line with e.g. Kydland and Prescott (1982), Cooley and Prescott (1995) and Prescott (2002, 2004). There is a large literature that estimates the Frisch labor supply elasticity from micro data. Domeij and Floden (2006) argue that labor supply elasticity estimates are likely to be biased downwards by up to 50 percent. However, the authors survey the existing micro Frisch labor supply elasticity estimates and conclude that many estimates range between 0 and 0.5. Further, Kniesner and Ziliak (2005) estimate a Frisch labor supply elasticity of 0.5 while and Kimball and Shapiro (2003) obtain a Frisch elasticity close to 1. Hence, this literature suggests an elasticity in the range of 0 to 1 instead of a value of 3 as suggested by Prescott (2006).

In the most closely related public-finance-in-macro literature, e.g. House and Shapiro (2006), a value of 1 is often used. We shall follow that choise as our benchmark calibration, and regard a value of 3 as the alternative specification.

[6]Similar to Rogerson (2007), we calculate hours worked per person for the US and the EU-15 economy by using data on total annual hours worked from the Groningen Growth and Development Centre (http://www.ggdc.net) and data on population aged 15-64 from the OECD (http://stats.oecd.org/wbos/default.aspx).

In summary, we use $\eta = 2$ and $\varphi = 1$ as the benchmark calibration for the CFE preferences, we use $\eta = 1$ and $\varphi = 3$ as alternative calibration and we compare the latter to a Cobb-Douglas specification for preferences with an intertemporal elasticity of substitution equal to unity and imposing $\bar{n} = 0.25$, implying a Frisch elasticity of 3.

3.3.3 EU-15 Model

To calculate results for the EU-15 as well as individual countries, we calibrate government tax and spending data the model to data for the EU-15 economic area as well as individual countries, keeping production and preference parameters as in the US model. Appendix A.1 summarizes how we calculate EU-15 tax rates, debt to GDP and transfer to GDP ratios. For the years from 1975 to 2000 mean tax rates in the EU-15 economy are equal to $\bar{\tau}^n = 0.38$, $\bar{\tau}^k = 0.34$ and $\bar{\tau}^c = 0.17$.[7] In our quarterly stationarized model we set $\bar{b}$ such that $\psi\frac{\bar{b}}{\bar{y}} = 0.53 \times 4$ which corresponds to the mean annual debt to GDP ratio of 53 % in the data. As for the US we calculate the "implicit" government transfers to GDP ratio which is equal to 0.19 in the EU-15 economy. Hence we set $\bar{s}$ such that $\frac{\bar{s}}{\bar{y}} = 0.19$. See figure 1 for plots of the time series we use for the calibration. The balanced growth factor ψ is set to 1.0075 which is consistent with the mean annual growth of real GDP in the EU-15 countries of roughly 3 %. All other parameters are set to the same values as in the US model. Hence, we do not take a stand on structural differences other than implied by fiscal policy in the US and EU-15 economies. Note that this implies that the household may chooses a different amount of hours worked in the EU-15 model compared to the US model due to differences in fiscal policy. This corresponds to Prescott (2002, 2004) who argues that differences in hours worked between the US and Europe arise due to changes in labor income taxes. By contrast, Blanchard (2004) as well as Alesina, Glaeser, and Sacerdote (2005) argue that changes in preferences respectively labor market regulations and union policies rather than different fiscal policies are the driving forces for the observation that hours worked have fallen in Europe compared to the US.

[7] Note that due to lack of data Luxembourg is not included in these figures.

	Gov. Cons.	
	US	EU-15
Data	16.5	21.3
Model		
$\varphi = 1, \eta = 2$	15.2	20.9
$\varphi = 3, \eta = 1$	15.2	20.9
C-D	15.2	20.9

Table 4: Comparing measured and implied government consumption.

4 Results

A summary of our results is in table 1.

As a first check on the model, consider tables 4, 5 and 6. Note that the results for the US across the three preference specifications must coincide by construction, as we have imposed $\bar{n} = 0.25$ to solve for the preference parameters for the US, whereas they could differ in principle for the EU-15. The differences are minor or absent, however. Table 4 shows that the implied government consumption coincides closely with measured government consumption. This means that total taxes collected minus transfers minus debt service as fraction of GDP in the model and the data coincide. For taxes, this is largely due to the Mendoza-Razin-Tesar methodology, as the tax rates there are derived from NIPA calculations. Similarly, the model delivers approximately correct results for the sources of government tax revenue as a share of GDP, see table 5. While the models overstate the taxes collected from labor income in the EU 15, they provide the correct numbers for revenue from capital income taxation, indicating that the methodology of Mendoza-Razin-Tesar is reasonable capable of delivering the appropriate tax burden on capital income, despite the difficulties of taxing capital income in practice. Table 6 sheds further light on this comparison: hours worked are overstated total capital is understated for the EU 15 by the model.

The Laffer curve for labor income taxation in the US is shown in figure **??**. 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 φ are the same at the benchmark steady state. The location of the maxima are tabulated in table 1 as a range. Figures 4 and 5 show the sensitivity of the Laffer curve to variations in η and φ. The peak of the

	Labor Tax Rev. US	Labor Tax Rev. EU-15	Cap. Tax Rev. US	Cap. Tax Rev. EU-15	Cons. Tax Rev. US	Cons. Tax Rev. EU-15
Data	14.9	20.5	8.3	7.5	3.6	9.5
Model						
$\varphi = 1, \eta = 2$	16.6	24.3	8.2	7.4	3.2	9.8
$\varphi = 3, \eta = 1$	16.6	24.3	8.2	7.4	3.2	9.8
C-D	16.6	24.3	8.2	7.4	3.2	9.8

Table 5: Comparing measured and implied sources of tax revenue.

	Priv. Cons. US	Priv. Cons. EU-15	Capital US	Capital EU-15	Hours Worked US	Hours Worked EU-15
Data	67.0	57.9	260	312	25.0	19.8
Model						
$\varphi = 1, \eta = 2$	63.9	57.6	232	239	25.0	**22.4**
$\varphi = 3, \eta = 1$	63.9	57.6	232	239	25.0	21.8
C-D	63.9	57.6	232	239	25.0	21.8

Table 6: Comparing measured and calculated key macroeconomic aggregates: consumption, capital (in % of GDP) and hours worked (in % total time)

Laffer curve shifts up and to the right, as η and φ are decreased. Figure 6 shows the dependence of the maximum of the Laffer curve on η and φ in more detail, with a line drawn at 100% for the benchmark calibration for comparison. The dependence on η arises due to the nonseparability of preferences in consumption and leisure. Capital adjusts as labor adjusts across the balanced growth paths.

Likewise, figure 8 shows the Laffer curve with respect to capital income taxation in the US, with figures 9, 10 and 11 exploring the sensitivity with respect to φ and η. Note in particular, that for a wide range of parameters, that the steady state level of capital is below the benchmark level at the revenue-maximizing tax rate: the additional income there is generated from additional labor income tax due to higher labor input.

A comparison to the EU-15 in figure 12 finds the EU 15 to be very close to its peak in terms of capital income taxation. A comparison to the EU-15 in figure 7 shows that the Laffer curve is considerably flatter there, with the current tax rate closer to the peak, despite a lower level of capital income taxation. To understand this result better, figure 13 decomposes the source of the tax revenue variation in greater detail. As the capital income tax is varied, the quantitatively larger effect arises from variation in the labor income tax: while the capital income tax revenue keeps rising until rather substantial levels of the capital income tax, it is the labor income tax revenue which is sharply declining beyond the Laffer curve peak. Since labor taxes are higher in Europe, the peak of the capital income tax Laffer curve therefore arrives earlier.

One may seek to maximize tax revenue, varying labor taxes and capital income taxes jointly. The corresponding "Laffer hills" are shown in figure 14) and 15 for the benchmark and the alternative parameterizations of η and φ. On all four pictures, both the US and the EU 15 emerge as being on the wrong side in terms of capital income taxation: in order to increase tax revenue, it would help to decrease capital income taxes and increase labor income taxes instead. This exercise is related to the more standard Ramsey-type exercise of finding the optimal tax structure, given a certain level of government expenditure. In light of the no-tax-on-capital-in-the-long-run result by Chamley (1986), the result here is not surprising. Note that zero taxation on capital is not optimal here, since we impose taxes on initial capital to be the same as taxes on capital income in the long run.

It seems, however, that the political equilibrium has shifted capital taxes up, though. Comparing somewhat arbitrarily the tax rates in 1975 and 2000, figure 16) shows that policy in the EU 15 has shifted closer to the peak of the Laffer curve, i.e. towards a less efficient tax system. The reason why it is so hard to eliminate capital income taxation may lie in the short-run political pressure. Figure 17 shows a dynamic scoring exercise, comparing the tax revenue lost at any particular horizon to the tax revenue lost from a calculation without incentive effects. The efficiency gains from lowering capital income taxes take considerable time, as is evident from this figure or the corresponding numbers provided in table 7. Note that these calculations rely on the short-run dynamics of the model as stated.

Variations of the model with e.g. habit formation or adjustment costs to capital may keep much of the steady state comparisons above intact, but have potentially a large impact on these dynamic scoring calculations. One might also conjecture lags between announcing a policy change and actually implementing it to have considerable impact on the dynamics. This issue has been raised by Judd (1985), who shows that anticipated future investment tax credits may reduce current investment. In addition, an immediate income tax cut that is financed by future cuts in government expenditures also depresses current investment. We have plotted the results for tax changes announced five years ahead of time in figure

	Percent Self-Financing	
	Steady State	after 1st year
1% Labor Tax Cut		
US	16	14
EU-15	42	35
1% Capital Income Tax Cut		
US	46	5
EU-15	82	10

Table 7: Dynamic scoring calculations: calculating the degree of self-financing of tax cuts over time.

17. It appears that the dynamics is rather similar, once the tax change is implemented and that the announcement has little impact in the periods preceeding implementation. This surprised us and further research should be devoted to the robustness of this result.

The changes in tax revenue may be used for changing the transfers to households rather than changes in government consumption. This has a considerable effect for labor income taxation, but not much for capital income taxation, as figures 18 and 19 show.

So far, the focus has been on the US versus the EU 15. Large cross-country variations arise within the EU-15, however. Figures 20 and 21 show the distances to the peak of the Laffer curves both in terms of percentage points in taxes as well as percent tax revenues. While all countries appear to be on the left side of the Laffer curve with respect to labor taxation, some - e.g. Sweden and Denmark - are on the wrong side with respect to capital income taxation. As a case in point, figure 22 and 23 compare the Laffer curves for Portugal and Denmark. It appears that Portugal has a considerably more efficient tax system than Denmark. Figure 24 compares predicted and actual working time across countries, as tax rates are varied. While there is some positive correlation, the fit could clearly be better. This figure should provide some caution in interpreting the results here too strictly: there apparently is more to changes in hours worked than just the variations in tax rates documented here.

5 Conclusion

This paper examines the following question: how does the behavior of households and firms in the US compared to the EU-15 adjust if fiscal policy changes taxes? The Laffer curve provides us with a framework to think about the incentive effects of tax cuts. Therefore, the goal of this paper is to examine the shape of the Laffer curve quantitatively in a simple neoclassical growth model calibrated to the US as well as to the EU-15 economy. We show that there exist robust steady state Laffer curves for labor taxes as well as capital taxes. According to the model the US and the EU-15 area are located on the left side of their Laffer curves. However the EU-15 countries are much closer to the slippery slopes than the US. Our results show that if taxes in the EU-15 area continue to rise as they have done in the past, the peak of the Laffer curve becomes very close. By contrast, tax cuts will boost the incentives to work and invest in the EU-15 economy.

In addition, our results indicate that tax cuts in the EU-15 area are to a much higher degree self-financing compared to the US which again reflects higher incentive effects from tax cuts in the EU-15 economy compared to the US. We therefore conclude that there rarely is a free lunch due to tax cuts. However, a large fraction of the lunch will be paid for by the efficiency gains in the economy due to tax cuts.

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Figure 1: Data used for Calibration of the Baseline Models

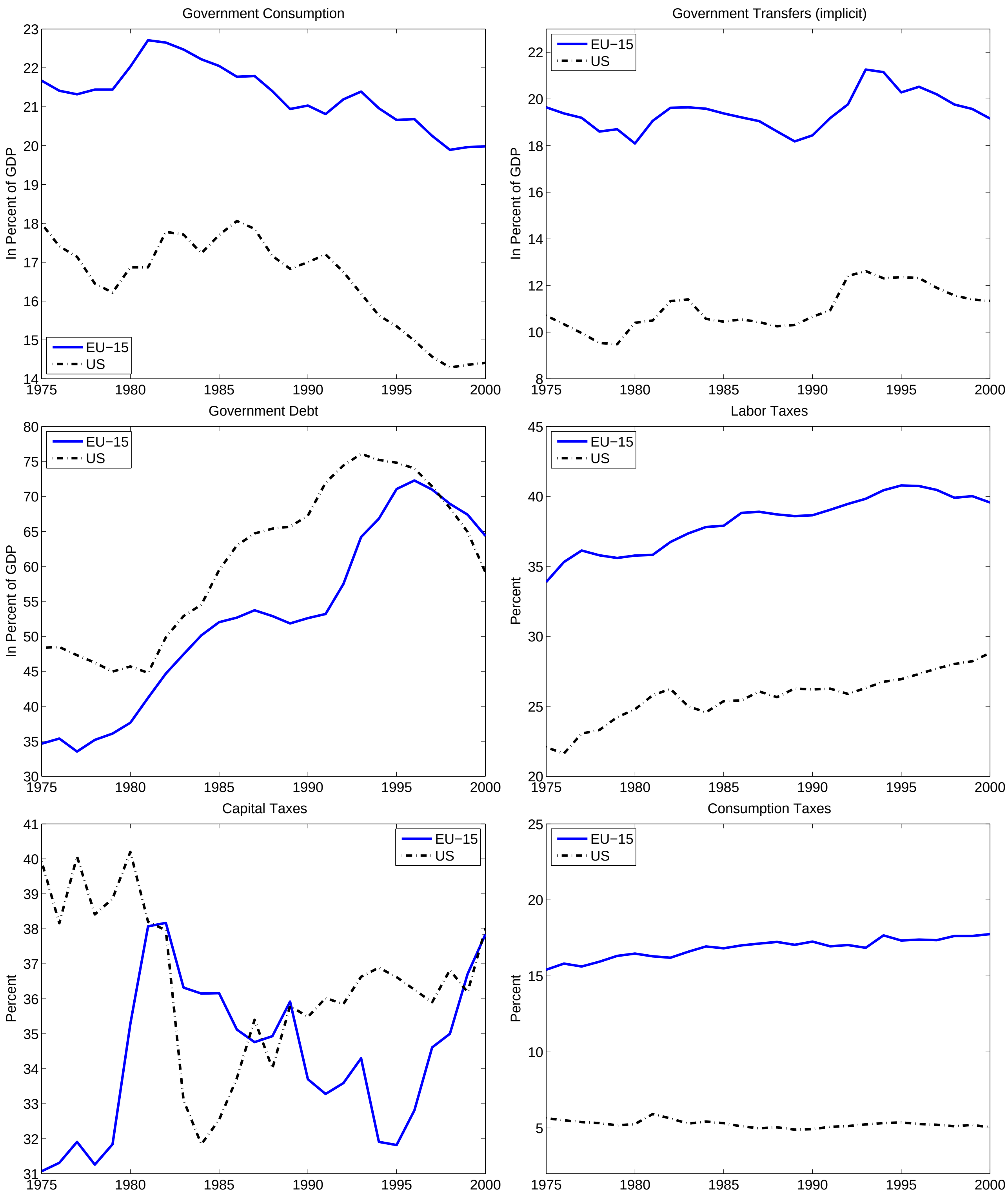


Figure 2: Data 5: Marginal vs Effective Tax Rates

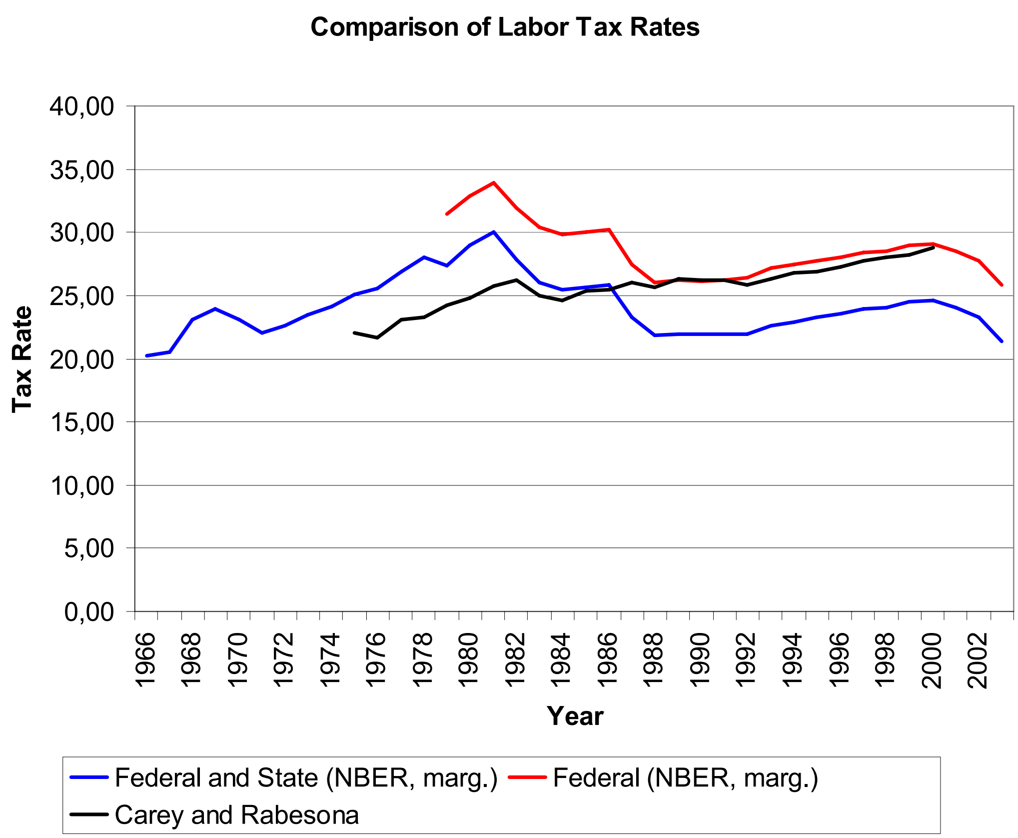


Figure 3: The US Laffer Curve

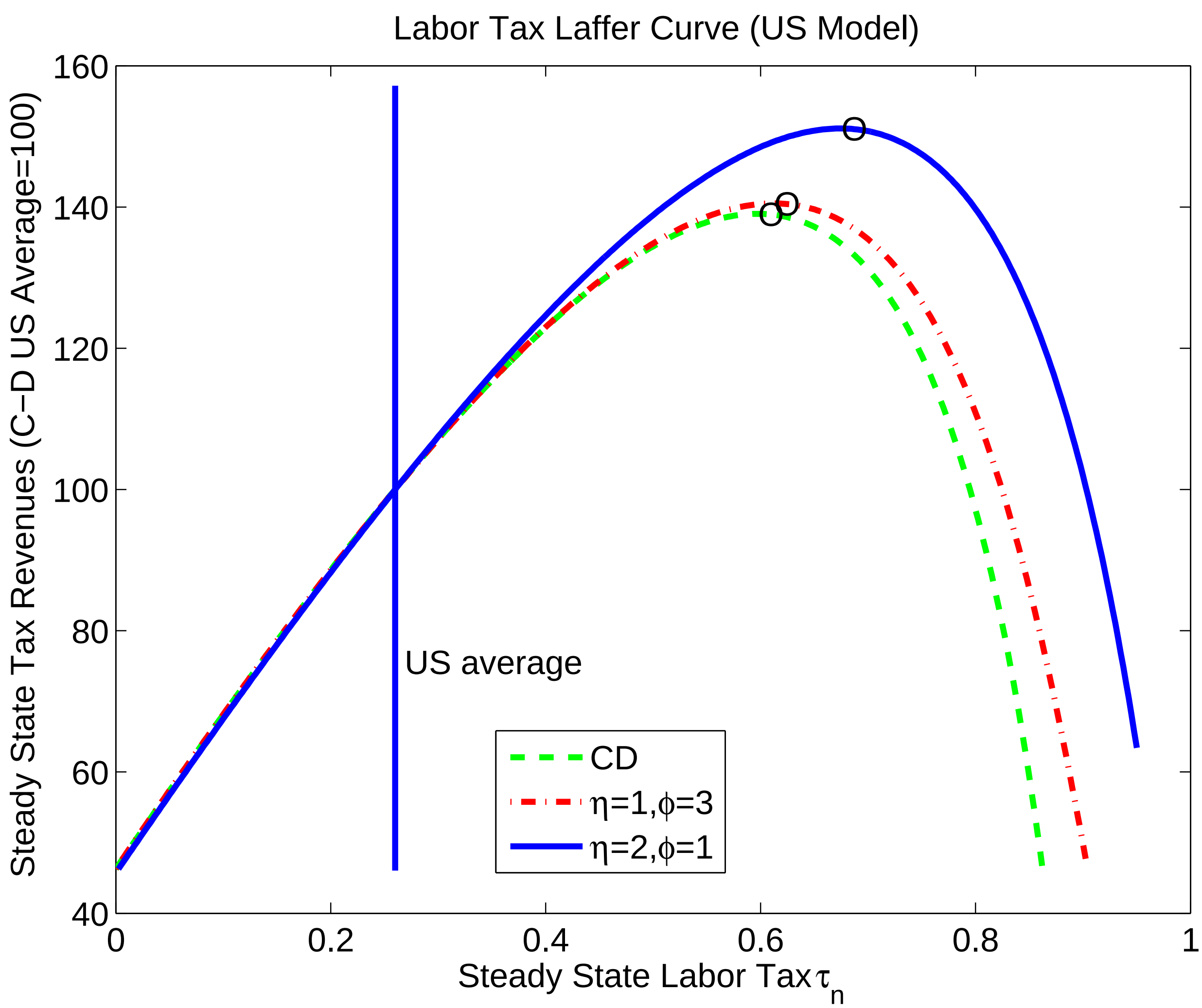


Figure 4: Labor Tax: vary Frisch elasticities

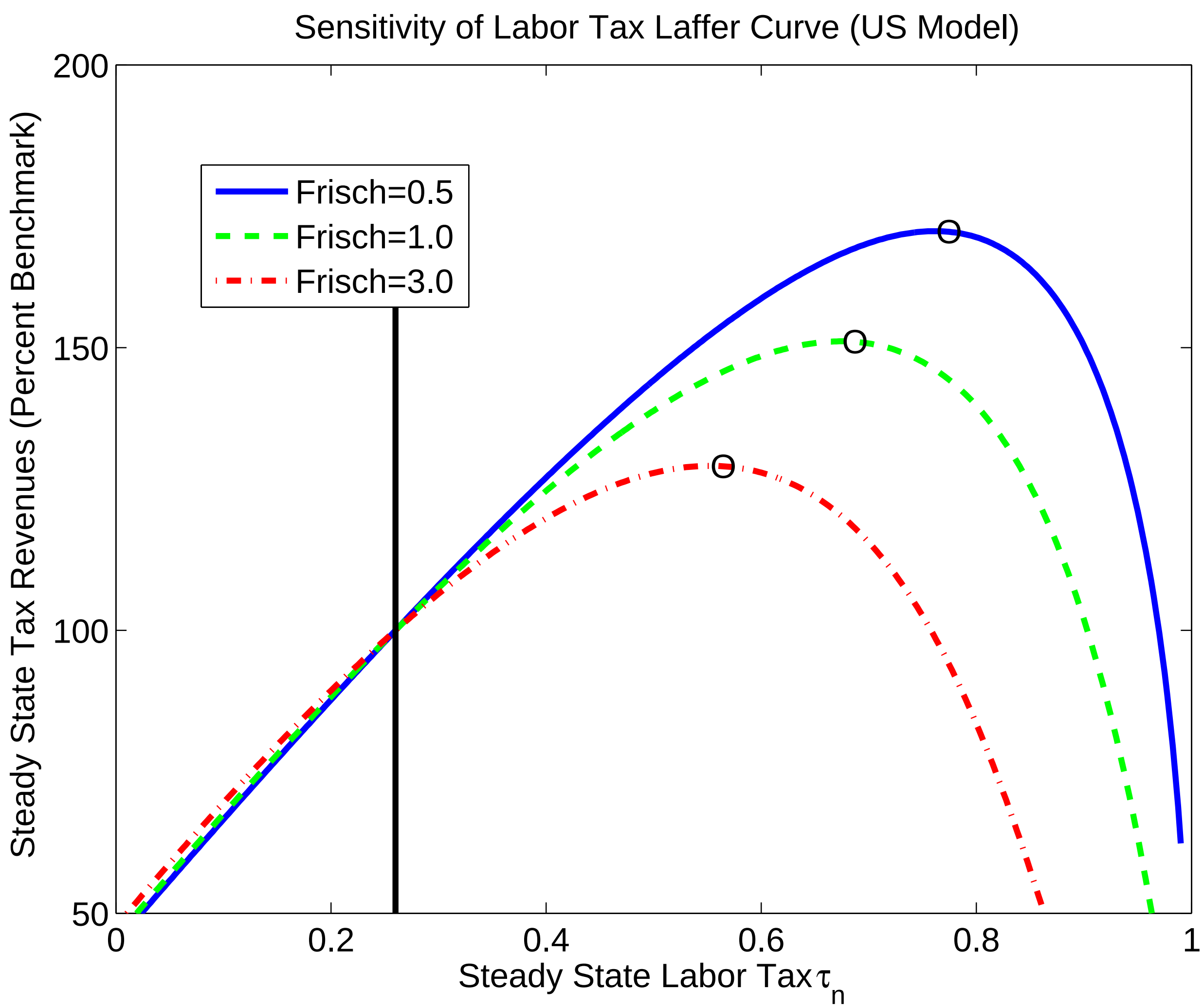


Figure 5: Labor Tax: vary IES

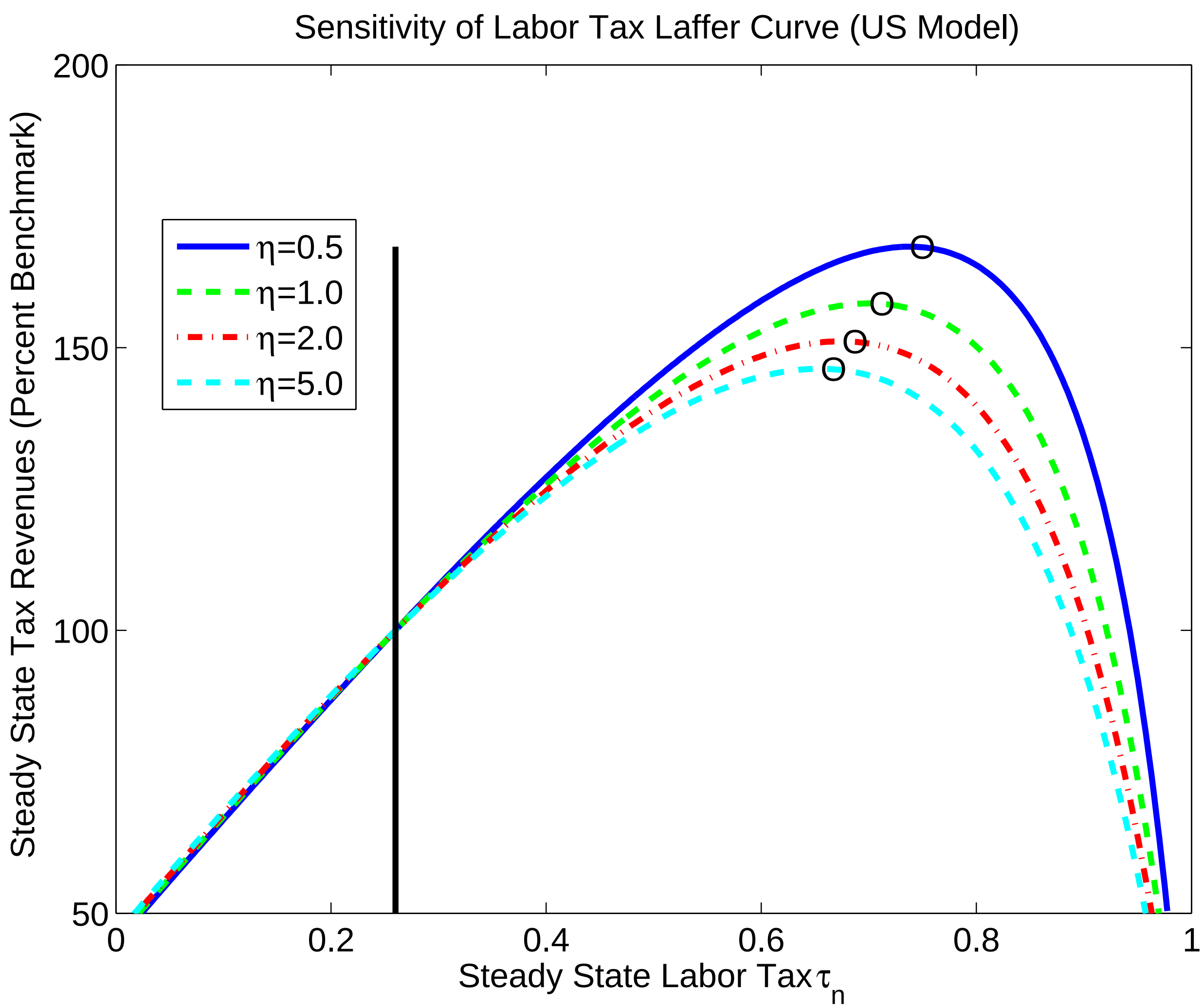
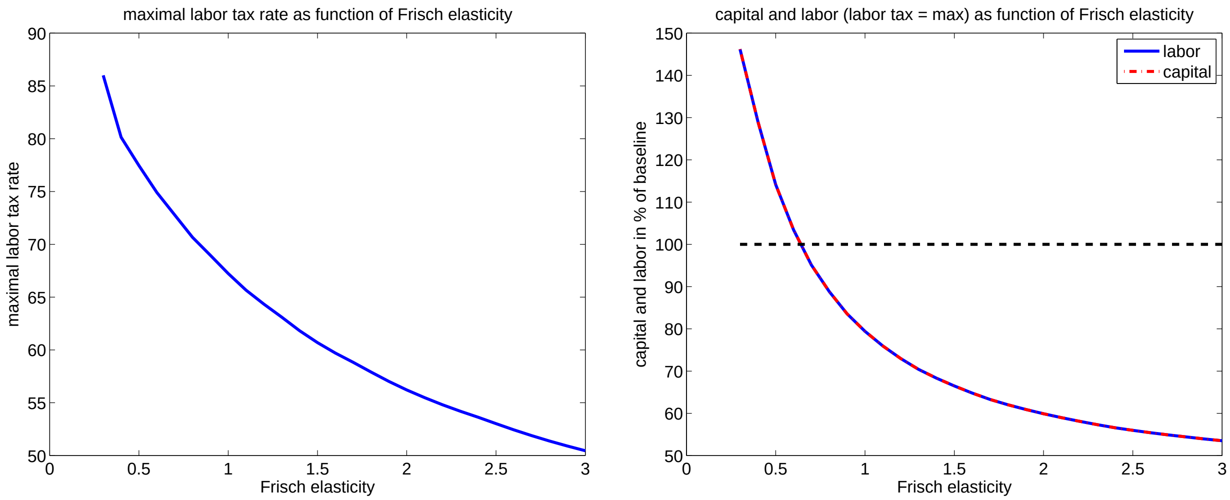


Figure 6: Labor Tax

maximal tax rate | capital and labor

Vary φ, keep $\eta = 2$:



Vary η, keep $\varphi = 1$:

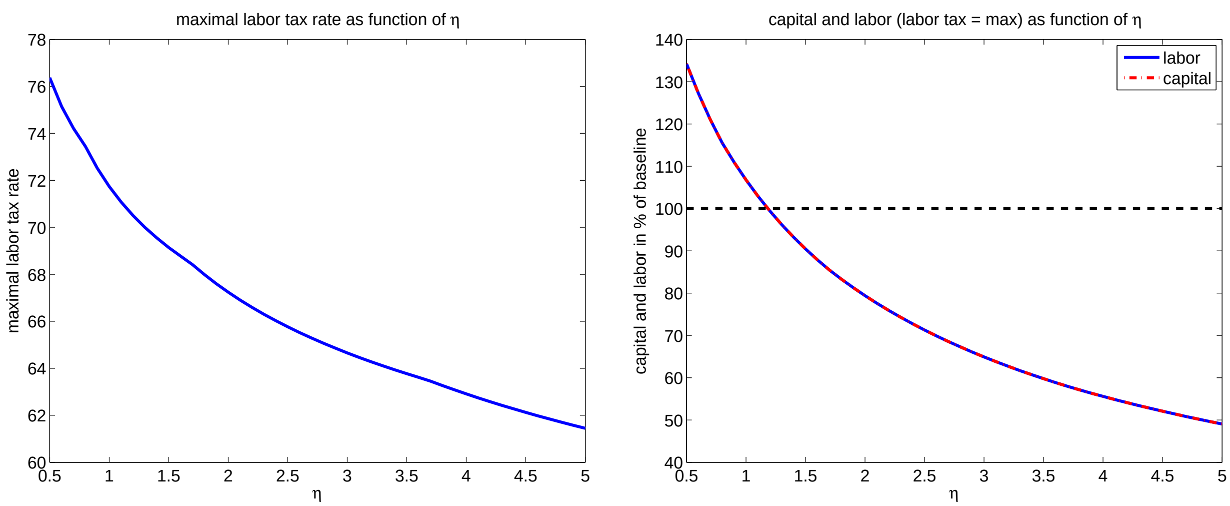


Figure 7: Labor Tax

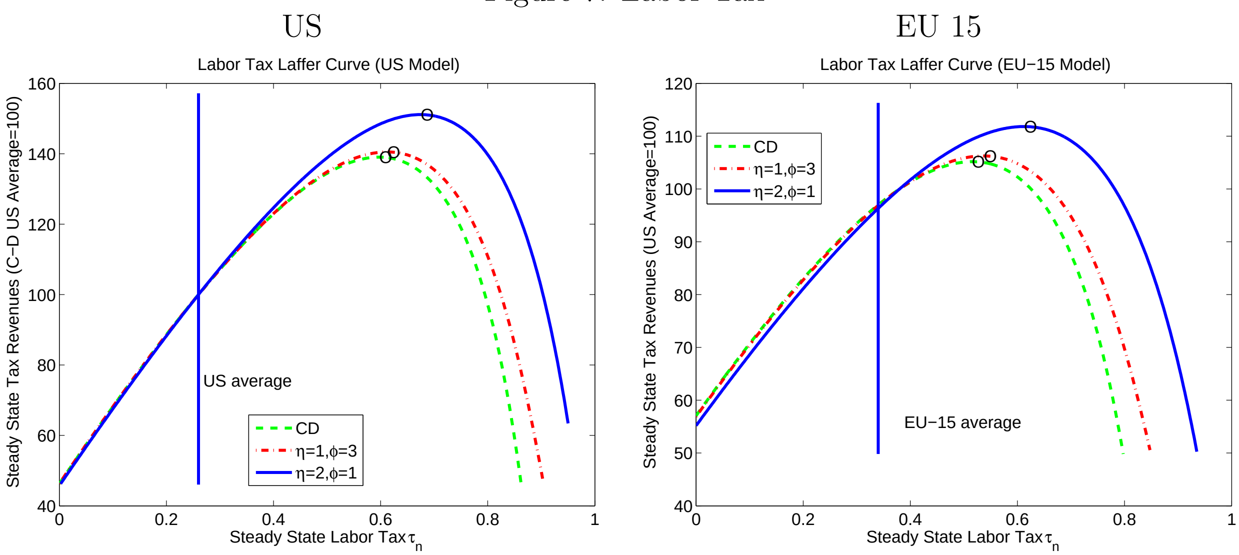


Figure 8: Capital Income Tax

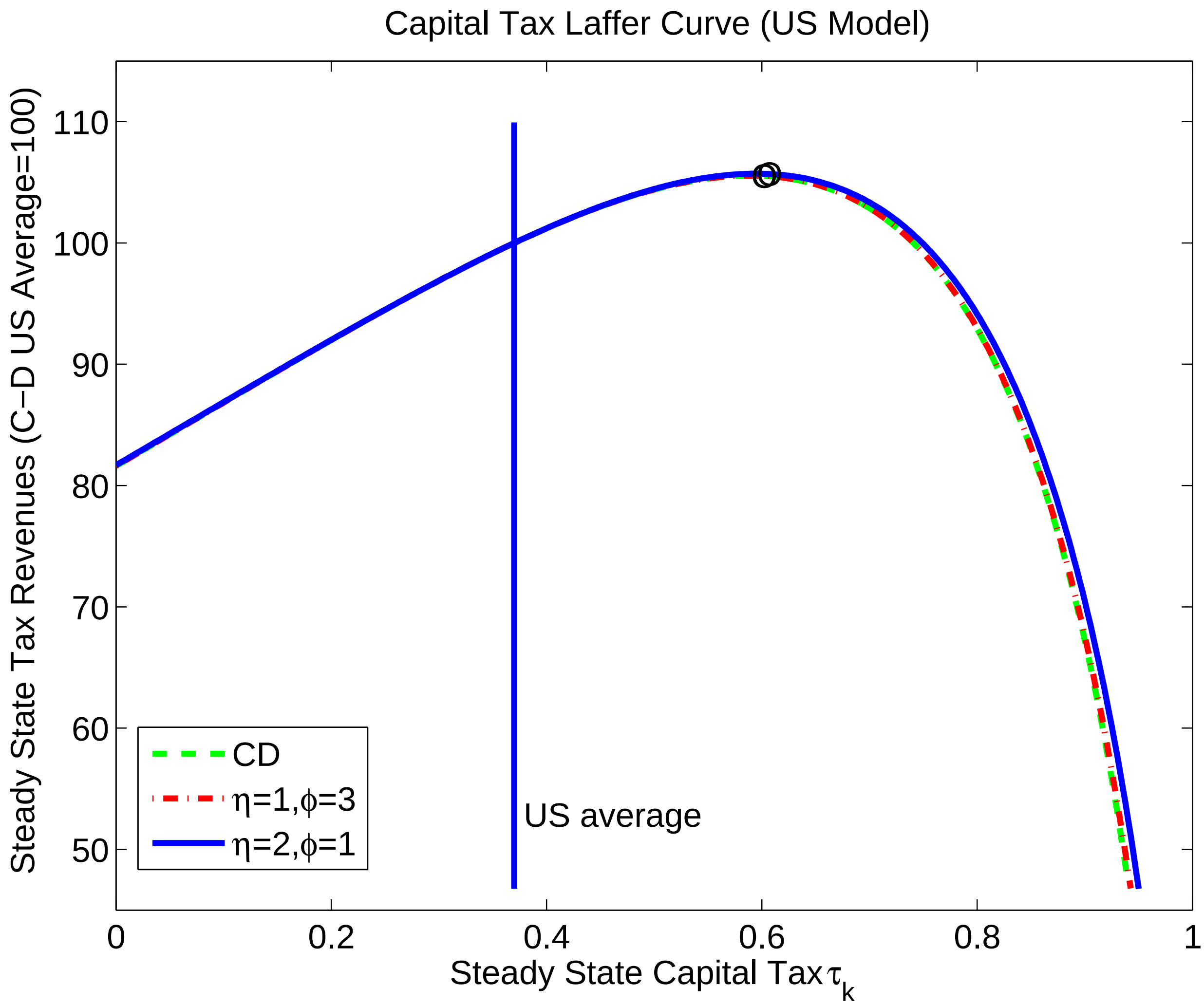


Figure 9: Capital Income Tax: vary Frisch elasticities

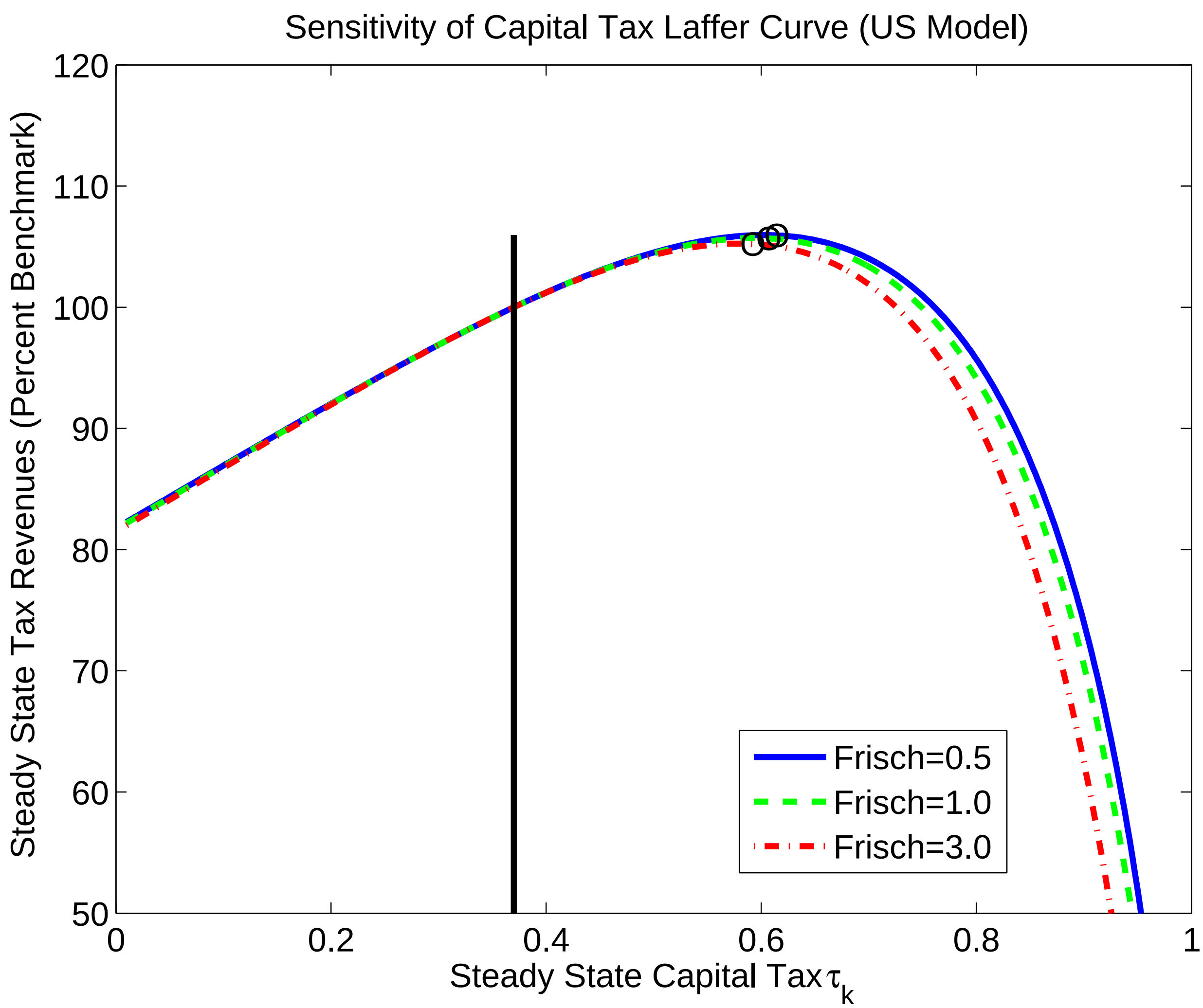


Figure 10: Capital Income Tax: vary IES

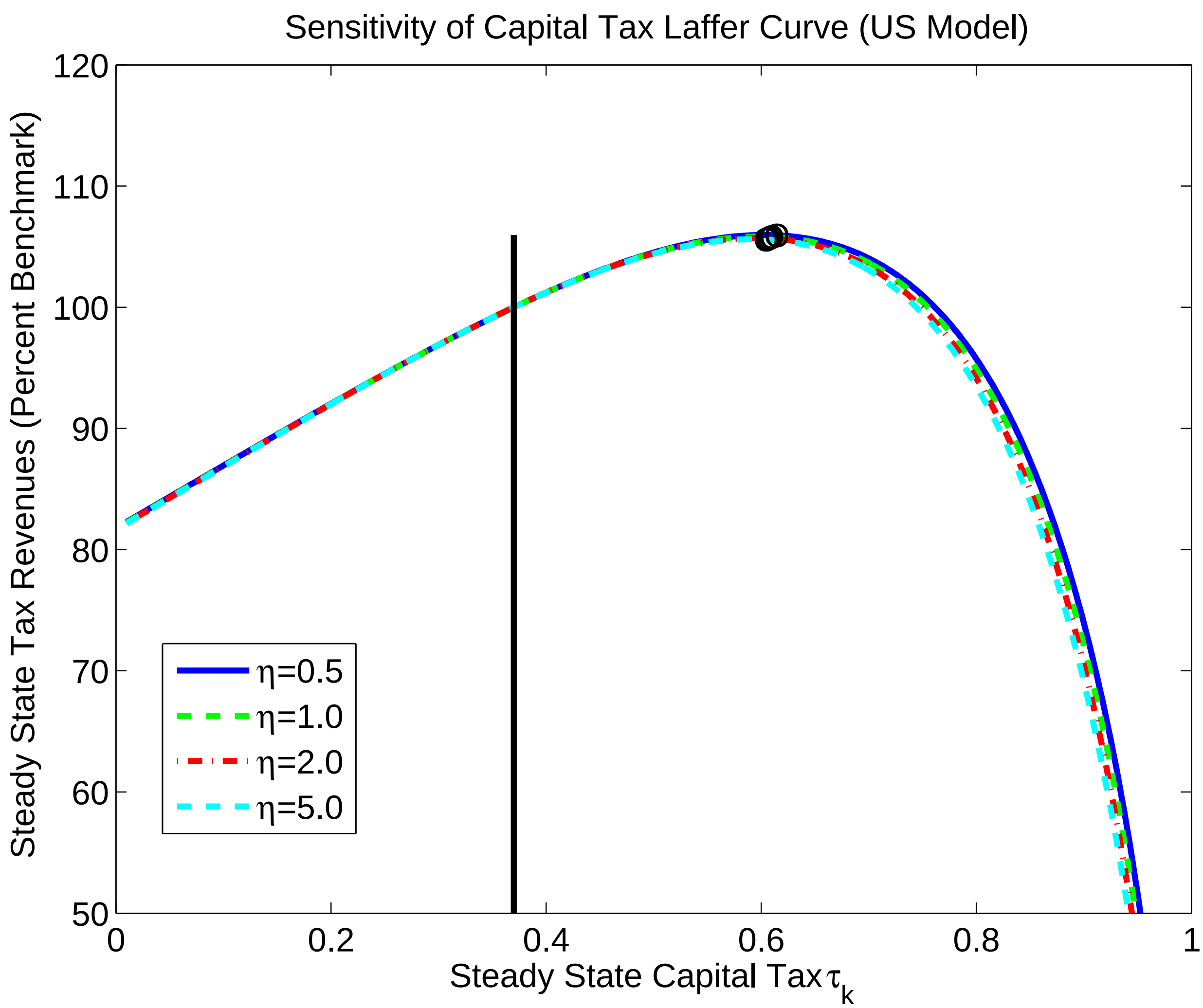
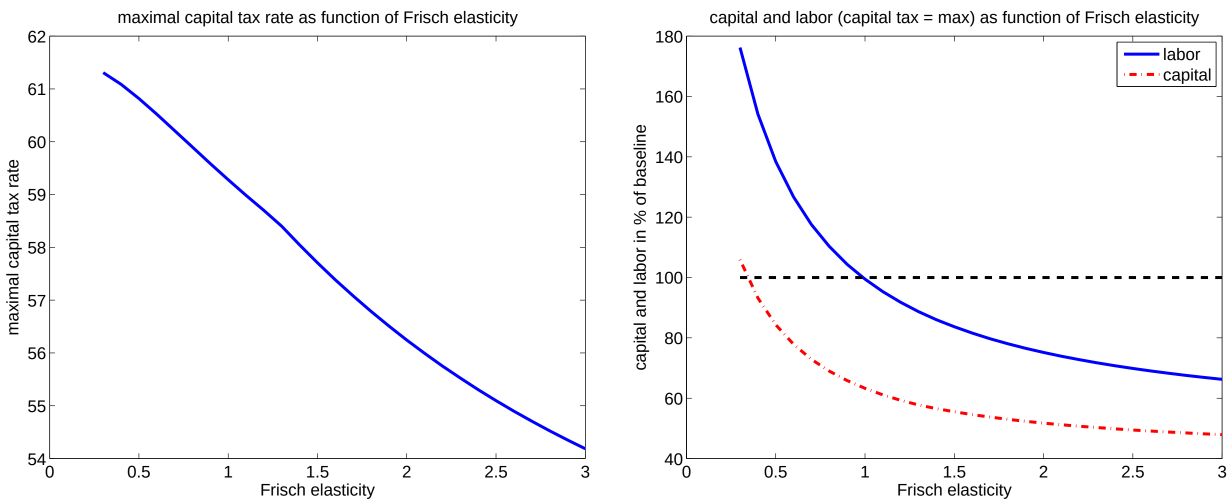


Figure 11: Capital Income Tax

maximal tax rate | capital and labor

Vary φ, keep $\eta = 2$:



Vary η, keep $\varphi = 1$:

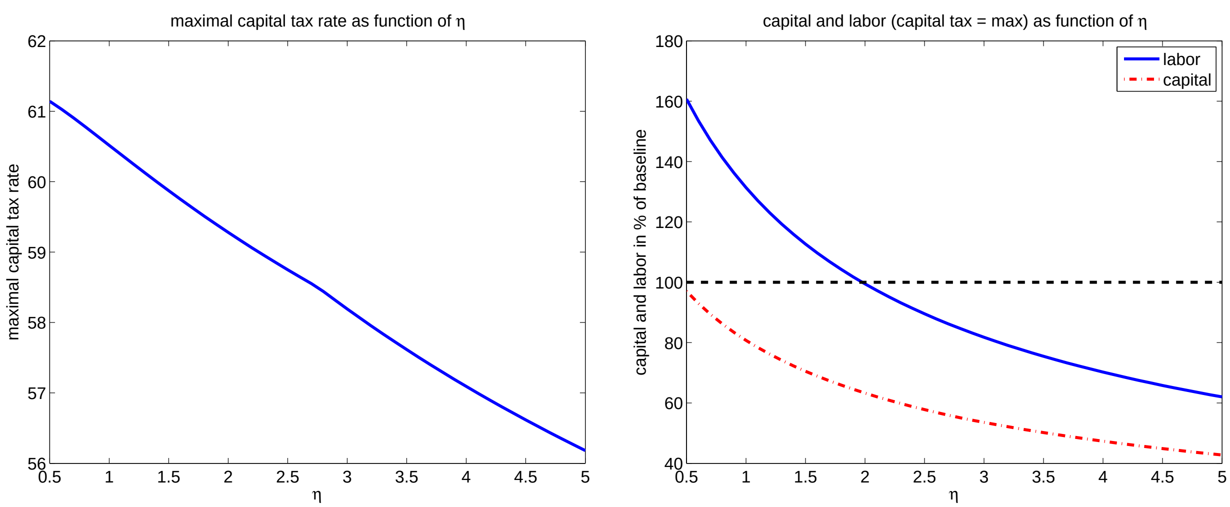


Figure 12: Capital Income Tax, US vs EU-15

US EU 15

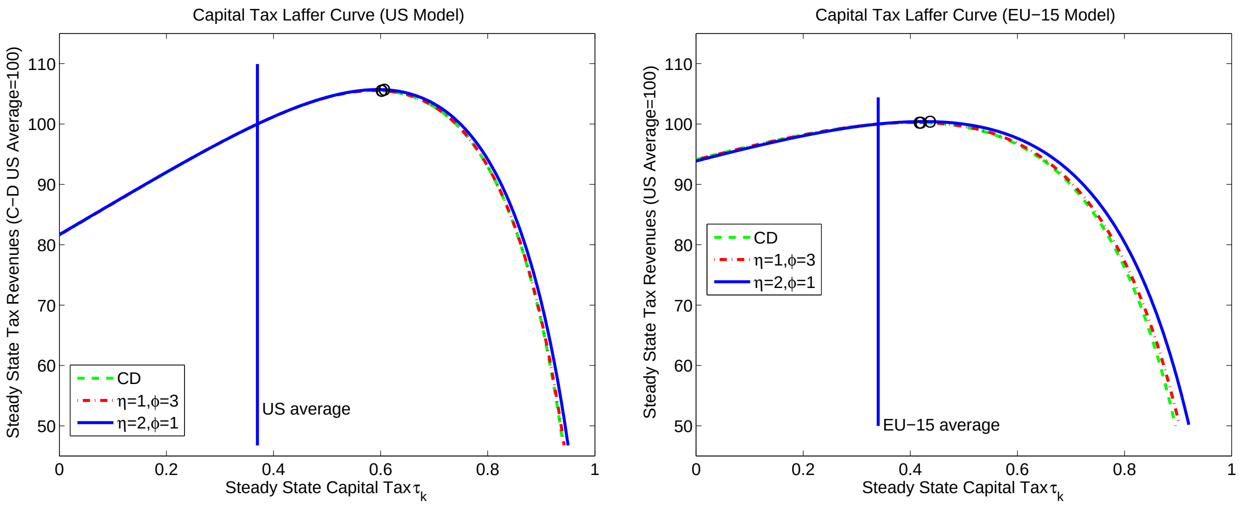


Figure 13: Capital Income Tax, US vs EU-15: The pieces

US EU 15

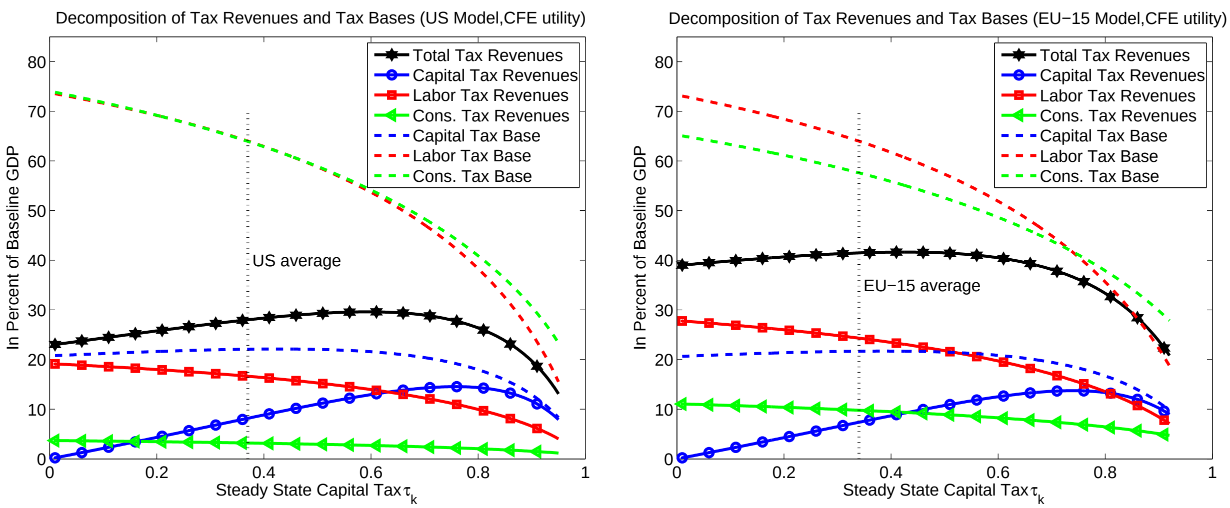


Figure 14: "Laffer hill" with $\eta = 2$, Frisch $= 1$.

US EU 15

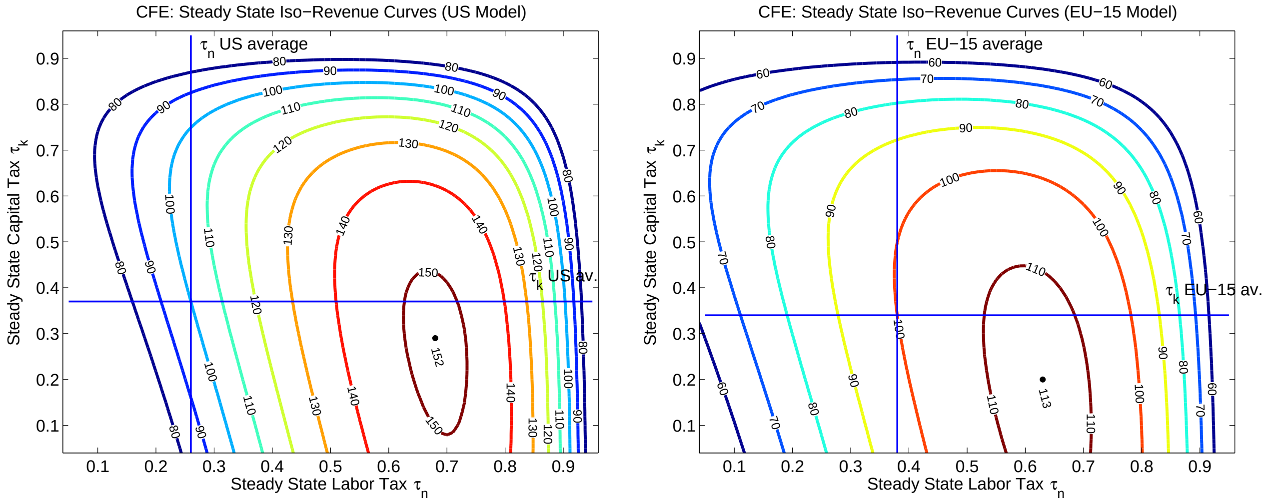


Figure 15: "Laffer hill" with $\eta = 1$, Frisch $= 3$.

US EU 15

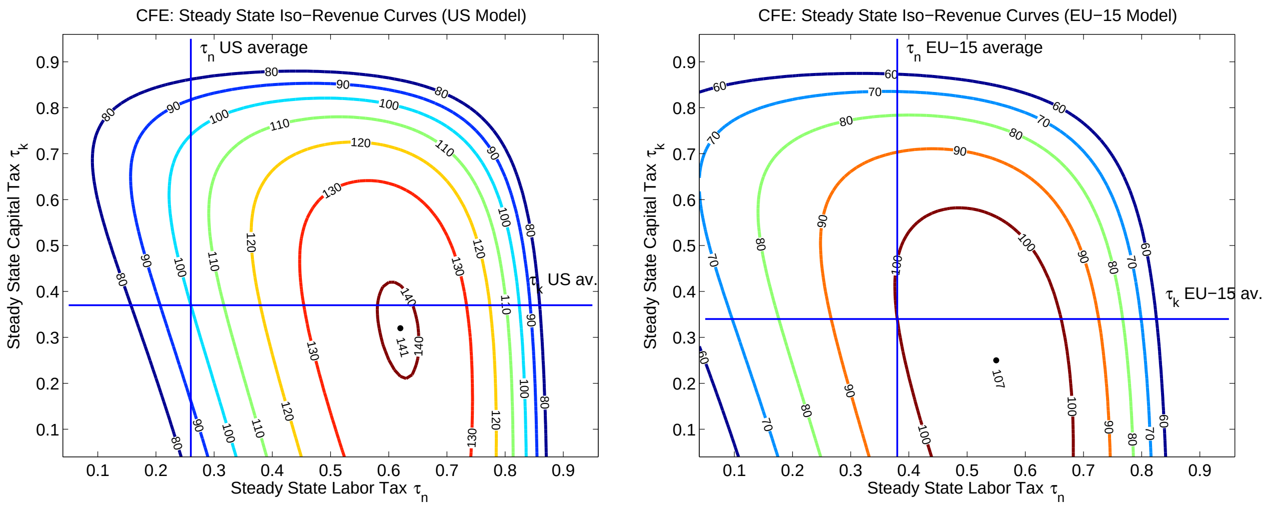


Figure 16: Capital Income Tax: time shift

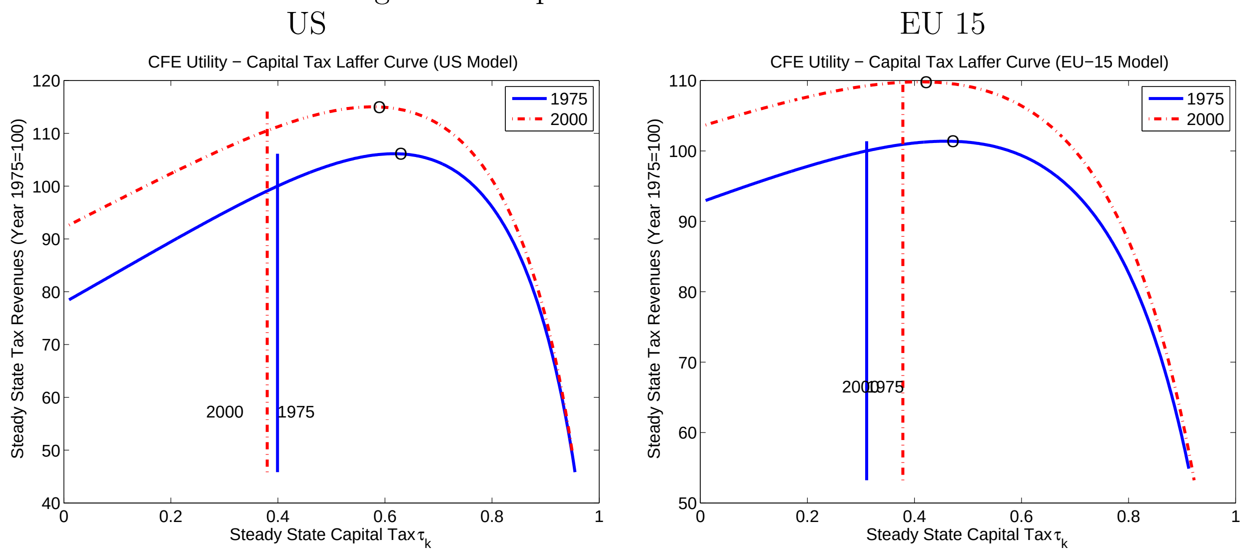


Figure 17: Capital tax cut, CD: dynamic scoring

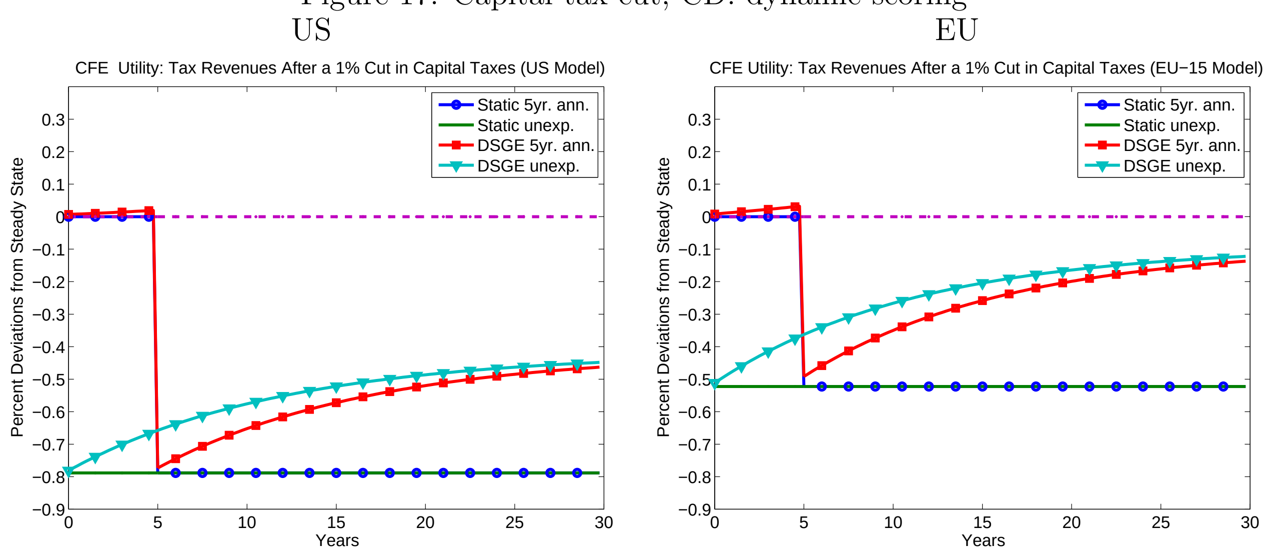


Figure 18: Labor Tax, US: gov. cons. or transfers

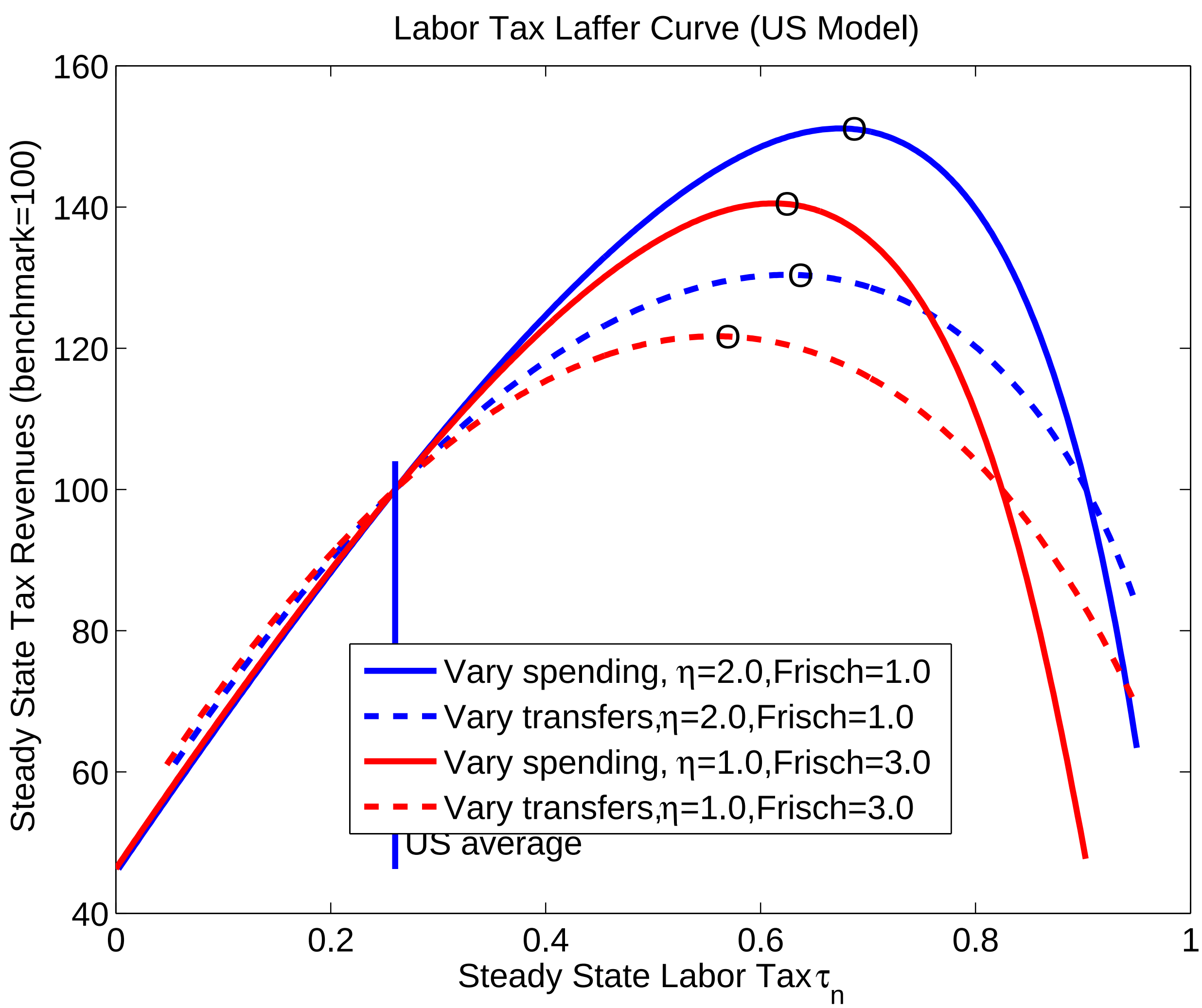


Figure 19: Cap.Inc. Tax, US: gov. cons. or transfers

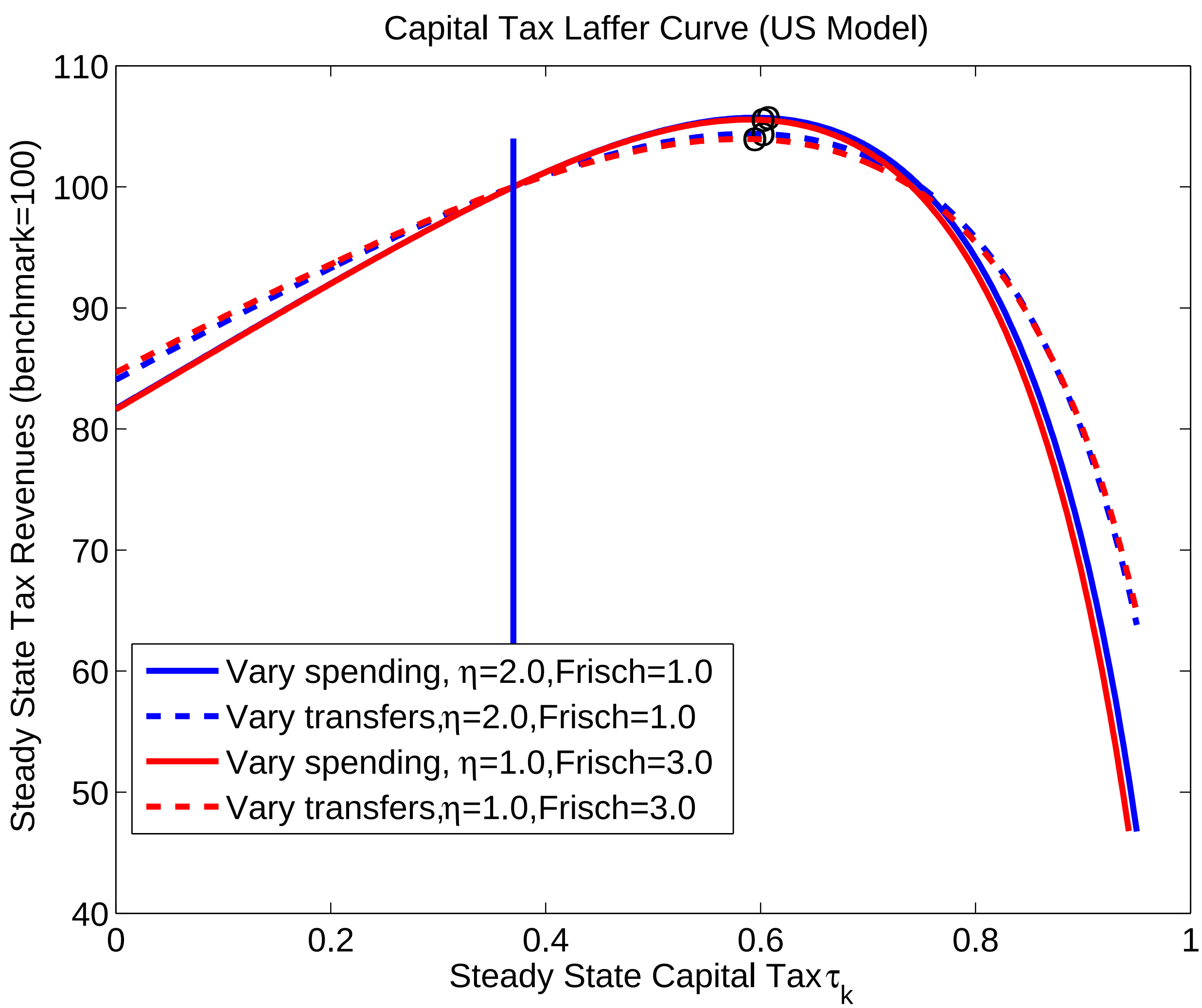
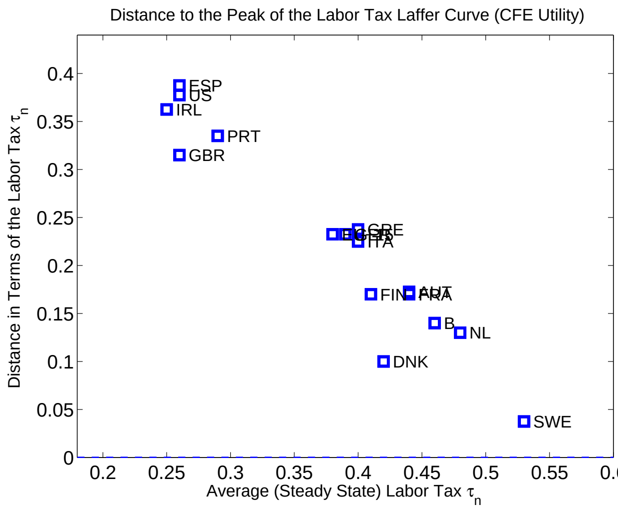


Figure 20: EU Countries, Labor Tax: distance to peak
tax rate ("horizontal") in % tax revenue ("vertical"), in % $\bar{y}$



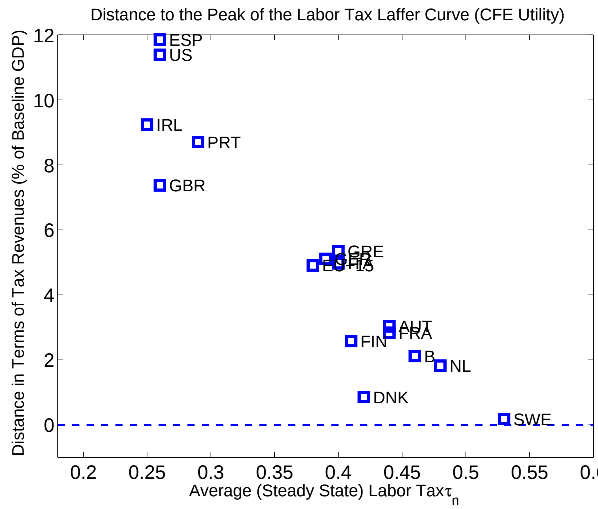
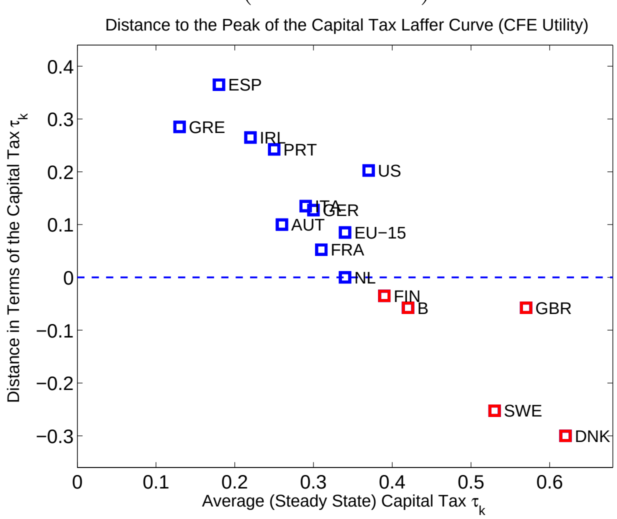


Figure 21: EU Countries, Labor Tax: distance to peak
tax rate ("horizontal") in % tax revenue ("vertical"), in % $\bar{y}$



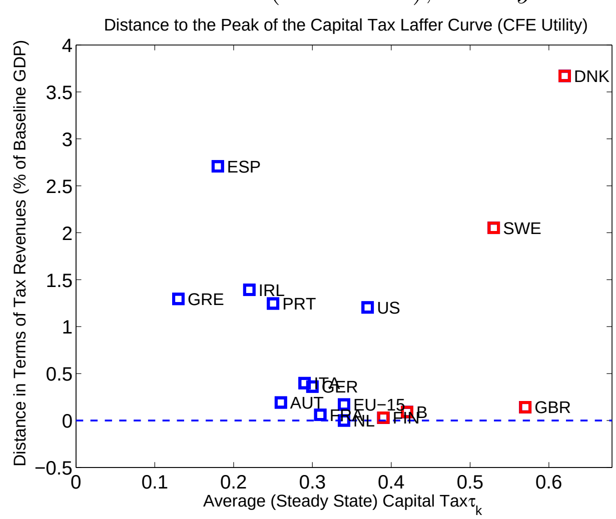


Figure 22: Labor Tax: Portugal vs Denmark

Portugal Denmark

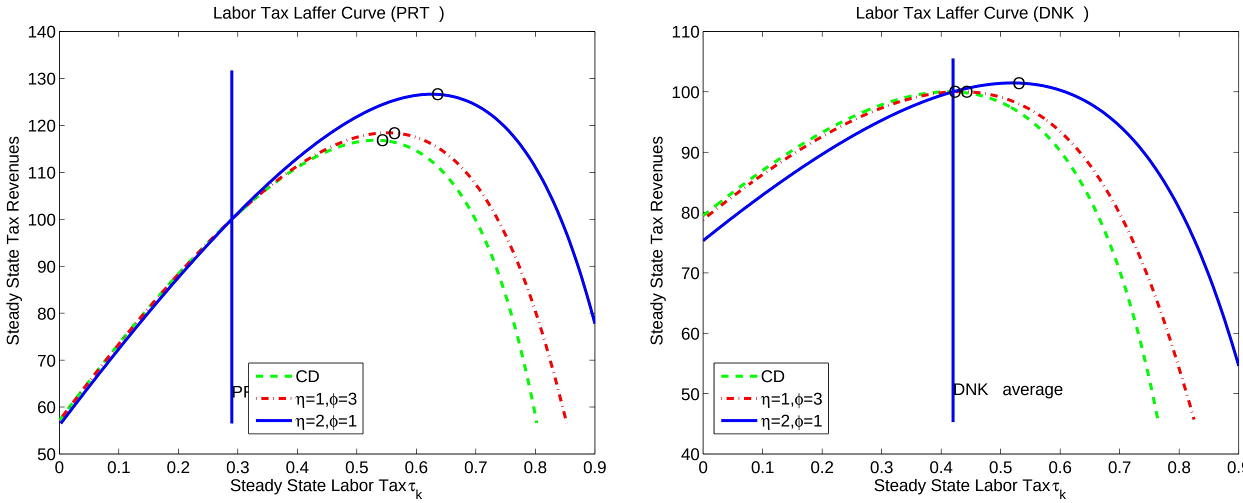


Figure 23: Cap. Inc. Tax: Portugal vs Denmark

Portugal Denmark

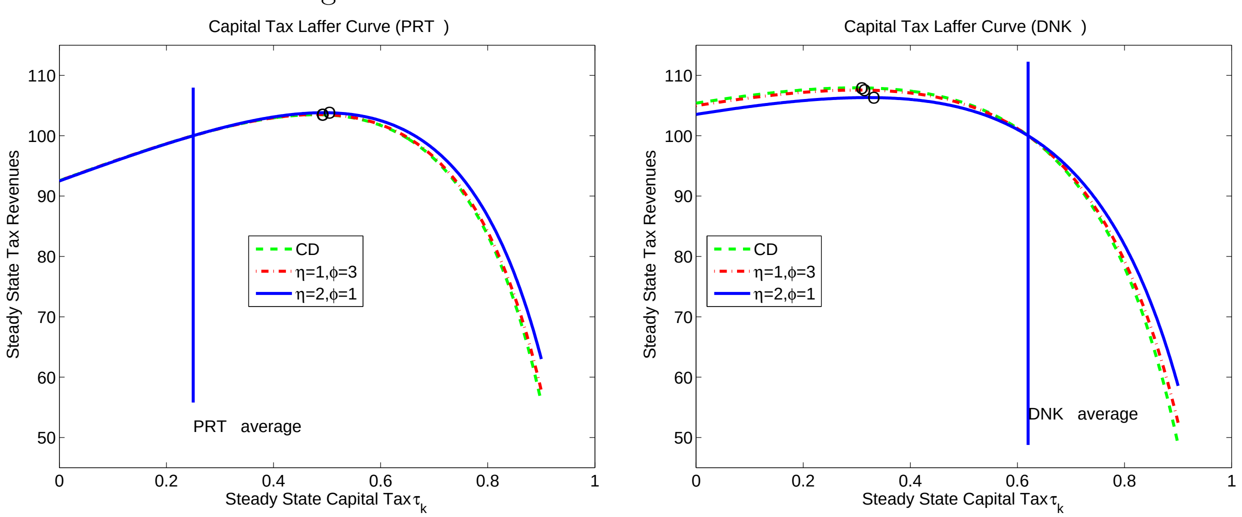
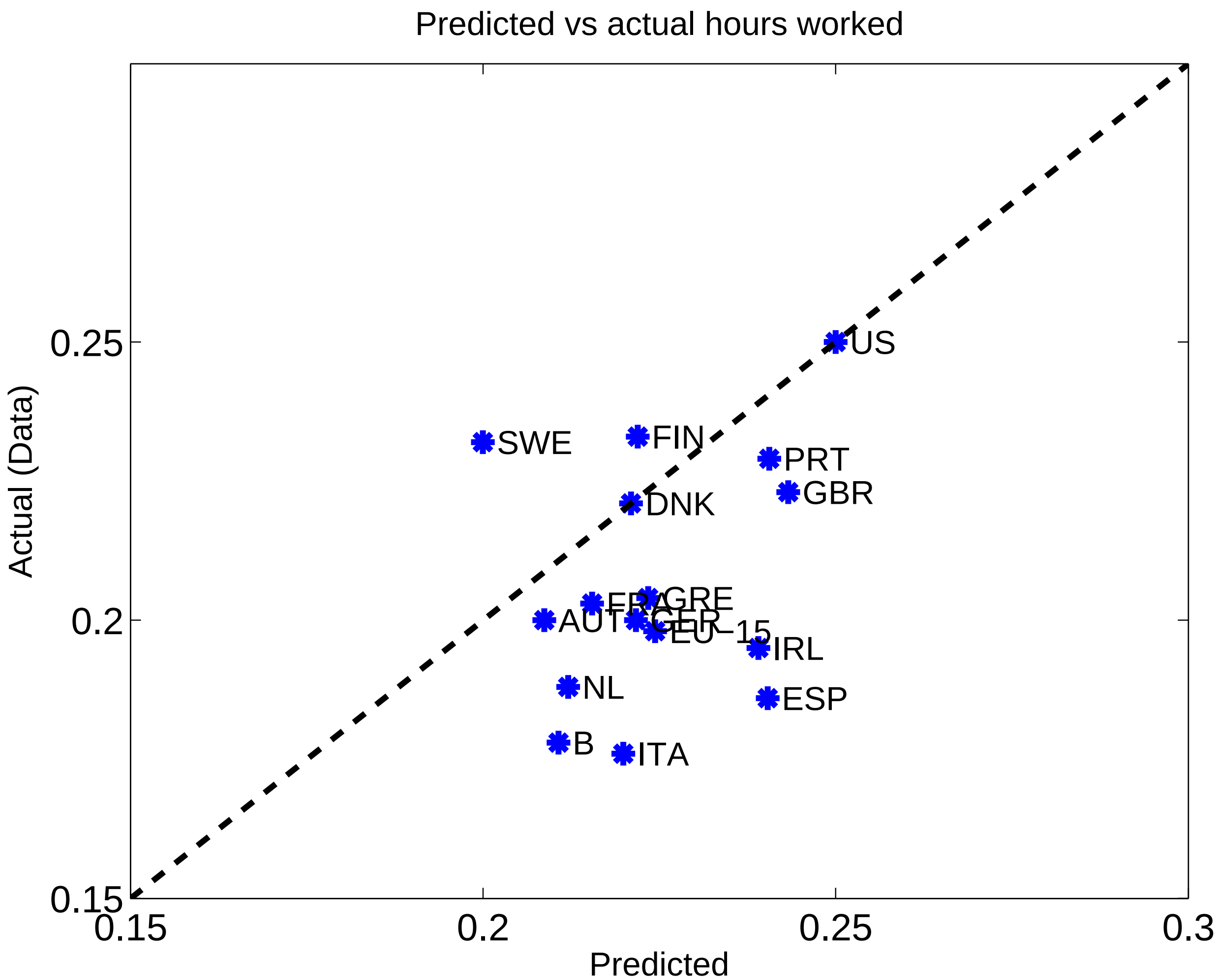


Figure 24: Prediction vs Data



A Appendix

A.1 EU-15 Tax Rates and GDP Ratios

In order to obtain EU-15 tax rates and GDP ratios we proceed as follows. E.g., EU-15 consumption tax revenues can be expressed as:

$$\tau^c_{EU-15,t} c_{EU-15,t} = \sum_j \tau^c_{j,t} c_{j,t} \tag{26}$$

where j denotes each individual EU-15 country. Rewriting equation (26) yields the consumption weighted EU-15 consumption tax rate:

$$\tau^c_{EU-15,t} = \frac{\sum_j \tau^c_{j,t} c_{j,t}}{c_{EU-15,t}} = \frac{\sum_j \tau^c_{j,t} c_{j,t}}{\sum_j c_{j,t}}. \tag{27}$$

The numerator of equation (27) consists of consumption tax revenues of each individual country j whereas the denominator consists of consumption tax revenues divided by the consumption tax rate of each individual country j. Formally,

$$\tau^c_{EU-15,t} = \frac{\sum_j T^{Cons}_{j,t}}{\sum_j \frac{T^{Cons}_{j,t}}{\tau^c_{j,t}}}. \tag{28}$$

The dataset of Carey and Rabesona (2002) contains individual country data for consumption taxes. Further, the methodology of Mendoza, Razin, and Tesar (1994) allows to calculate implicit individual country consumption tax revenues so that we can easily calculate the EU-15 consumption tax rate $\tau^c_{EU-15,t}$. Likewise, applying the same procedure we calculate EU-15 labor and capital tax rates. Taking averages over time yields the tax rates we report in table 2.[8]

In order to calculate EU-15 GDP ratios we proceed as follows. E.g., the GDP weighted

[8]Note that these tax rates are similar to those when calculating EU-15 tax rates from simply taking the arithmetic average of individual country tax rates. In this case, we would obtain $\bar{\tau}^n = 0.38$, $\bar{\tau}^k = 0.35$ and $\bar{\tau}^c = 0.19$.

EU-15 debt to GDP ratio can be written as:

$$\frac{b_{EU-15,t}}{y_{EU-15,t}} = \frac{\sum_j \frac{b_{j,t}}{y_{j,t}} y_{j,t}}{\sum_j y_{j,t}} \tag{29}$$

where b_j and y_j are individual country government debt and GDP. Likewise, we apply the same procedure for the EU-15 transfer to GDP ratio.[9] Taking averages over time yields the numbers used for the calibration of the model.

A.2 Analytical Characterization of the Slope of the Laffer Curve

In this section we derive an analytical characterization of the slope of the Laffer curve for unexpected and announced labor and capital tax cuts. We detrend all variables that are non-stationary by the balanced growth path ψ^t with $\psi = \xi^{\frac{1}{1-\theta}}$. Then, we log-linearize the equations that describe the equilibrium. Hat variables denote percentage deviations from steady state, i.e. $\hat{T}_t = \frac{T_t - \bar{T}}{\bar{T}}$. Breve variables denote absolute deviations from steady state, i.e. $\breve{\tau}_t^n = \tau_t^n - \bar{\tau}^n$. See the technical appendix for a full representation of the stationary equilibrium equations as well as the the log-linearized equations. Without loss of generality we assume that consumption taxes are constant over time, i.e. $\breve{\tau}_t^c = 0\ \forall t$.

A.2.1 Unexpected Tax Cuts

For unexpected tax cuts, we assume that capital and labor taxes evolve according to: $\breve{\tau}_t^k = \rho_{\tau^k} \breve{\tau}_{t-1}^k + \epsilon_t$ and $\breve{\tau}_t^n = \rho_{\tau^n} \breve{\tau}_{t-1}^n + \nu_t$. Using the log-linearized system of equations we can solve for the recursive equilibrium law of motion for $\hat{k}_t$ and $\hat{T}_t$ following Uhlig (1999). I.e.,

$$\hat{k}_t = \eta_{kk} \hat{k}_{t-1} + \pi \breve{\tau}_t^k + \nu \breve{\tau}_t^n \tag{30}$$

$$\hat{T}_t = \eta_{Tk} \hat{k}_{t-1} + \mu \breve{\tau}_t^k + \omega \breve{\tau}_t^n. \tag{31}$$

[9] Note again, that these GDP ratios are close to those when simply taking the arithmetic average. In this case, we would obtain an annual debt to GDP ratio of 55 % and a transfer to GDP ratio of 19 %.

After some tedious manipulations we can express tax revenues $\hat{T}_t$ as follows:

$$\begin{aligned}\hat{T}_t = \eta_{Tk}\eta_{kk}^t\hat{k}_{-1} \quad &+ \quad \left[\frac{\eta_{Tk}\pi}{\eta_{kk}}\left(\frac{\rho_{\tau^k}^{t+1}-\eta_{kk}^{t+1}}{\rho_{\tau^k}-\eta_{kk}}\right)+\left(\mu-\frac{\eta_{Tk}\pi}{\eta_{kk}}\right)\rho_{\tau^k}^t\right]\breve{\tau}_0^k \\ &+ \quad \left[\frac{\eta_{Tk}\nu}{\eta_{kk}}\left(\frac{\rho_{\tau^n}^{t+1}-\eta_{kk}^{t+1}}{\rho_{\tau^n}-\eta_{kk}}\right)+\left(\omega-\frac{\eta_{Tk}\pi}{\eta_{kk}}\right)\rho_{\tau^n}^t\right]\breve{\tau}_0^n\end{aligned} \tag{32}$$

The coefficients in front of $\breve{\tau}_0^k$ and $\breve{\tau}_0^n$ can be interpreted as the slope of the Laffer curve. Suppose we consider permanent tax changes only, i.e. $\rho_{\tau^k} = \rho_{\tau^n} = 1$ and no initial deviation of capital, i.e. $\hat{k}_{-1} = 0$. Then, if $\|\eta_{kk}\| < 1$ we obtain:

$$\lim_{t\to\infty}\hat{T}_t \quad = \quad \left[\frac{\eta_{Tk}}{1-\eta_{kk}}\pi+\mu\right]\breve{\tau}_0^k+\left[\frac{\eta_{Tk}}{1-\eta_{kk}}\nu+\omega\right]\breve{\tau}_0^n. \tag{33}$$

The coefficients in front of $\breve{\tau}_0^k$ and $\breve{\tau}_0^n$ characterize the slope of the long-run Laffer curve. Since the coefficients of the recursive equilibrium law of motion are rather complicated functions of the model parameters we rely on numerical evaluations instead, resulting e.g. in figure 17.