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Abstract

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 the US and the EU-15 area are located on the left side of their labor and capital tax Laffer curves, but the EU-15 economy being much closer to the slippery slopes than the US. Our results indicate that since 1975 the EU-15 area has moved considerably closer to the peaks of their Laffer curves. We find that the slope of the Laffer curve in the EU-15 economy is much flatter than in the US which documents a much higher degree of distortions in the EU-15 area. A dynamic scoring analysis shows that more than one half of a labor tax cut and more than four fifth of a capital tax cut are self-financing in the EU-15 economy.

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

JEL classification: E0, E60, H0

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, Jr. (1990)

1 Introduction

This paper sheds new light on an old debate - the shape of the Laffer curve. In 1974 Arthur B. Laffer noted during a business dinner that ”there are always two tax rates that yield the same revenues”.[1] After being asked, he illustrated the trade off between average tax rates and tax revenues on his restaurant napkin. In the 1980’s, the so-called supply-side economists

[1] see Wanniski (1978).

claimed that the US were on the slippery slope side of the Laffer curve and therefore, tax cuts would increase tax revenues. In response to the Reagan tax cuts, however, government tax revenues dropped. Perhaps then, the US was on the left side of the Laffer curve.

Thus, one ought to investigate the left side of the Laffer curve more closely. This is important for two reasons. First, the knowledge of the *peak* is important: if it is close, one should be careful about raising taxes to avoid the slippery slope side. Second, the *slope* reminds us of the incentive effects of tax changes. How strong are these effects quantitatively?

The goal of this paper is to examine the shape of the Laffer curve quantitatively in a simple neoclassical growth model. We model each economic area as a closed economy. In the model, 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 and to the EU-15 economy. We use three different preference specifications to achieve this goal. An important quantity is the Frisch elasticity of labor. While it is equal to 3 for a Cobb-Douglas specification of the preferences in our benchmark calibration, it is set to 0.3 for a Greenwood-Hercowith-Huffman specification, while both deliver the same result on a key tax experiment. We also provide a sensitivity analysis as well as an analysis for individual European countries.

We show that there exist steady state Laffer curves for labor taxes as well as capital taxes. This result is robust with respect to variations of preferences of the household. For consumption taxes, however, the existence of a Laffer curve depends on the underlying preferences.

According to the predictions of the model both economies - the US and the EU-15 area - 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 examine how the Laffer curves have shifted between 1975 and 2000 for the US and the EU-15 area. 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 area has moved considerably closer to the peak for both - labor and capital taxes.

An individual country analysis for the EU-15 area reveals that in terms of labor taxes all individual EU-15 countries are closer to the slippery slopes of their Laffer curves than the US. For capital taxes this conclusion holds also for the majority of countries in the EU-15 area. Finally, the long run slopes of the labor and capital tax Laffer curves are smaller in all individual EU-15 countries compared to the US.

We quantify the dynamic impact of unexpected and announced tax cuts, financed by corresponding cuts in government spending. The results for our baseline calibration are as follows. For US capital taxes, we find that an unexpected permanent 1 % tax cut corresponds to an endogenous *cut* of government spending of 1.6 % on impact and 0.8 % in the long run. A 5-year-in-advance announced permanent 1 % cut of capital taxes leads to an endogenous *increase* of government spending of up to 0.4 % during the announcement period and a *cut* of government expenditures of 0.8 % in the long run. For the EU-15 economy, we obtain the same qualitative results. However, quantitatively, the figures are smaller than in the US. Thus, the slope of the Laffer curve in the EU-15 economy is much flatter than in the

US documenting much higher distortions in the EU-15 area.

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 19% of a labor tax cut and 47% of a capital tax cut are self-financing in the steady state. In the EU-15 economy 54% of a labor tax cut and 85% of a capital tax cut are self-financing. Hence, the efficiency gains from cutting taxes in the EU-15 area are considerably larger than in the US economy.

Thus, a large fraction of the lunch will typically be paid for by the efficiency gains in the economy due to tax cuts. A tax cut may not deliver a free lunch. But it often delivers a cheap lunch.

The paper is organized as follows. Section two summarizes the existing literature. The model is derived in section three. In section four we discuss the results. Finally, section five concludes.

2 Related Literature

There is a comparably large literature on the effects of fiscal policy on aggregate fluctuations and growth.

One branch of literature investigates the effects of fiscal policy in endogenous growth models. Ireland (1994) shows that there exists a dynamic Laffer curve in an AK model framework. However, using a similar framework, Bruce and Turnovsky (1999) and Novales and Ruiz (2002) find, that an unrealistically high degree of intertemporal substitution is needed to generate the desired result that a tax cut is self financing. Agell and Persson

(2001) argue that the assumption of a constant government share on the economy drives the Bruce and Turnovsky result. Once this share is allowed to vary in response to changes in tax rates then there exist dynamic Laffer curves in AK models for empirically plausible elasticities of intertemporal substitutions.

Another branch of literature focuses on the effects of fiscal policy in an exogenous growth context. 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 neoclassical growth model with heterogenous agents. They focus on the redistributional effects of capital tax cuts. However, in their heterogenous agents framework, they show 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 with endogenous labor taxes. However, these authors focus on the effects of endogenous labor and capital taxes and a balanced government budget rule and show that indeterminacy can occur in such a setup. Our paper by contrast features exogenous tax rates which implies that indeterminacy will not occur. Moreover, we concentrate on a rigorous characterization and comparison of the Laffer curve for labor and capital taxes for the US and EU-15 economy.

Floden and Linde (2001) examine the effects of government redistribution schemes in the presence of uninsurable idiosyncratic productivity risk in a parameterized model of the US and Sweden. According to their results, 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 in the US and Sweden. They report that Sweden is on the slippery slope side for several tax instruments while the US is on the left side. These papers however do not focus on the Laffer curve as such but rather briefly mention the implications of their models with respect to it. By contrast, this paper provides a clear cut and fully fledged analysis of the shape of the Laffer curve for the US and EU-15 economy.

Prescott (2004a) 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. He finds that Europeans turned to work less than Americans since labor taxes have risen more in European countries. Our work is in line with Prescott's findings. However, for his main result Prescott (2004a) investigates only the labor market relation of his model and based on this he analyzes the implied incentive effects for labor supply due to labor tax changes. The present paper analyzes the incentive effects of changes in labor, capital and consumption taxes in a general equilibrium framework with endogenous government consumption in the light of the Laffer curve.

Finally, Mankiw and Weinzierl (2005) pursue a dynamic scoring exercise in a neoclassical growth model for the US economy. Dynamic scoring accounts for the feedback effect from lower taxes to growth via increased incentives to participate on the markets. They find that in the US half of a capital tax cut is self financing compared to a static scoring exercise. The present paper extends their work in two dimensions. First, we set up a model that has alternative features like i.e., consumption taxes and endogenous government consumption. Second, we calculate the dynamic scoring effect for the EU-15 and compare it to the US.

3 The Model

We use a standard neoclassical growth model, extended with fiscal policy.[2] In particular, 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.[3] Time is discrete, $t = 0, 1, ..., \infty$.

The representative household maximizes the discounted sum of life-time utility subject to an intertemporal budget constraint and a capital flow equation.

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

[2]Following Prescott (2004a) we abstract from a monetary sector. See Leeper and Yun (2005) for an exposition of the fiscal theory of the price level with monetary-fiscal policy interactions and their effects on the Laffer curve.

[3]This assumption implies that input factor markets for labor and capital are internationally independent. Labor immobility between the US and the EU-15 is a well known fact and a commonly used assumption in the literature. 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. However, for explicit tax policy in open economies see i.e., Mendoza and Tesar (1998) or Kim and Kim (2004) and the references therein.

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 utility providing government consumption g_t as given.[4] Further, the household receives wages w_t, dividends d_t and profits Π_t from the firm. Moreover, the household receives 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 (2004a) and in line with Mendoza, Tesar and Razin (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.

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

where z_t denotes total factor productivity which is defined as $z_t = \xi^t \gamma_t$. We assume that γ_t follows a stationary stochastic AR(1) process.

[4]For similar models with valuable government spending see i.e. Christiano and Eichenbaum (1992), Baxter and King (1993), McGrattan (1994), Lansing (1998), Cassou and Lansing (2004) and Klein, Krusell and Rios-Rull (2004).

The government faces the following budget constraint,

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

where government tax revenues T_t can be summarized as

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

We assume that lump-sum transfers s_t as well as the three tax rates on labor, capital and consumption follow exogenous AR(1) processes. To keep things simple, we assume that government consumption is adjusted accordingly to balance the government budget. Thus, we assume that government debt does not deviate from its balanced growth path[5] i.e., $b_{t-1} = \psi^t \bar{b}, \forall t \geq 0$ and therefore the government budget

(3) can be rewritten as

$$g_t = \psi^t \bar{b}(\psi - R_t^b) + T_t - s_t. \tag{5}$$

3.1 The 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, taxes and γ_t, 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

[5] This assumption is similar to Lucas (1990). For models with variable debt and alternative financing forms see i.e., Ludvigson (1996) or Schmitt-Grohe and Uribe (1997) and the references therein.

growth factor ψ^t. The technical appendix A summarizes the equations that describe the stationary equilibrium. For the dynamics, we log-linearize the equations around the balanced growth path and use Uhlig (1999) to solve the model. See the technical appendix B for a description of the system of log-linearized equations.

3.2 Preference Specifications

We consider three different utility functions for the representative agent. First, we assume 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). We consider this as our favorite preference specification since it is most widely used in the macroeconomic literature. Second we analyze the model when a power utility function $U_{pow}(c_t, n_t) = \frac{(\frac{c_t}{\psi^t})^{1-\eta'}-1}{1-\eta'} - \kappa' \frac{1}{1+\phi'} n_t^{1+\phi'}$ is assumed as in Clarida, Gali and Gertler (2002), Gali (2002), King and Rebelo (1999) or Merz (1995). Finally, we consider the case of GHH preferences as in Greenwood, Hercowitz and Huffmann (1988) or Correia, Neves and Rebelo (1995). In this case utility takes the following form, $U_{ghh}(c_t, n_t) = \frac{(c_t - \kappa'' \psi^t \frac{1}{1+\phi''} n_t^{1+\phi''})^{1-\eta''}-1}{1-\eta''}$. Note that we augment POW and GHH preferences by ψ^t to obtain a formulation that is consistent with balanced growth.

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 results of Carey and Rabesona (2002) who recalculate average tax rates on labor, capital and consumption from 1975 to 2000 following the methodology developed by Mendoza, Razin and Tesar (1994).[6] In principle, there are five arguments why we use 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 average tax rates for labor, capital and consumption for our countries of interest. Second, if any we probably make an error on side of caution since 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 average 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 average tax rates following

[6] Carey and Rabesona (2002) also develop a new methodology to calculate average tax rates. We take a conservative stand here and use the part of their work where the average 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.

the methodology of Mendoza, Razin and Tesar (1994) facilitates comparison to previous studies that also use these tax rates as i.e. 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. Although our data comes on an annual basis, time is taken to be quarters in our calibration.

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 average annual debt to GDP ratio in the data of 61 $\%$. 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.[7] See figure (1) for plots of the time series we used for the calibration of the above variables. The exogenous balanced growth factor ψ is set to 1.0075 which corresponds to the average annual growth rate of real US GDP of roughly 3 $\%$. 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 discount factor $\beta \in [0.9915, 0.9926]$. Further, we set the capital share $\theta = 0.36$ as in Kydland and Prescott (1982). In

[7]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.

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 %. Steady state technology $\bar{\gamma}$ is normalized to one. Let us turn to the parameterization of preferences. We set κ', κ'' and α such that the household chooses $\bar{n} = 0.25$ in this baseline calibration. This is consistent with McGrattan and Rogerson (2003) who provide evidence that workers supply on average roughly 40 hours of work per calendar-week.

Our previous choices of steady states and parameter values were motivated by restrictions imposed by the data. However, there are parameters left in the models that need to be pinned down and that are potentially free. These parameters are:

$$\eta, \eta', \eta'', \phi', \phi''.$$

We apply the following discipline in order to pin down these parameters. First, we set η equal to 1 which is in line with i.e., Cooley and Prescott (1995) and King and Rebelo (1999). This implies a unit elasticity of intertemporal substitution with respect to consumption for C-D preferences i.e., $1/\sigma_{cc}^{US} = -\frac{U_c}{U_{cc}\bar{c}} = \frac{1}{1-\alpha(1-\eta)} = 1$.[8] We also impose $1/\sigma_{cc}^{US} = 1$ for POW and GHH preferences and it turns out that we need to set $\eta' = 1$ and $\eta'' = 0.855$. For POW preferences this is in line with Gali (2002) and for GHH utility this is roughly in line with one of the experiments in Correia, Neves and Rebelo (1995).

[8]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. Hence, our choice reflects a combination of both extremes.

3.3.2 Frisch Labor Supply Elasticity

In order to discipline our choices for ϕ' and ϕ'' observe that the model with C-D preferences is already fully parameterized. That is we are already able to calculate i.e., steady state tax revenues in the C-D case. Note further that $1/\phi'$ and $1/\phi''$ are the Frisch elasticities of labor supply[9] in the case of POW and GHH preferences. Hence, these parameters should matter a lot for the labor supply decision of households and in turn for government tax revenues if i.e., labor income taxes are changed.

There are two ways to proceed. One is to estimate or calibrate each parameter specification separately. The different preference specifications, each with their own specific parameter choices, then deliver potentially rather different results for the impact of tax changes on tax revenues. In such a comparison, it is hard to evaluate, how much of the differences are due to specific features of the preferences, and how much are due to implicit and possibly unintended variations across preference specifications, due to the preference-specific parameter choices. A comparison along these lines provides only limited information, in particular as there is considerable disagreement regarding key parameters in the literature. We return to this issue when discussing sensitivity to the parameterization, and in particular figure (3).

We therefore chose to proceed differently. We have chosen a benchmark calibration for our favorite Cobb Douglas preference specification, and calculated the local marginal impact on total tax revenues from a change in

[9]In general, the Frisch elasticity is defined as $\sigma_f = \frac{dn}{dw}\frac{w}{n}|_{\bar{U}_c}$. Hence, from our model we can derive $\sigma_f = -\frac{U_n}{\bar{n}}\left(\frac{U_{cn}U_{nc}}{U_{cc}} - U_{nn}\right)^{-1}$.

labor taxation along the steady state Laffer curve. We have then chosen ϕ' and ϕ'' to keep this quantity the same for the US economy, i.e. such that $\frac{\partial \bar{T}^{US}_{C-D}}{\partial \bar{\tau}^{n}} = \frac{\partial \bar{T}^{US}_{POW}}{\partial \bar{\tau}^{n}} = \frac{\partial \bar{T}^{US}_{GHH}}{\partial \bar{\tau}^{n}}$. Thus, the change of government tax revenues after changing the steady state labor income tax is identical across all three preference specifications at our baseline calibration. We take the resulting baseline calibration for the POW and GHH preferences seriously, if the resulting parameters are within the range of values suggested in the literature. Put differently, our procedure allows us to pin down preference parameters across the three preference specifications within the range suggested in the literature so that the resulting implications are compatible and comparable. This has some surprising implications.

The specific value of the Frisch labor supply elasticity is of course of central importance for the shape of the Laffer curve. Note that in the case of our favorite C-D preferences, the Frisch elasticity cannot be pinned down by a free parameter. It is given by $\frac{1-\bar{n}}{\bar{n}} \frac{1-\alpha(1-\eta)}{\eta}$ and equals 3 in our baseline calibration. This value is in line with i.e. Kydland and Prescott (1982), Cooley and Prescott (1995) and Prescott (2004a). Due to our above calibration discipline that the slopes of the labor tax Laffer curves should be the same across preferences we need to set $\phi' = 1/3$. For POW preferences this value is roughly in line with Rotemberg and Woodford (1997). Thus, also for POW preferences the Frisch labor supply elasticity is 3. In allowing for this value for C-D and POW preferences we follow Prescott (2004b). He surveys the literature and discusses at length that the Frisch labor supply elasticity should be 3 in macroeconomic models.

However, there is also 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, Chari, Kehoe and McGrattan (2000) find an elasticity of 0.8 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 (2004b).

As it turns out, our model is not inconsistent with these rather low Frisch labor supply estimates. Indeed, for the GHH preferences we need to set $\phi'' = 3.879$ in order to fulfill our calibration discipline that the slope of the labor tax Laffer curves are equal across preferences. Hence, this implies an elasticity of roughly 0.26 and is well within if not on the lower end of the above micro estimate range. Why then is the Frisch labor supply elasticity for GHH utility so different from POW and C-D utility if the slopes of the labor tax Laffer curves are all the same? The reason is in breaking the connection between income and substitution effects for the GHH specification, and more specifically, the quasi-linearity of GHH preferences with respect to consumption. This implies that the labor supply decision is entirely determined by the real wage. Hence, only the substitution effect (and no income effect) determines the labor supply decision. Since typically, the substitution effect results in a reduced labor supply in response to a labor tax increase, while the income effect delivers an increase, and since the latter is missing in the GHH specification, the Frisch labor elasticitiy is considerably lower.

Conversely, an elasticity as high as for C-D and POW would imply much larger reductions in labor supply due to the substitution effect which would imply a flatter slope of the labor tax Laffer curve.

We will pursue a sensitivity analysis in section 4.3 with respect to the parameters $\eta, \eta', \eta'', \phi', \phi''$ in order to evaluate their implications for the shape of the Laffer curve.

3.3.3 EU-15 Model

As an alternative, we calibrate the model to data for the EU-15 economic area. Appendix A summarizes how we calculate EU-15 tax rates, debt to GDP and transfer to GDP ratios. For the period from 1975 to 2000 average tax rates in the EU-15 economy are equal to $\bar{\tau}^n = 0.38$, $\bar{\tau}^k = 0.34$ and $\bar{\tau}^c = 0.17$.[10] 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 average 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 used for the calibration. The balanced growth factor ψ is set to 1.0075 which is consistent with the average 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

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

policy. This corresponds to Prescott (2004a) 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 rather than different fiscal policies are the driving forces for the observation that hours worked have fallen in Europe compared to the US.

Tables (1) and (2) summarize the calibration and the parameterization of the baseline models. Additionally, table (3) shows further characteristics of our different preference assumptions which will be of particular importance for the dynamics of our models respectively for the slope of the Laffer curve.

4 Results

The following section discusses the results of our models. We concentrate on the following aspects: steady states and steady state Laffer curves, sensitivity analysis, shifts of Laffer curves over time, joint variations of tax rates, individual european country Laffer curves, dynamic effects of tax cuts and a dynamic scoring exercise.

4.1 Steady States

Table (4) compares the government share on GDP of the data and the baseline models. In the data, the government consumption to GDP ratio is 16.5 percent for the US and 21.3 percent for the EU-15 countries. Our baseline models predict 15.2 percent for the US and 20.9 percent for the EU-15.[11] Although there is some gap we argue that the models are roughly able to match average government consumption to GDP data.[12]

The models are also roughly in line with the total government expenditures to GDP ratio for both - the US and the EU-15. The bigger gap occurs since in our models, total government expenditures are the sum of government consumption, transfers and net-interest payments only. We abstract from additional expenditures as i.e., government investment, government military investment and subsidies which certainly affect total government expenditures in the data.

At this point, we want to emphasize the labor supply decisions of the households. We set κ', κ'' and α in the US model such that the agent chooses to work $\bar{n}_{us} = 0.25$. We use the same numbers for these structural parameters as well in the the EU-15 model. It turns out that the household chooses to work $\bar{n}_{c-d} = 0.22$, $\bar{n}_{pow} = 0.22$ and $\bar{n}_{ghh} = 0.23$ in the EU-15 economy. Thus, higher tax rates and government shares on GDP reduce the incentive to work and generate lower labor supply. This result corresponds to Prescott (2004a) who finds that lower labor supply in the EU countries is due to higher tax burdens.[13]

[11] One might wonder, why all three models predict the same steady state ratios. The real interest rate is the same across models which implies that the capital to output ratio is the same and due to that all other *ratios* are the same along our models.

[12] The match could be improved by allowing for different values for δ or $\bar{R}$. However, we to not take a stand on structural differences other than implied by fiscal policy.

[13] Prescott (2004a) reports in table 2 actual labor supply of Germany, France, Italy, United Kingdom and USA for the periods from 1970-1974 and 1993-1996. Taking the average over time and over the 4 European countries shows that in these countries labor supply is 14% lower compared to the US. Our models predict that in the EU-15 labor supply is - depending on preferences - between 8% and 12% lower than in the US. Taking the average over preferences of our EU-15 models implies that European labor supply is roughly 11% lower than in the US.

Table (5) summarizes the tax revenue to GDP ratios for labor, capital and consumption taxes.[14] For the US, labor tax revenues are the largest source of revenue followed by capital and consumption taxes. For the EU-15 labor tax revenues also contribute mostly to government revenues. Conversely to the US, consumption tax revenues are the second largest source of revenue in the EU-15 followed by capital tax revenues. Aside from the fact that the models are able to match this structural difference, the quantitative match is acceptable as well.

Finally, table (6) compares the steady state consumption, investment and capital to output ratios of the models with the data. The models understate the consumption and capital to output ratios but overstate the investment to output ratio. More importantly however, the US and EU-15 models are able to capture the relative differences of US and EU-15 data. That is, the models correctly predict that US consumption to GDP is higher than in the EU-15 area. Conversely, the models also predict that the investment and capital to GDP ratios are smaller in the US compared to the EU-15 economy.

We conclude that although the absolute match of the models is not perfect, the models roughly match the relative differences between the US and EU-15. Hence, the following results regarding the absolute numbers of i.e., the peaks of the Laffer curves should be interpreted with caution. Most insightful will be the relative comparisons of the US and the EU-15 economies.

[14] The methodology of Mendoza, Razin and Tesar (1994) of calculating average tax rates allows to calculate implicit tax revenues to GDP ratios for our three tax rates.

4.2 Steady State Laffer Curves

The top panel of figure (2) shows steady state Laffer curves for labor taxes in the US and EU-15 Model. We obtain the Laffer curves by varying the steady state labor tax rate - while holding all other taxes and parameters fixed - and then computing total tax revenues in steady state. In order to facilitate comparison across preferences and models we normalize steady state tax revenues by steady state tax revenues obtained for C-D utility at the baseline tax rate. Three things are noticeable. First, the US and the EU-15 economies are located on the left side of the labor tax Laffer curves for all preferences specifications. Second, the EU-15 economy is much closer to the peak than the US. Third, the slope of the labor tax Laffer curves at the average tax rate is flatter in the EU-15 compared to the US implying much higher distortions in the EU-15 economy.[15] Note that as a consequence of our calibration/parameterization discipline of section 3.3 the slope of the US labor tax Laffer curve is locally identical for all preference specifications at the US average labor income tax rate. For the EU-15 labor tax Laffer curve this is not the case since we use the same parameters as in the US model. This implies i.e., different and lower labor supply across preferences in the EU-15 and hence different slopes of the labor tax Laffer curve in the EU-15.

The mid panel of figure (2) draws steady state Laffer curves for capital taxes. Here the results are even more striking. Again, both economies are on the left side of the capital tax Laffer curve but the EU-15 economy is

[15]Note that there exists a maximum tax rate up to which we can calculate Laffer curves. The government budget constraint in steady state is given by: $\bar{g} = (\psi - \bar{R})\bar{b} - \bar{s} + \bar{T}$. If tax rates become very high tax revenues may be smaller than interest and transfer payments and hence, government consumption would be negative.

much closer to the peak than the US. Moreover, the slope of the EU-15 capital tax Laffer curve at the average tax rate is almost flat for all three preference specifications. Cutting capital income taxes - even to zero as Chamley (1986) and Lucas (1990) show to be optimal - would imply only marginal losses in tax revenues.

The bottom panel of figure (2) depicts steady state tax revenues dependent on consumption taxes. For C-D preferences there does not exist a steady state Laffer curve for steady state consumption taxes.[16] The income and substitution effects cancel exactly which implies that labor supply is unchanged when the consumption tax changes. By contrast, consumption falls but never to zero since it has a positive value in the utility function. In particular, consumption falls with the same rate as the consumption tax rate rises. Since labor supply is unchanged capital is also constant and thus tax revenues from these factors are unchanged. This implies that tax revenues converge to an upper bound for C-D preferences. In case of POW preferences the parameter η' determines whether the income or the substitution effect dominates and hence whether there exists a Laffer curve. If $\eta = 1$ both effects cancel exactly and no consumption tax Laffer curve occurs. For $\eta < 1$ the substitution effect dominates and hence labor supply and capital fall in addition to consumption - a consumption tax Laffer curve arises. In case of $\eta > 1$ the income effect dominates and labor supply and capital rise while consumption falls - tax revenues converge to an upper bound again. For GHH preferences, however, there always exists a Laffer curve. The income effect

[16]Note that i.e., $\bar{\tau}^c = 0.5$ is a 50 % tax rate. Hence figure (2) depicts consumption taxes on the interval from 0 to 1000 %. We also experimented with a maximum steady state consumption tax rate of 100 000 % but our result that there is no consumption tax Laffer curve for C-D remains.

is zero for this utility function and thus labor supply, capital and consumption fall if consumption taxes rise.

However, across preferences we obtain a mixed result with respect to the existence of the consumption tax Laffer curve. If anything, the slope of tax revenues with respect to consumption taxes is steeper in the US than in the EU-15 model - documenting again higher distortions EU-15 area.

4.3 Sensitivity Analysis

The labor supply elasticity plays a key role for the shape of the Laffer curve. For POW and GHH preferences figure (3) shows the effects of different Frisch elasticities of labor supply ($\frac{1}{\phi'}$ resp. $\frac{1}{\phi''}$) on the shape of the Laffer curve.[17] We choose alternative values for ϕ' and ϕ'' from the literature. I.e., Pencavel (1986) estimates $\phi = 6.7$, Chari, Kehoe and McGrattan (2000) choose $\phi = 1.25$ and Rotemberg and Woodford (1997) estimate $\phi = 0.47$. We also experiment with $\phi = 3$. For each of these alternative values we redo our calibration exercise of section 3.3 (holding η' and η'' fixed) and then we vary steady state tax rates as before.

For POW preferences, figure (3) reveals that the shape of the Laffer curve changes modestly with the Frisch labor supply elasticity. By contrast, for GHH utility we obtain dramatic changes with possible peaks at almost the entire tax range.

Nevertheless, a clear picture emerges. The lower ϕ' resp. ϕ'', the higher

[17] We noted earlier that for the C-D case the Frisch labor supply elasticity is determined endogenously. In particular is depends not only on the parameters α and η but also on steady state labor supply. Since $\bar{n}$ changes with different tax rates the Frisch elasticity changes endogenously too. Therefore we cannot pin down the elasticity to one particular value as in the POW and GHH case.

is the Frisch elasticity of labor supply and the earlier occurs the peak of the Laffer curve. This result is intuitive. A rise in labor taxes reduces the real after-tax wage. If the household's labor supply is more elastic with respect to the real after-tax wage, it will reduce its labor supply more strongly. Therefore, the marginal increase of tax revenues is smaller with higher labor supply elasticities - the peak occurs earlier.

In addition, we also pursue a sensitivity analysis with respect to η, η' and η''. Interestingly, steady state tax revenues in the case of C-D and GHH preferences are invariant with respect to changes in η and η''. That is, steady state labor supply, steady state capital and steady state consumption do not depend on η and η''.[18] By contrast, in the case of POW preferences steady state tax revenues depend on η' via the labor supply decision of the household i.e., $\kappa' \bar{n}^{\phi'} \bar{c}^{\eta'} = (1-\theta)\frac{1-\bar{\tau}^n}{1+\bar{\tau}^c}\frac{\bar{y}}{\bar{n}}$. We choose alternative values for η' from the literature. I.e., House and Shapiro (2004) set $\eta' = 5$, King and Rebelo (1999) use $\eta' = 3$ in their extended model and Lucas (1990) chooses $\eta' = 2$. We further experiment with $\eta' = 0.2$ and $\eta' = 0.5$. For each of these alternative values we redo our calibration exercise of section 3.3 (holding ϕ' fixed) and then we vary steady state tax rates as before.

Figure (4) shows that the shape of the Laffer curve for steady state capital income taxes changes with different values for η' in the case of POW preferences. In particular, the higher η' the later occurs the peak of the Laffer curve. This result is intuitive. The higher η' the more risk averse is the

[18]Variations in η or η'' lead only to variations in β since $\bar{R}$ is given in our model. However, β has no effect on the steady state of labor, capital and consumption. Nevertheless, η and η'' are of course important for the dynamics of the models.

household. Due to precautionary savings motives, the household reduces its capital holdings less in case of a higher η'. Hence, the peak of the Laffer curve occurs later the higher η'.

4.4 Shifts of Laffer Curves

The preceding analysis is based on the calibration of the models to the average of taxes, transfers etc. to post-war data. One might wonder, how the Laffer curves have shifted over time during this period. We investigate this by calculating the Laffer curves at different points i.e., for the earliest and latest available observations in our dataset. US data for the year 1975 suggests that we set $\bar{\tau}^n = 0.22$, $\bar{\tau}^k = 0.40$, $\bar{\tau}^c = 0.06$, $\bar{s}/\bar{y} = 0.11$ and $\psi\bar{b}/\bar{y} = 0.48 \times 4$. Alternatively, for the year 2000 we obtain the following values for the US: $\bar{\tau}^n = 0.29$, $\bar{\tau}^k = 0.38$, $\bar{\tau}^c = 0.05$, $\bar{s}/\bar{y} = 0.11$ and $\psi\bar{b}/\bar{y} = 0.59 \times 4$. Using these two alternative sets of variables and holding all other parameters fixed, we calculate steady state Laffer curves for labor and capital taxes for the US model.[19]

For our favorite C-D preferences, the left panel of figure (5) shows that the labor tax Laffer curve has shifted very little and that the US have moved closer to the peak. By contrast, the capital tax Laffer curve has shifted outwards and the US have hardly moved relative to the peak. The outward shift is mostly due to the rise in labor taxes.

Lets turn to the EU-15 economy. According to the data for the year 1975,

[19] In detail, we use the alternative tax rates and set $\bar{b}$ and $\bar{s}$ such that the model matches the debt and transfer to GDP ratio while holding all other parameters fixed as in the baseline calibration. Then, we vary steady state tax rates to calculate the Laffer curves.

we set $\bar{\tau}^n = 0.34$, $\bar{\tau}^k = 0.31$, $\bar{\tau}^c = 0.16$, $\bar{s}/\bar{y} = 0.17$ and $\psi\bar{b}/\bar{y} = 0.31 \times 4$. For the year 2000 the data suggests $\bar{\tau}^n = 0.42$, $\bar{\tau}^k = 0.38$, $\bar{\tau}^c = 0.21$, $\bar{s}/\bar{y} = 0.19$ and $\psi\bar{b}/\bar{y} = 0.62 \times 4$. The right panel of figure (5) shows the corresponding Laffer curves for the EU-15 area. For labor taxes the EU-15 economy has moved considerably closer to the peak and the slope has flattened. Even more strikingly, in the case of capital taxes the EU-15 economy has moved almost exactly to the top of the Laffer curve. Hence, we conclude that since 1975 the EU-15 area has moved closer to the peaks of their steady state Laffer curves.

4.5 Joint Variations of Steady State Taxes

The previous sections analyzed the effects of variations of single steady state tax rates on steady state tax revenues. Now, we consider joint variations of steady state capital and labor tax rates. We do so by varying $\bar{\tau}^k = \bar{\tau}^n$ jointly holding all other parameters fixed. Then, we calculate steady state tax revenues. Figure (6) shows the resulting Laffer curves for the US and EU-15 Model. Again, the results indicate that the US and EU-15 are located on the left side of the Laffer curve. However, the EU-15 are closer to the slippery slopes.

We also calculate steady state iso-tax revenue curves. That is, we work out the combinations of steady state capital and labor tax rates that yield a given level of government tax revenues. Figure (7) shows the steady state iso-tax revenue curves for the US and EU-15 model. Notice that for steady state labor taxes the EU-15 economy is much closer located to the summit of the ”Laffer hill” than the US. Moreover, the figure reveals that the ”Laffer hill” of the US model has a steeper slope compared to the EU-15. That is, in order to increase tax revenues from say 90 to 100 tax rates need to change less compared to the EU-15 model.

4.6 Individual European Country Laffer Curves

In the previous sections we have compared steady state Laffer curves of the US and EU-15 economy. The latter, however, consists of individual countries with most probably different fiscal policies. How do steady state Laffer curves look like for individual european countries? We proceed as follows. For each individual country we calculate the average over time of tax rates for consumption, labor and capital. In addition we compute the transfer to GDP ratio as well as the debt to GDP ratio for each country. Then we feed our model with these five variables that characterize country specific fiscal policies. Further, we keep all other parameters unchanged and then calculate steady state Laffer curves for each country.

The top panel of figure (8) plots the distance in terms of tax rates to the peak of the steady state Laffer curves for each european country. In addition, we add the US as well as the EU-15 average. The figure reveals that all european countries are closer to the peaks of their labor tax Laffer curves compared to the US. Interestingly, Sweden appears to be on the slippery slope side of the labor tax Laffer curve.[20] For capital taxes the majority of

[20]Floden and Linde (2001) report a similar finding for labor taxes. Further, Jonsson and Klein (2003) report that Sweden is on the slippery slope side of the Laffer curve for several tax instruments.

european countries are closer to the peak of their Laffer curves. Only Spain, Greece, Ireland and Portugal have a larger distance to the peak than the US. However, these countries together have only a relatively small share on total european GDP. For capital taxes the model predicts that the Netherlands, Finland, Belgium, Great Britain, Sweden and Denmark are located on the slippery slope sides of their Laffer curves.

The mid panel depicts the distance to the peak of the individual country Laffer curves in terms of tax revenues expressed in percent of country specific baseline GDP. For labor taxes the figure shows that tax revenues raise only modestly for the majority of european countries if they would move to the peak of their Laffer curve. In all cases the increase in tax revenues is less than for the US. By contrast, for capital taxes Sweden and Denmark could raise much more revenues by moving to the top of their Laffer curve since they are located relatively far on the slippery slope side.

Finally, the lower panel shows the slope of the Laffer curves for a 1 percent increase of steady state labor and capital taxes. We measure the slope as the change of tax revenues in percent of baseline GDP. The slope of the US labor and capital tax Laffer curve is steeper compared to all european countries which documents higher distortions in the EU-15.

The analysis shows that there is considerable country specific variation within Europe with respect to the shape of the Laffer curve. However, the EU-15 average economy captures fairly well the relative differences between the US and Europe. This is especially true for the distance to the peak for labor taxes. Regarding the distance to the peak for capital taxes this applies to the majority of european countries with most economic weight in terms of GDP. Finally, the EU-15 average economy summarizes well that the slope of the labor and capital tax Laffer curves are flatter in all individual european countries compared to the US. Hence, in the following sections we return to a comparison of the US and the average EU-15 economic area.

4.7 Unexpected vs. Announced Tax Cuts

We now turn to the dynamic properties of the models. In principle, the government may chooses to cut taxes either unexpectedly or with a pre-announcement period. Figure (9) depicts the responses of tax revenues to unexpected and 5-year-in-advance announced labor and capital tax cuts for the US model.[21,22] Appendix B as well as the technical appendix B explain in detail how we obtain these results. The subsequent results focus on the C-D utility case. However, the results are robust with respect to our alternative preference specifications. Some interesting results are worth to be pointed out here.

First, an unexpected permanent labor tax cut leads to a fall of tax revenues for low steady state tax rates. However, if steady state tax rates become sufficiently large, tax revenues will increase in response to the tax cut. This is due to the incentive effect. A cut from very high tax levels creates

[21] We analyze tax cuts that are symmetric. Giannitsarou (2003) shows that supply-side reforms can be asymmetric under adaptive learning. The author shows that if a capital tax cut coincides with a negative technology shock the transition to the new steady state is slower than if the capital tax cut would coincide with a positive technology shock.

[22] We have chosen a five year pre-announcement horizon here for illustrative purposes. However, it also reflects the maximum length of a legislative period in most modern democracies. On optimal pre-announcement durations of optimal labor and capital tax reforms see Domeij and Klein (2005) and Trabandt (2006).

very strong incentives to work. This enlarges the tax base by more than the reduction of the tax rate. Therefore, we observe a Laffer curve effect even for the dynamics.

Second, an unexpected permanent capital tax cut always leads to a drop in tax revenues in the short-run. However, in the long-run we also observe a dynamic Laffer effect dependent on the level of steady state taxes. The short-run drop - irrespective of the level of taxes - occurs since capital is immobile and therefore cannot react immediately.

Third, an announced labor tax cut leads to a decrease of tax revenues in the short-run regardless of the level of steady state labor taxes. This is due to two effects. The announcement of lower future labor taxes induces the household to work less and to accumulate less capital. Thus tax revenues from these two factors decrease. By contrast, consumption rises during the announcement period due to lower investment. The first effect dominates the latter and thus tax revenues fall in the announcement period. It should be mentioned here that House and Shapiro (2004) document a similar effect. However, when policy is put into place, we observe the dynamic Laffer effect as before.

Fourth, an announced capital tax cut leads to an increase of tax revenues during the announcement period followed by the dynamic Laffer effect in the long-run. The announcement of a cut in capital taxes creates an investment boom which in turn induces a rise in labor supply. Thus tax revenues from labor and capital increase. By contrast, consumption decreases in order to accumulate capital. Again, the consumption effect is dominated by the capital/labor effect during the announcement period. In the long-run, however, we observe the Laffer effect dependent on the level of steady state capital taxes.

Fifth, tables (7) and (8) show the evolution of government consumption for the US and EU-15 model for the baseline calibration. I.e., for US capital taxes, we find that an unexpected permanent 1 % tax cut corresponds to an endogenous cut of government spending of 1.61 % on impact and 0.77 % in the long-run. A five-year-in-advance announced permanent 1 % cut of capital taxes leads to an endogenous increase of government spending of up to 0.38 % during the announcement period and a cut of government expenditures of 0.77 % in the long run. For the EU-15 economy, we obtain the same qualitative results. However, quantitatively, the figures for unexpected tax cuts and the long-run values for announced tax cuts are smaller than in the US. Thus, the slope of the Laffer curve in the EU-15 economy is much flatter than in the US which again documents a much higher degree of distortions in the EU-15 area compared to the US.

5 Dynamic Scoring

Our previous results indicate that tax cuts are not fully self-financing in the US and EU-15 area. However, it is interesting to which extend tax cuts are self-financing given the positions of the US and EU-15 on their respective Laffer curves. Following Mankiw and Weinzierl (2005), we perform a static and dynamic scoring exercise for steady state tax revenues in response to i.e., a steady state capital tax cut. Static scoring is obtained from cutting steady state capital taxes while holding capital, hours and consumption at their steady state levels. Hence, there is no dynamic feedback effect from lower taxes to i.e., higher capital accumulation. By contrast, dynamic scoring allows for the feedback effect from lower taxes to higher capital accumulation and corresponds to the response of tax revenues in our DSGE model. Hence, χ is the fraction of the static effect that equals the dynamic effect i.e.,

$$\frac{\partial \bar{T}^{DSGE}}{\partial \bar{\tau}^k} = \chi \frac{\partial \bar{T}^{Static}}{\partial \bar{\tau}^k}. \tag{6}$$

Then, the degree of self-financing can be calculated as $100(1-\chi)$. We find for the US model that 19% of a labor tax cut and 47% of a capital tax cut are self-financing in the steady state.[23] In the EU-15 economy 54% of a labor tax cut and 85% of a capital tax cut are self-financing. Hence, the efficiency gains from cutting taxes in the EU-15 area are comparably large.

These results are obtained from a steady state analysis and do not take a transition over time into account. Figure (10) shows the responses of tax revenues to unexpected and announced labor and capital tax cuts for static as well as dynamic scoring over time. Again, the plots reveal that the size of the dynamic feedback effect is considerable. For each point in time we calculate the proportions of tax cuts that are self-financing. Tables (9) and (10) summarize our results. It turns out that in the EU-15 area the degree of

[23] Note that Mankiw and Weinzierl (2005) report for their model that 17% of a labor tax cut and 53% of a capital tax cut is self-financing. Recently, Leeper and Yang (2006) 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 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. By contrast, 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 thereby confirming Mankiw and Weinzierl.

self-financing is higher compared to the US at every point in time during the transition period.

Also following Mankiw and Weinzierl (2005), we calculate the

"Present Value" of the self-financing. To do so, we sum up the discounted changes in the static as well as DSGE tax revenues. As discount factors we use the after-tax real interest rates obtained from the dynamics. Finally, we calculate the self-financing as before using now the previously calculated discounted sums. For the US model we obtain a "Present Value" of self-financing for unexpected labor tax cuts of 19 $\%$ and -2.2% for 5-year-in-advance announced labor tax cuts.[24] For unexpected capital tax cuts the "Present Value" is 37 $\%$ and for 5-year-in-advance announced capital tax cuts we obtain a "Present Value" of 48 $\%$.

The same exercise yields the following results in the EU-15 model. The "Present Value" of self-financing for unexpected labor tax cuts is 53 $\%$ and 18% for 5-year-in-advance announced labor tax cuts. For unexpected capital tax cuts the "Present Value" is 65 $\%$ and for 5-year-in-advance announced capital tax cuts we obtain a "Present Value" of 82 $\%$.

Our results show that by any measure there is a much higher degree of self-financing possible in the EU-15. This shows again that there are higher distortions in the EU-15 area compared to the US.

[24]The negative number for 5-year-in-advance announced labor tax cuts is due to the fact that tax revenues fall in the announcement period in the DSGE model but in the static model tax revenues remain constant at zero. Hence, the discounted sum of changes in tax revenues can become larger in absolute value in the DSGE case than in the static model case which produces the negative self-financing number.

To sum up: our analysis reveals 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. The lunch is not free, but it is cheap.

6 Conclusion

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 much 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. The lunch is not free, but it is cheap.

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Appendix

A EU-15 Tax Rates and GDP Ratios

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

$$\tau^c_{EU-15,t} c_{EU-15,t} = \sum_j \tau^c_{j,t} c_{j,t} \tag{7}$$

where j are the individual EU-15 countries. Rewriting equation (7) yields the consumption weighted EU-15 consumption tax rate:

$$\tau^c_{EU-15,t} = \frac{\sum_j \tau^c_{j,t} c_{j,t}}{c_{EU-15,t}} = \frac{\sum_j \tau^c_{j,t} c_{j,t}}{\sum_j c_{j,t}}. \tag{8}$$

The numerator of equation (8) 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,

$$\tau^c_{EU-15,t} = \frac{\sum_j T^{Cons}_{j,t}}{\sum_j \frac{T^{Cons}_{j,t}}{\tau^c_{j,t}}}. \tag{9}$$

The Carey and Rabesona (2002) dataset 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 (1).[25]

[25] 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. I.e., we would obtain $\bar{\tau}^n = 0.38$, $\bar{\tau}^k = 0.35$ and $\bar{\tau}^c = 0.19$.

In order to calculate EU-15 GDP ratios we proceed as follows. I.e., the GDP weighted EU-15 debt to GDP ratio can be written as:

$$\frac{b_{EU-15,t}}{y_{EU-15,t}} = \frac{\sum_j \frac{b_{j,t}}{y_{j,t}} y_{j,t}}{\sum_j y_{j,t}} \tag{10}$$

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.[26] Taking averages over time yields the numbers reported in tables (1), (4), (5) and (6).

B An 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. $\breve{\tau}^n_t = \tau^n_t - \bar{\tau}^n$. 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 all other exogenous processes are at their steady states i.e., $\hat{\gamma}_t = 0$, $\breve{\tau}^c_t = 0$ and $\hat{s}_t = 0$ $\forall t$.

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

B.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,

$$\hat{k}_t = \eta_{kk}\hat{k}_{t-1} + \pi\breve{\tau}_t^k + \nu\breve{\tau}_t^n \tag{11}$$

$$\hat{T}_t = \eta_{Tk}\hat{k}_{t-1} + \mu\breve{\tau}_t^k + \omega\breve{\tau}_t^n \tag{12}$$

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

$$\begin{aligned}\hat{T}_t = \eta_{Tk}\eta_{kk}^t\hat{k}_{-1} \quad &+ \quad \left[\frac{\eta_{Tk}\pi}{\eta_{kk}}\left(\frac{\rho_{\tau^k}^{t+1} - \eta_{kk}^{t+1}}{\rho_{\tau^k} - \eta_{kk}}\right) + \left(\mu - \frac{\eta_{Tk}\pi}{\eta_{kk}}\right)\rho_{\tau^k}^t\right]\breve{\tau}_0^k \\ &+ \quad \left[\frac{\eta_{Tk}\nu}{\eta_{kk}}\left(\frac{\rho_{\tau^n}^{t+1} - \eta_{kk}^{t+1}}{\rho_{\tau^n} - \eta_{kk}}\right) + \left(\omega - \frac{\eta_{Tk}\pi}{\eta_{kk}}\right)\rho_{\tau^n}^t\right]\breve{\tau}_0^n\end{aligned} \tag{13}$$

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:

$$\lim_{t\to\infty}\hat{T}_t \quad = \quad \left[\frac{\eta_{Tk}}{1-\eta_{kk}}\pi + \mu\right]\breve{\tau}_0^k + \left[\frac{\eta_{Tk}}{1-\eta_{kk}}\nu + \omega\right]\breve{\tau}_0^n \tag{14}$$

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 very complicated functions of the model parameters we rely on numerical evaluations presented in tables (7) and (8) and figure (9).

B.2 5-Year-In-Advance Announced Tax Cuts

In order to model announced labor as well as capital tax cuts we replace $\breve{\tau}_t^n$ and $\breve{\tau}_t^k$ in the log-linearized system of equations by $\breve{\tau}_t^{na20}$ and $\breve{\tau}_t^{ka20}$. Further, we add the following auxiliary variables to our system of equilibrium equations. For capital taxes: $\breve{\tau}_t^{ka20} = \breve{\tau}_{t-1}^{ka19}$, $\breve{\tau}_t^{ka19} = \breve{\tau}_{t-1}^{ka18}$, ..., $\breve{\tau}_t^{ka1} = \breve{\tau}_{t-1}^{ka0}$ with $\breve{\tau}_t^{ka0} = \rho_{\tau^{ka0}}\breve{\tau}_{t-1}^{ka0} + \epsilon_t$. For labor taxes: $\breve{\tau}_t^{na20} = \breve{\tau}_{t-1}^{na19}$, $\breve{\tau}_t^{na19} = \breve{\tau}_{t-1}^{na18}$, ..., $\breve{\tau}_t^{na1} = \breve{\tau}_{t-1}^{na0}$ with $\breve{\tau}_t^{na0} = \rho_{\tau^{na0}}\breve{\tau}_{t-1}^{na0} + \nu_t$. This structure implies that an innovation in say $\breve{\tau}_t^{ka0}$ in period $t = 0$ is fully observed by the individuals. However, it takes 20 periods (5 years) until $\breve{\tau}_t^{ka20}$ changes in the respective equations of the system of equations. Thus, the innovation in $\breve{\tau}_t^{ka0}$ in period $t = 0$ can be interpreted as an announcement that 5 years later capital taxes will be changed. Again, we use Uhlig (1999) to solve for the recursive equilibrium law of motion. I.e.,

$$\hat{k}_t = \eta_{kk}\hat{k}_{t-1} + \sum_{i=0}^{20} \pi_i \breve{\tau}_t^{kai} + \sum_{i=0}^{20} \nu_i \breve{\tau}_t^{nai} \tag{15}$$

$$\hat{T}_t = \eta_{Tk}\hat{k}_{t-1} + \sum_{i=0}^{20} \mu_i \breve{\tau}_t^{kai} + \sum_{i=0}^{20} \omega_i \breve{\tau}_t^{nai} \tag{16}$$

After some tedious manipulations and using $\sum_{i=0}^{20} \pi_i \breve{\tau}_{t-j}^{kai} = \sum_{i=0}^{20} \pi_i \breve{\tau}_{t-j-i}^{ka0}$ as well as $\sum_{i=0}^{20} \pi_i \breve{\tau}_{t-j}^{nai} = \sum_{i=0}^{20} \pi_i \breve{\tau}_{t-j-i}^{na0}$, we can express tax revenues $\hat{T}_t$ as follows:

$$\begin{aligned} \hat{T}_t = \eta_{Tk}\eta_{kk}^t \hat{k}_{-1} \quad &+ \quad \frac{\eta_{Tk}}{\eta_{kk}} \sum_{j=0}^{t} \eta_{kk}^j \sum_{i=0}^{20} \pi_i \breve{\tau}_{t-j-i}^{ka0} + \sum_{i=0}^{20} (\mu_i - \frac{\eta_{Tk}}{\eta_{kk}}\pi_i) \breve{\tau}_{t-i}^{ka0} \\ &+ \quad \frac{\eta_{Tk}}{\eta_{kk}} \sum_{j=0}^{t} \eta_{kk}^j \sum_{i=0}^{20} \nu_i \breve{\tau}_{t-j-i}^{na0} + \sum_{i=0}^{20} (\omega_i - \frac{\eta_{Tk}}{\eta_{kk}}\nu_i) \breve{\tau}_{t-i}^{na0} \end{aligned} \tag{17}$$

with $\breve{\tau}_t^{na0} = \rho_{\tau^{na0}}\breve{\tau}_{t-1}^{na0} + \nu_t$ and $\breve{\tau}_t^{ka0} = \rho_{\tau^{ka0}}\breve{\tau}_{t-1}^{ka0} + \epsilon_t$. Equation

(17) characterizes the slope of the Laffer curve for 5-year-in-advance capital and labor tax cuts. Suppose we consider permanent tax changes only, i.e. $\rho_{\tau^{ka0}} = \rho_{\tau^{na0}} = 1$ and no initial deviation of capital , i.e. $\hat{k}_{-1} = 0$. Then, if $\|\eta_{kk}\| < 1$ we obtain:

$$\lim_{t\to\infty} \hat{T}_t = \left[\frac{\eta_{Tk}}{1-\eta_{kk}} \sum_{i=0}^{20} \pi_i + \sum_{i=0}^{20} \mu_i\right] \breve{\tau}_0^{ka0} + \left[\frac{\eta_{Tk}}{1-\eta_{kk}} \sum_{i=0}^{20} \nu_i + \sum_{i=0}^{20} \omega_i\right] \breve{\tau}_0^{na0} \tag{18}$$

The coefficients in front of $\breve{\tau}_0^{ka0}$ and $\breve{\tau}_0^{na0}$ characterize the slope of the long run Laffer curve. Note that since $\sum_{i=0}^{20} \pi_i = \pi$, $\sum_{i=0}^{20} \mu_i = \mu$, $\sum_{i=0}^{20} \nu_i = \nu$ and $\sum_{i=0}^{20} \omega_i = \omega$ the long run slope of the Laffer curve is identical compared to the case of unexpected tax cuts (see equation (14)). Again, since the coefficients of the recursive equilibrium law of motion are very complicated functions of the model parameters we rely on numerical evaluations presented in tables (7) and (8) and figure (9).

C Tables and Figures

Table 1: Calibration of the baseline models

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

Table 2: Parameterizing the baseline models

Variable	US Model	EU-15 Model	Description	Restriction
η, η'	1.00	1.00	Det. IES for C-D and POW	$1/\sigma_{cc}^{US} = 1$
η''	0.855	0.855	Det. IES for GHH	$1/\sigma_{cc}^{US} = 1$
ϕ'	0.333	0.333	Inverse Frisch elasticity POW	$\frac{\partial \bar{T}_{POW}^{US}}{\partial \bar{\tau}^n} = \frac{\partial \bar{T}_{C-D}^{US}}{\partial \bar{\tau}^n}$
ϕ''	3.879	3.879	Inverse Frisch elasticity GHH	$\frac{\partial \bar{T}_{GHH}^{US}}{\partial \bar{\tau}^n} = \frac{\partial \bar{T}_{C-D}^{US}}{\partial \bar{\tau}^n}$
α	0.321	0.321	Consumption weight in C-D	$\bar{n}_{us} = 0.25$
κ'	4.479	4.479	Weight of labor in POW	$\bar{n}_{us} = 0.25$
κ''	341.79	341.79	Weight of labor in GHH	$\bar{n}_{us} = 0.25$
$\bar{\gamma}$	1.00	1.00	Technology (normalization)	-
θ	0.36	0.36	Capital share on production	Data
δ	0.015	0.015	Depreciation rate (quarterly)	Data

Table 3: Implications of preference assumptions.

	C-D Preferences			POW Preferences			GHH Preferences		
	Theory	Calibration		Theory	Calibration		Theory	Calibration	
		US	EU-15		US	EU-15		US	EU-15
$\sigma_{cc} = \frac{-U_{cc}\bar{c}}{U_c}$	$1-\alpha(1-\eta)$	1	1	η'	1	1	$\eta''(1-\frac{\kappa''}{\bar{c}(1+\phi'')}\bar{n}^{1+\phi''})^{-1}$	1	0.973
$\sigma_{cn,n} = \frac{-U_{cn}\bar{n}}{U_c}$	$\frac{(1-\eta)(1-\alpha)}{1-\bar{n}}\bar{n}$	0	0	0	0	0	$-\kappa''\eta''(\frac{\bar{c}}{\bar{n}^{1+\phi''}}-\frac{\kappa''}{1+\phi''})^{-1}$	-0.705	-0.573
$\sigma_{nc,c} = \frac{U_{nc}\bar{c}}{U_n}$	$(1-\eta)\alpha$	0	0	0	0	0	$-\eta''(1-\frac{\kappa''}{\bar{c}(1+\phi'')}\bar{n}^{1+\phi''})^{-1}$	-1	-0.973
$\sigma_{nn} = \frac{U_{nn}\bar{n}}{U_n}$	$\frac{((1-\alpha)\eta+\alpha)}{1-\bar{n}}\bar{n}$	0.333	0.278	ϕ'	0.333	0.333	$\phi''+\kappa''\eta''(\frac{\bar{c}}{\bar{n}^{1+\phi''}}-\frac{\kappa''}{1+\phi''})^{-1}$	4.584	4.452
$\sigma_w = \frac{-U_n}{U_c\psi^t}$	$\frac{(1-\alpha)}{\alpha(1-\bar{n})}\bar{c}$	1.579	1.206	$\kappa'\bar{n}^{\phi'}\bar{c}^{\eta'}$	1.579	1.206	$\kappa''\bar{n}^{\phi''}$	1.579	1.206
$\sigma_f = \frac{-U_nU_{cc}}{\bar{n}(U_{cn}U_{nc}-U_{nn}U_{cc})}$	$\frac{1-\bar{n}}{\bar{n}}\frac{1-\alpha(1-\eta)}{\eta}$	3	3.596	$\frac{1}{\phi'}$	3	3	$\frac{1}{\phi''}$	0.258	0.258

Note: σ_w and σ_f are not needed to determine the dynamics. These characteristics are listed here for completeness.

σ_w can be interpreted as the after-tax real wage. σ_f denotes the Frisch labor supply elasticity.

Table 4: Government share on GDP (in %)

	Government Consumption		Total Government Expenditures	
	US	EU-15	US	EU-15
Data	16.5	21.3	31.7	45.0
Model				
C-D	15.2	20.9	28.0	41.5
POW	15.2	20.9	28.0	41.5
GHH	15.2	20.9	28.0	41.5

Table 5: Sources of government tax revenue as a share of GDP (in %)

	Labor Tax Rev.		Capital Tax Rev.		Consumption Tax Rev.	
	US	EU-15	US	EU-15	US	EU-15
Data	14.9	20.5	8.3	7.5	3.6	9.5
Model						
C-D	16.6	24.3	8.2	7.4	3.2	9.8
POW	16.6	24.3	8.2	7.4	3.2	9.8
GHH	16.6	24.3	8.2	7.4	3.2	9.8

Table 6: Consumption, Investment and Capital as a share of GDP (in %)

	Priv. Consumption		Total Investment		Capital	
	US	EU-15	US	EU-15	US	EU-15
Data	67.0	57.9	17.8	20.6	260	312
Model						
C-D	63.9	57.6	20.9	21.5	234	240
POW	63.9	57.6	20.9	21.5	234	240
GHH	63.9	57.6	20.9	21.5	234	240

Table 7: <u>US Model</u>: dynamic effects of unexpected and 5-year-in-advance announced permanent 1% tax cuts; C-D utility; baseline calibration.

	$\hat{T}_t$				$\hat{g}_t$			
	$t=0$	$t=19$	$t=20$	$t=\infty$	$t=0$	$t=19$	$t=20$	$t=\infty$
Labor Tax Cut								
unexpected	-1.89	-1.86	-1.86	-1.84	-3.58	-3.48	-3.48	-3.38
announced	-0.34	-1.06	-2.09	-1.84	-0.50	-2.00	-4.39	-3.38
Capital Tax Cut								
unexpected	-0.64	-0.53	-0.52	-0.42	-1.61	-1.19	-1.17	-0.77
announced	0.07	0.20	-0.60	-0.42	0.10	0.38	-1.46	-0.77

Table 8: <u>EU-15 Model</u>: dynamic effects of unexpected and 5-year-in-advance announced permanent 1% tax cuts; C-D utility; baseline calibration.

	$\hat{T}_t$				$\hat{g}_t$			
	$t=0$	$t=19$	$t=20$	$t=\infty$	$t=0$	$t=19$	$t=20$	$t=\infty$
Labor Tax Cut								
unexpected	-0.83	-0.76	-0.75	-0.69	-1.78	-1.56	-1.55	-1.36
announced	-0.30	-0.96	-1.15	-0.69	-0.47	-1.91	-2.69	-1.36
Capital Tax Cut								
unexpected	-0.39	-0.23	-0.22	-0.07	-1.06	-0.59	-0.57	-0.15
announced	0.06	0.20	-0.33	-0.07	0.10	0.40	-0.87	-0.15

Note: $\hat{T}_t$ and $\hat{g}_t$ denote percentage deviations of tax revenues and government consumption from steady state. t counts quarters.

Table 9: US Model: Dynamic Scoring for unexpected and 5-year-in-advance announced permanent 1 % tax cuts; C-D utility; baseline calibration.

	Degree of Self-Financing (in Percent)					
	$t = 0$	$t = 10$	$t = 20$	$t = 40$	$t = 80$	Steady State
Labor Tax Cut						
unexpected	17.5	18.2	18.6	19.2	19.6	19.2
announced	-	-	8.4	14.3	18.5	19.2
Capital Tax Cut						
unexpected	19.5	28.1	34.0	41.9	45.7	46.6
announced	-	-	24.6	36.4	44.7	46.6

Table 10: EU-15 Model: Dynamic Scoring for unexpected and 5-year-in-advance announced permanent 1 % tax cuts; C-D utility; baseline calibration.

	Degree of Self-Financing (in Percent)					
	$t = 0$	$t = 10$	$t = 20$	$t = 40$	$t = 80$	Steady State
Labor Tax Cut						
unexpected	46.1	49.1	51.2	53.5	55.1	54.4
announced	-	-	25.4	41.6	52.6	54.4
Capital Tax Cut						
unexpected	25.0	44.4	57.7	72.9	83.1	85.1
announced	-	-	37.8	63.6	81.2	85.1

Note: t counts quarters. "Self-Financing" is calculated as $1 - \frac{\hat{T}_t^{DSGE}}{\hat{T}_t^{Static}}$.

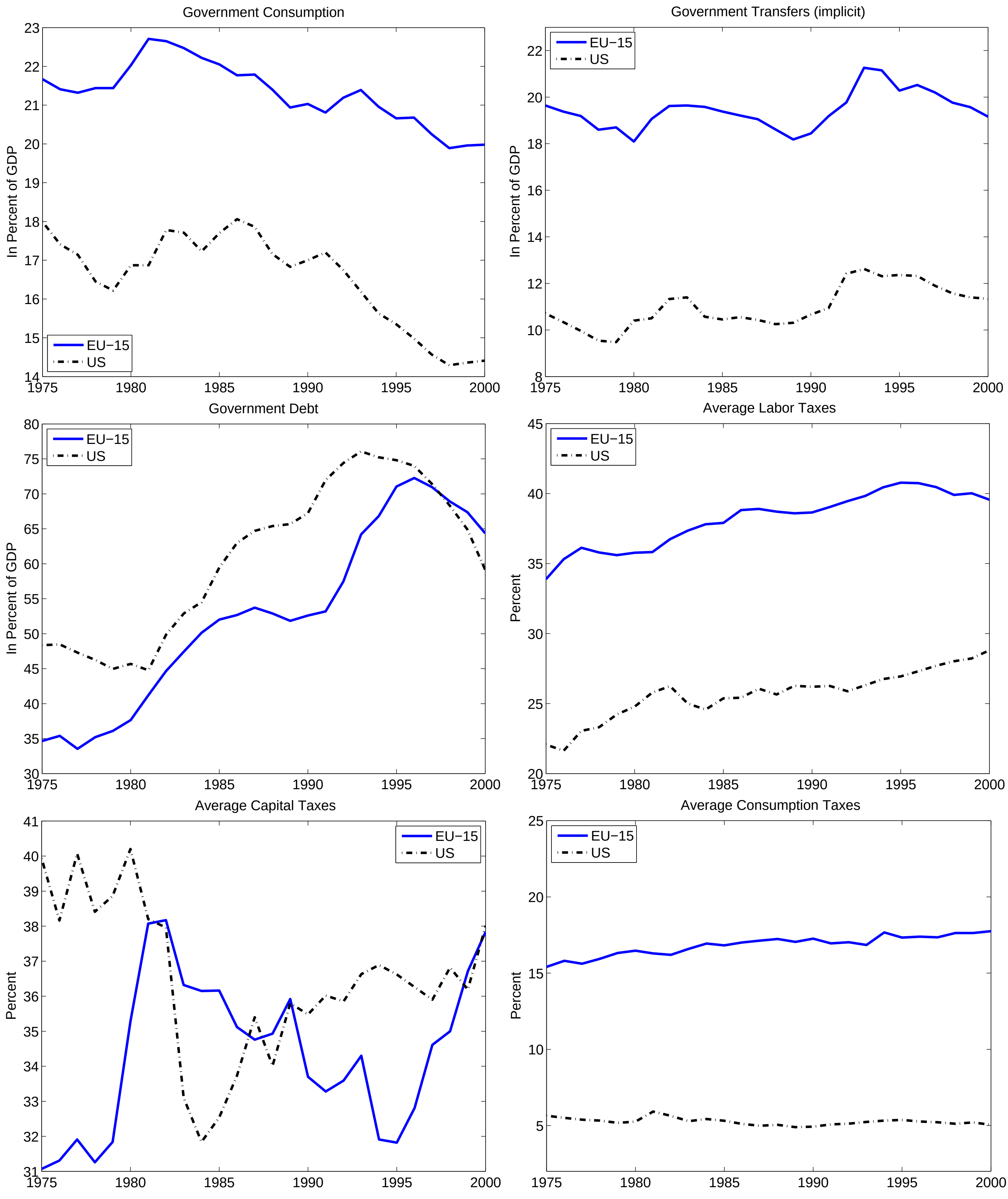

Figure 1: Data used for calibration of the baseline models.

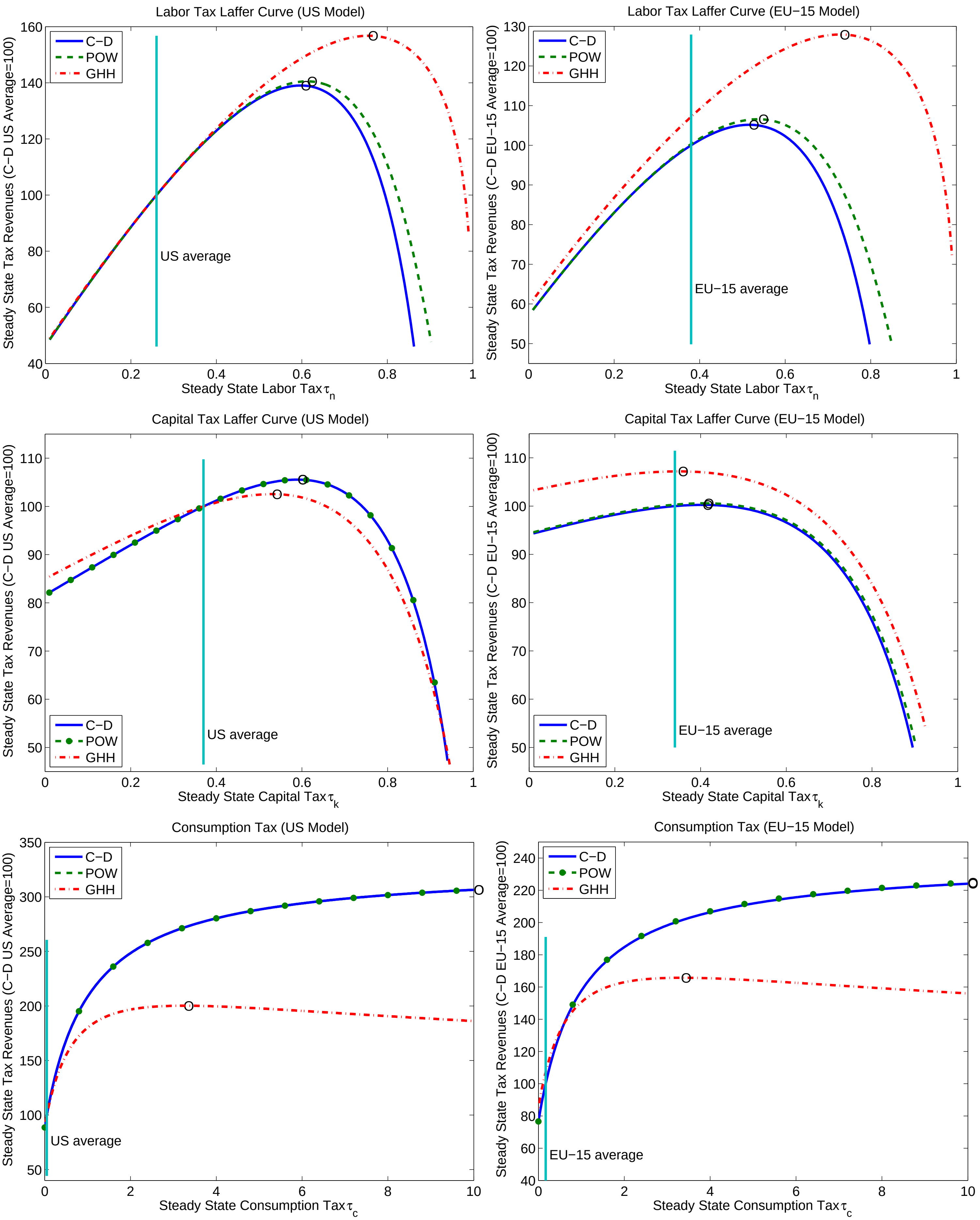

Figure 2: Steady state Laffer curves.

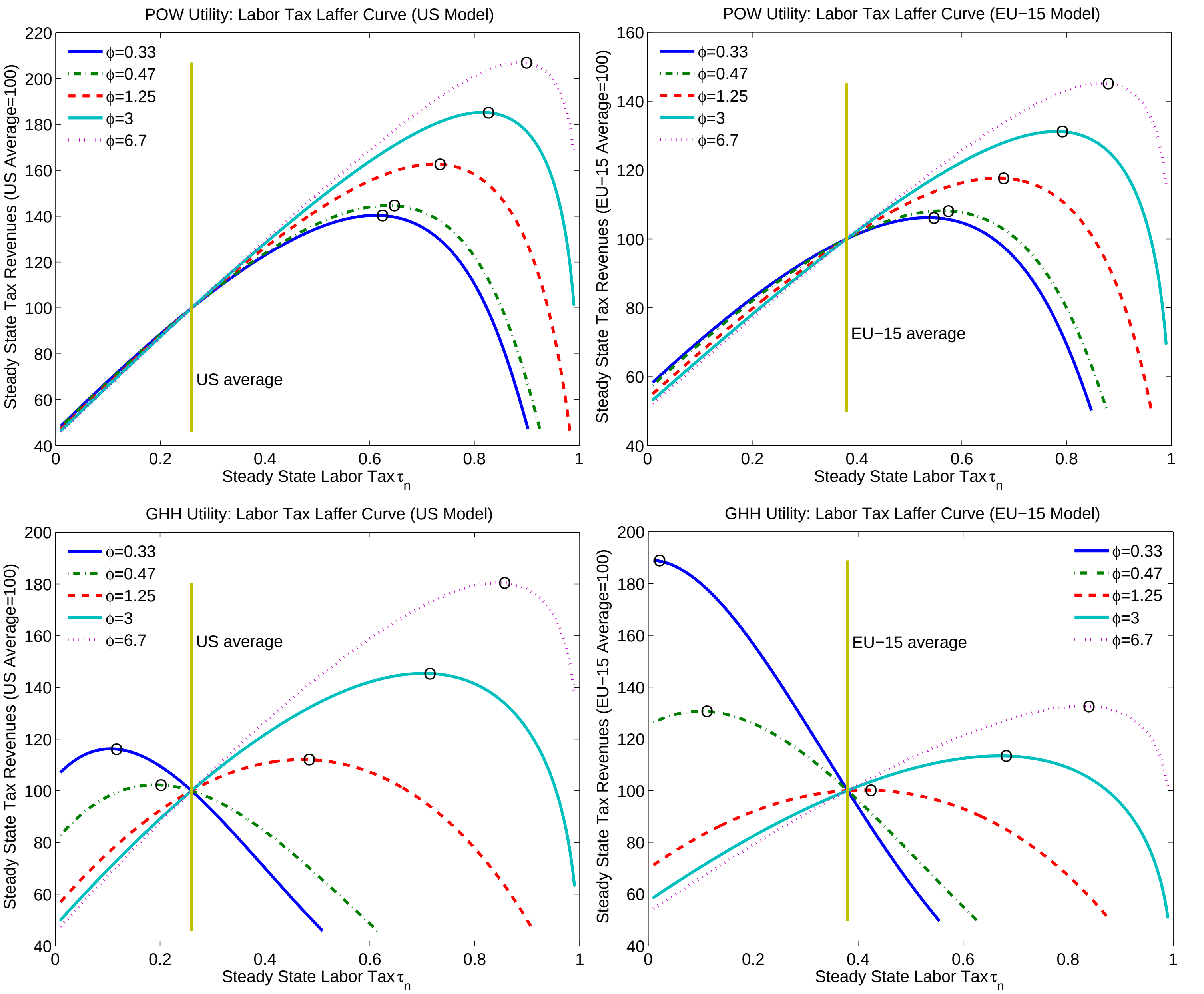

Figure 3: Sensitivity analysis on ϕ' and ϕ''.

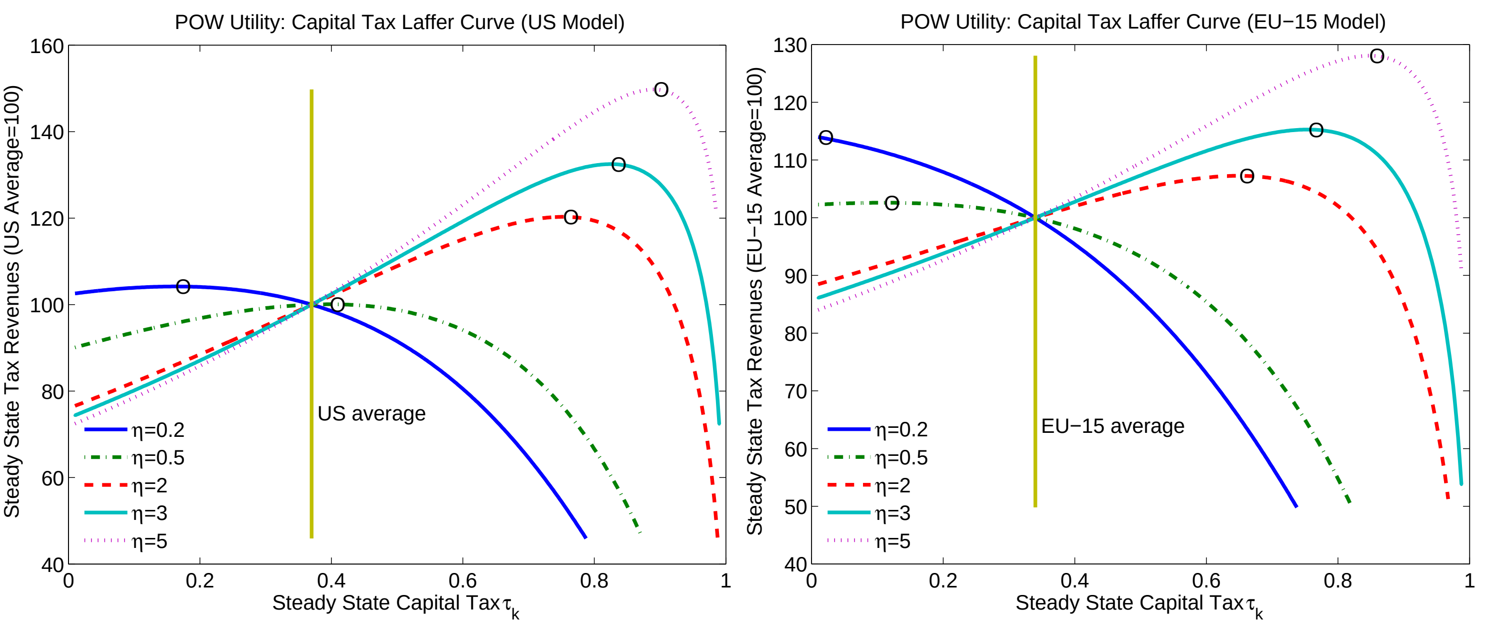

Figure 4: Sensitivity analysis on η'.

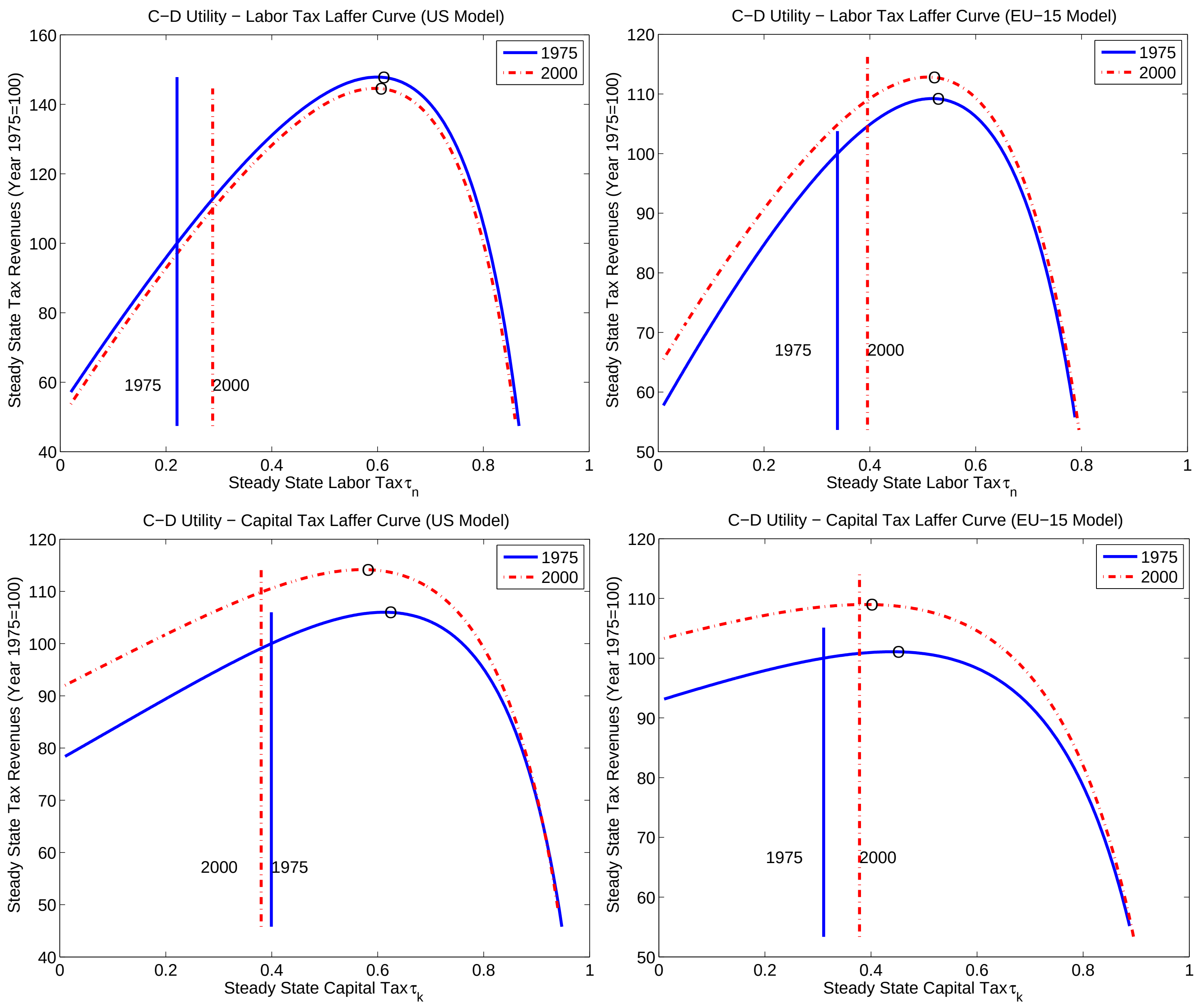

Figure 5: Shifts of Laffer curves over time. C-D utility.

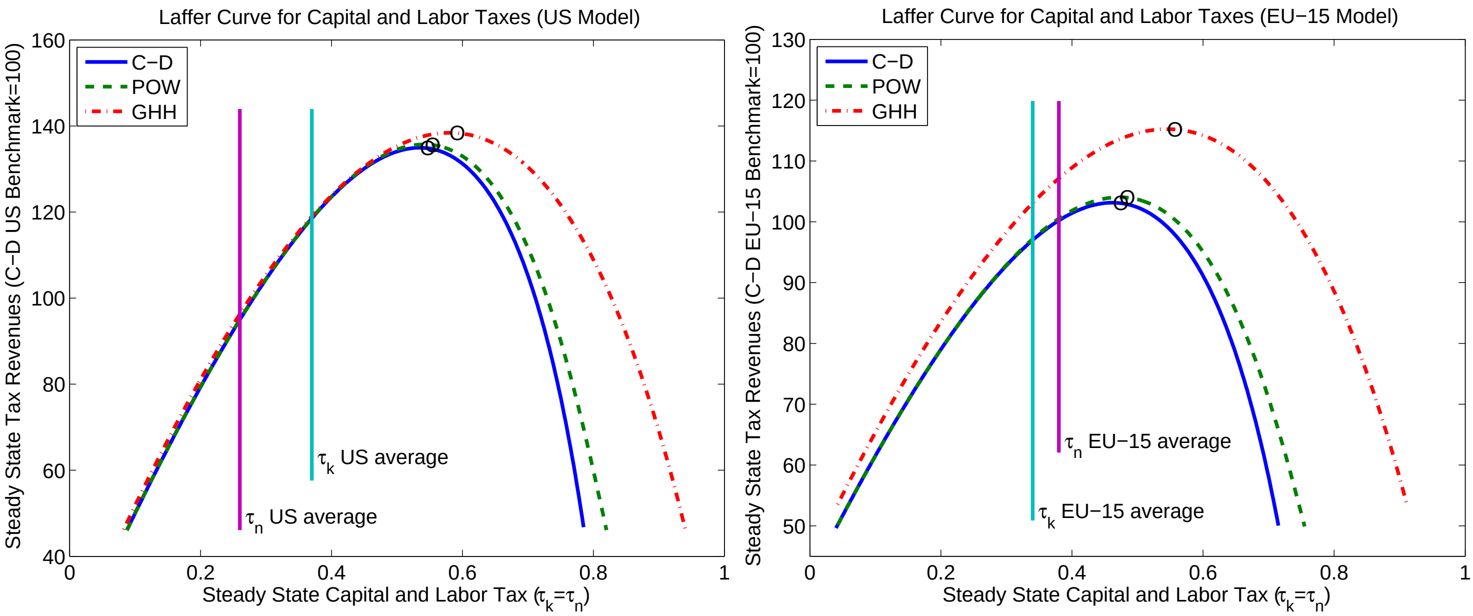

Figure 6: Steady state Laffer curve for capital and labor taxes ($\bar{\tau}^k = \bar{\tau}^n$).

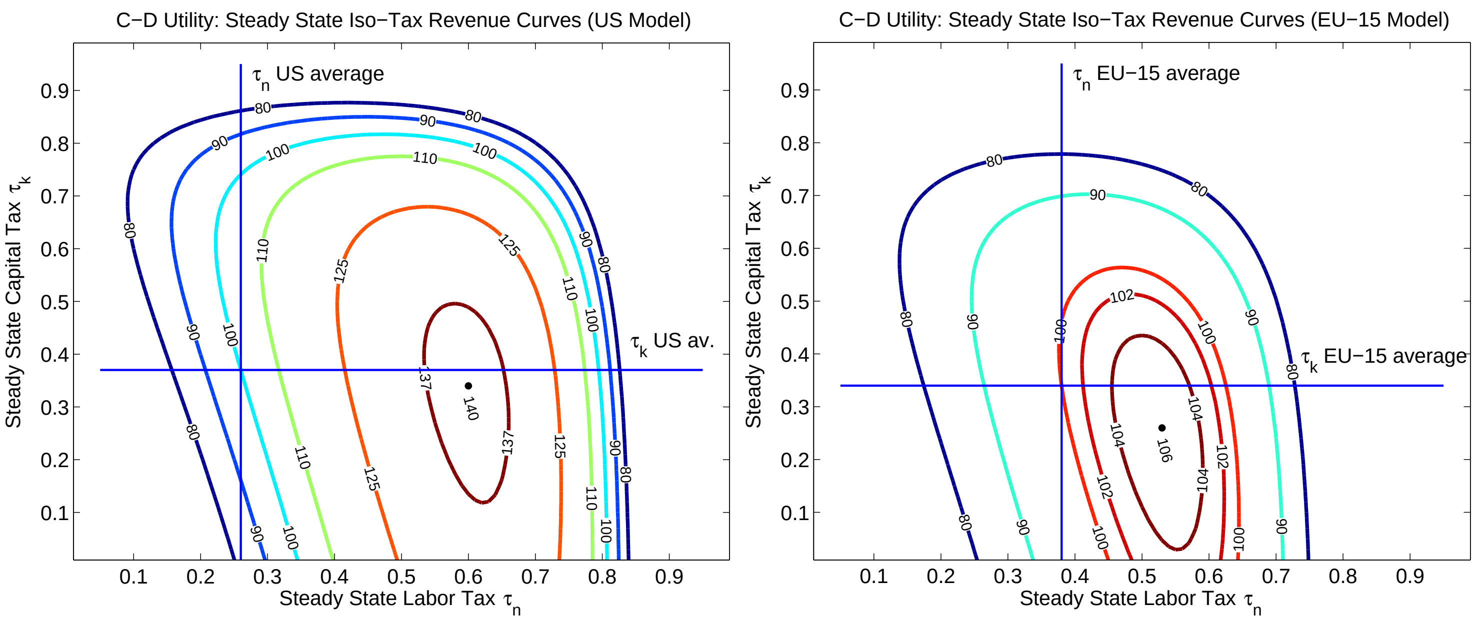

Figure 7: Steady state iso-tax revenue curves for capital and labor taxes; C-D utility; Baseline calibration with US and EU-15 steady state tax revenues=100.

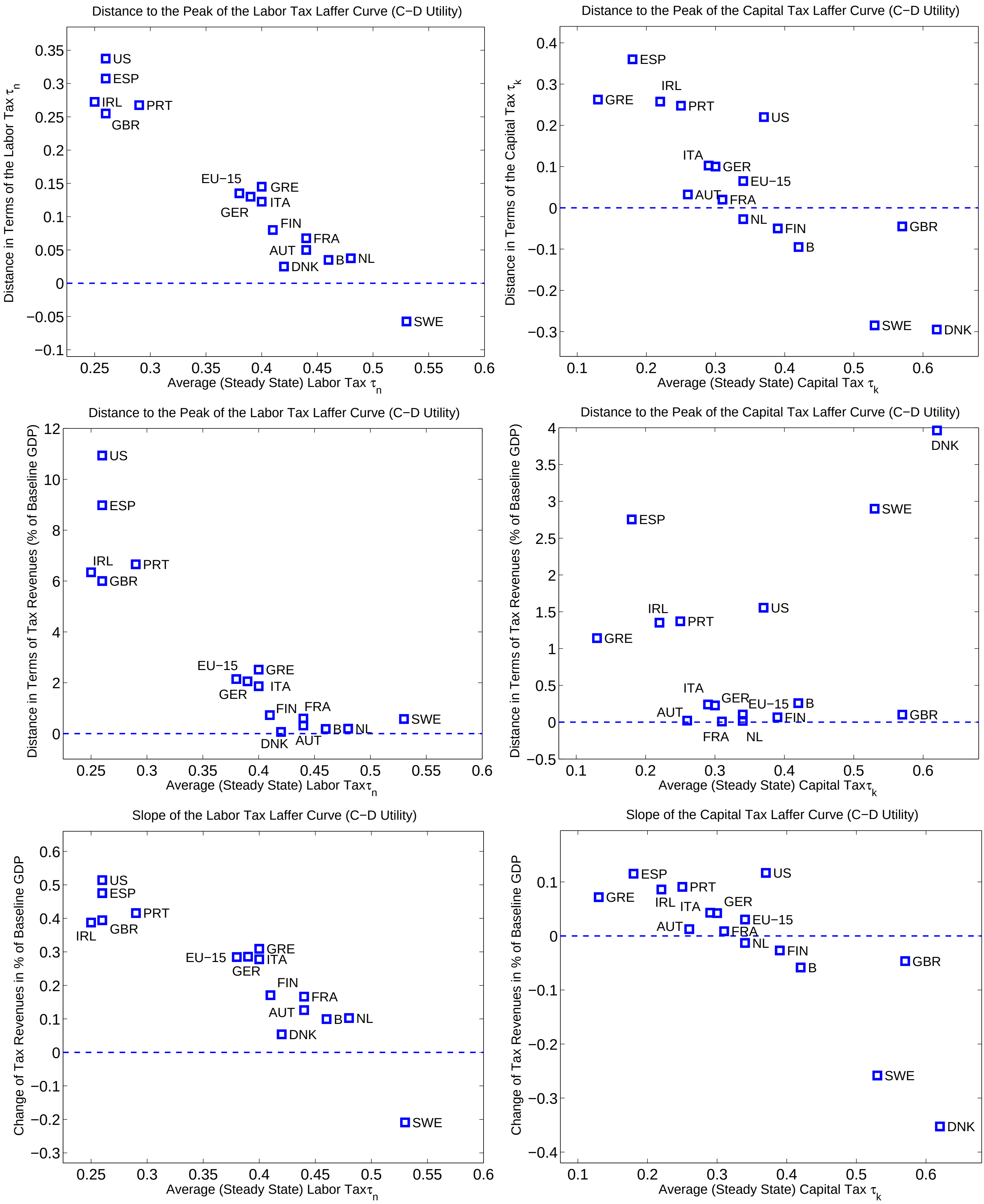

Figure 8: Individual european country labor and capital tax Laffer curves (C-D utility, steady state). The upper two panels show the distance to the peak of Laffer curves measured either in tax units or tax revenues in percent of baseline GDP. The lower panel depicts the slope of the Laffer curves measured as the change of tax revenues in percent of baseline GDP in response to a 1 percent steady state tax increase.

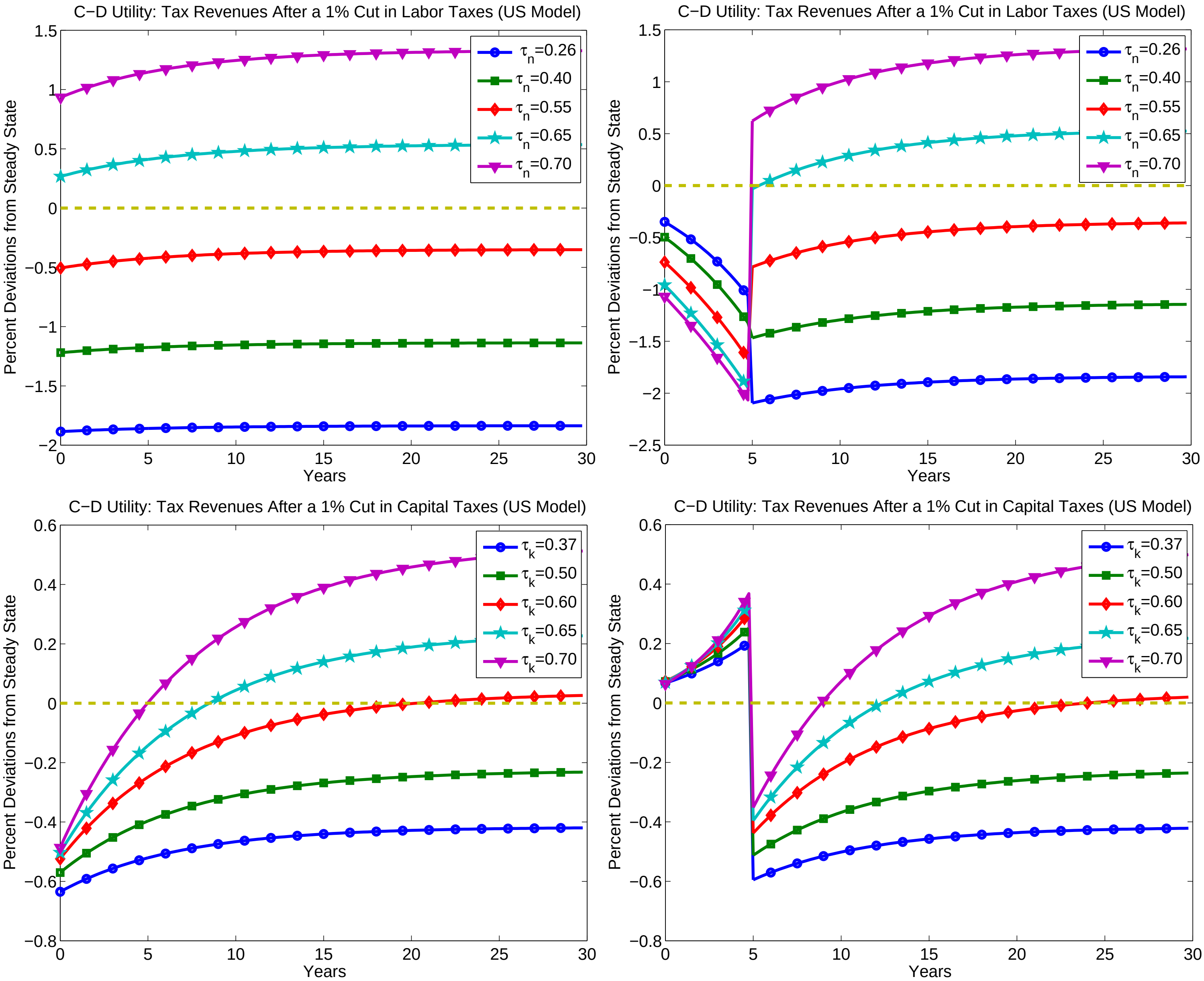

Figure 9: US Model: Dynamic effects of unexpected and 5-year-in-advance announced permanent 1 % tax cuts; Different steady state tax rates; C-D utility.

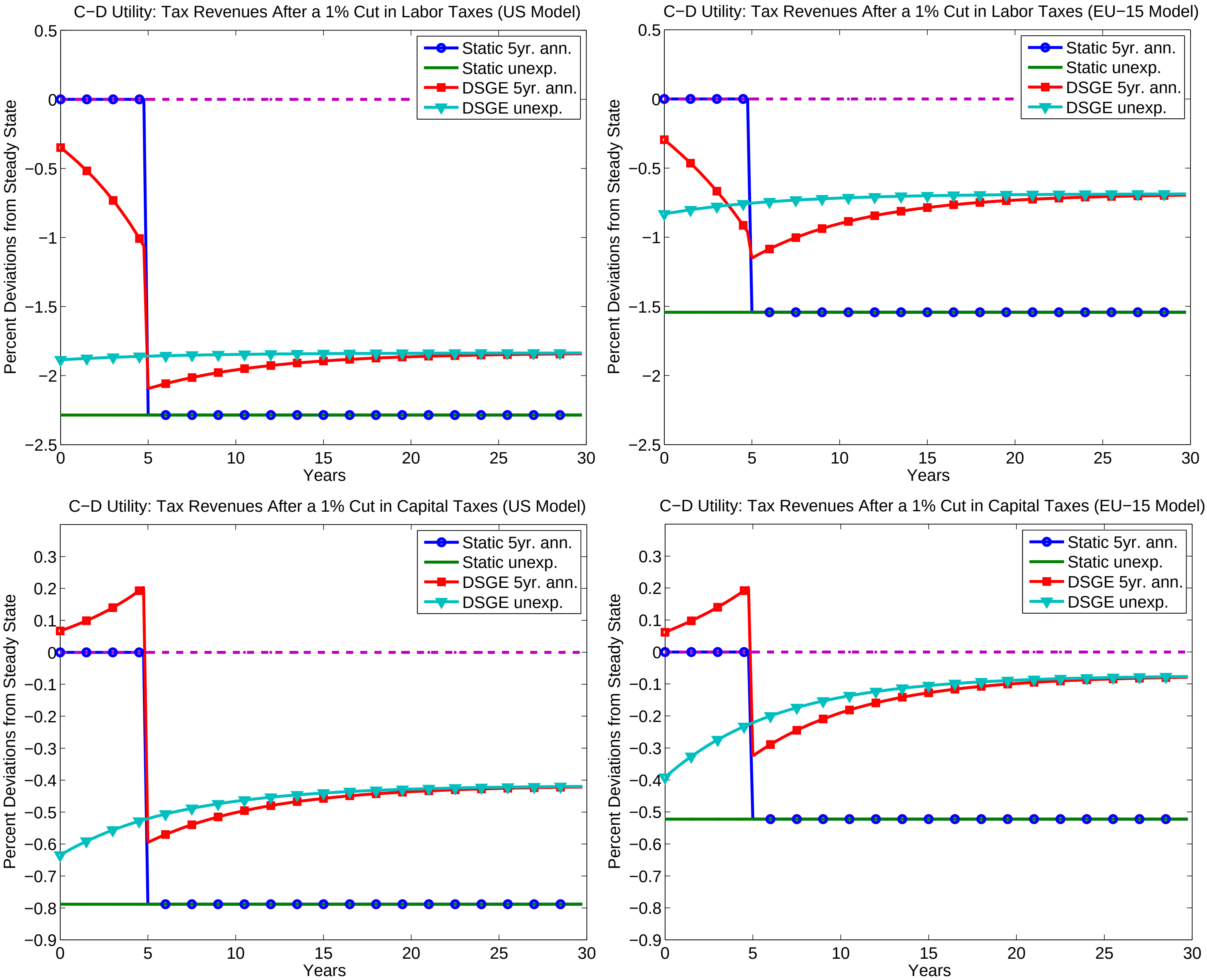

Figure 10: Dynamic vs. static effects of unexpected and 5-year-in-advance announced permanent 1 % tax cuts; baseline calibration; C-D utility.

Technical Appendix

A Stationary Equilibrium

We detrend all variables that are non-stationary by the balanced growth path ψ^t with $\psi = \xi^{\frac{1}{1-\theta}}$. I.e., $c_t = \tilde{c}_t\psi^t$, $x_t = \tilde{x}_t\psi^t$, $y_t = \tilde{y}_t\psi^t$, $g_t = \tilde{g}_t\psi^t$, $s_t = \tilde{s}_t\psi^t$, $T_t = \tilde{T}_t\psi^t$, $k_{t-1} = \tilde{k}_{t-1}\psi^t$. All stationary variables like taxes, interest rates, hours worked and the cyclical component of technology γ_t are not detrended. I.e., $n_t = \tilde{n}_t$, $\gamma_t = \tilde{\gamma}_t$, $R_t = \tilde{R}_t$, $R^b_t = \tilde{R}^b_t$, $\tau^n_t = \tilde{\tau}^n_t$, $\tau^k_t = \tilde{\tau}^k_t$, $\tau^c_t = \tilde{\tau}^c_t$. The following equations describe the stationary equilibrium:

Households labor supply decision:

$$-\frac{U_{\tilde{n}}(t)}{U_{\tilde{c}}(t)\psi^t} = (1-\theta)\frac{1-\tilde{\tau}^n_t}{1+\tilde{\tau}^c_t}\frac{\tilde{y}_t}{\tilde{n}_t} \tag{19}$$

Households Euler equation for capital:

$$\beta E_t\left[\frac{U_{\tilde{c}}(t+1)}{U_{\tilde{c}}(t)}\frac{1+\tilde{\tau}^c_t}{1+\tilde{\tau}^c_{t+1}}\tilde{R}_{t+1}\right] = 1 \tag{20}$$

Households Euler equation for government bonds:

$$\beta E_t\left[\frac{U_{\tilde{c}}(t+1)}{U_{\tilde{c}}(t)}\frac{1+\tilde{\tau}^c_t}{1+\tilde{\tau}^c_{t+1}}\tilde{R}^b_{t+1}\right] = 1 \tag{21}$$

Capital accumulation equation:

$$\psi\tilde{k}_t = (1-\delta)\tilde{k}_{t-1} + \tilde{x}_t \tag{22}$$

Real return on capital:

$$\tilde{R}_t = (1-\tilde{\tau}^k_t)(\theta\frac{\tilde{y}_t}{\tilde{k}_{t-1}} - \delta) + 1 \tag{23}$$

Aggregate resource constraint:

$$\tilde{c}_t + \tilde{g}_t + \tilde{x}_t = \tilde{y}_t \tag{24}$$

Firms production function:

$$\tilde{y}_t = \tilde{\gamma}_t \tilde{k}_{t-1}^{\theta} \tilde{n}_t^{1-\theta} \tag{25}$$

Government tax revenues:

$$\tilde{T}_t = \tilde{\tau}_t^c \tilde{c}_t + (1-\theta)\tilde{\tau}_t^n \tilde{y}_t + \tilde{\tau}_t^k (\theta \frac{\tilde{y}_t}{\tilde{k}_{t-1}} - \delta)\tilde{k}_{t-1} \tag{26}$$

Government budget constraint:

$$\tilde{g}_t = \bar{b}(\psi - \tilde{R}_t^b) + \tilde{T}_t - \tilde{s}_t \tag{27}$$

Exogenous AR(1) processes:

$$\{\tilde{\tau}_t^c, \tilde{\tau}_t^n, \tilde{\tau}_t^k, \tilde{s}_t, \tilde{\gamma}_t\} \tag{28}$$

After assigning steady state values for tax rates, technology, transfers and debt, equations (19) to (27) determine the steady state for all other variables.

B Log-linear Equations

Hat variables denote percentage deviations from steady state. I.e., $\hat{y}_t = \frac{y_t - \bar{y}}{\bar{y}}$. Breve variables denote absolute deviations from steady state, e.g. $\breve{\tau}_t^n = \tau_t^n - \bar{\tau}^n$. The following equations determine the log-linear dynamics of the model:

Households labor supply decision:

$$(1+\sigma_{cn,n}+\sigma_{nn})\hat{n}_t = \hat{y}_t - (\sigma_{cc}+\sigma_{nc,c})\hat{c}_t - \frac{1}{1-\bar{\tau}^n}\breve{\tau}^n_t - \frac{1}{1+\bar{\tau}^c}\breve{\tau}^c_t \quad (29)$$

Households Euler equation for capital:

$$E_t\left[\hat{R}_{t+1} - \sigma_{cc}(\hat{c}_{t+1}-\hat{c}_t) - \sigma_{cn,n}(\hat{n}_{t+1}-\hat{n}_t) - \frac{1}{1+\bar{\tau}_c}(\breve{\tau}^c_{t+1}-\breve{\tau}^c_t)\right] = 0 \quad (30)$$

Households Euler equation for government bonds:

$$E_t\left[\hat{R}^b_{t+1} - \sigma_{cc}(\hat{c}_{t+1}-\hat{c}_t) - \sigma_{cn,n}(\hat{n}_{t+1}-\hat{n}_t) - \frac{1}{1+\bar{\tau}_c}(\breve{\tau}^c_{t+1}-\breve{\tau}^c_t)\right] = 0 \quad (31)$$

Capital accumulation equation:

$$\psi\hat{k}_t = (1-\delta)\hat{k}_{t-1} + (\psi-1+\delta)\hat{x}_t \quad (32)$$

Real return on capital:

$$\bar{R}\hat{R}_t = \left(\bar{R}-1+\delta(1-\bar{\tau}^k)\right)(\hat{y}_t-\hat{k}_{t-1}) - \frac{\bar{R}-1}{1-\bar{\tau}^k}\breve{\tau}^k_t \quad (33)$$

Aggregate resource constraint:

$$(1-\xi-\frac{\bar{g}}{\bar{y}})\hat{c}_t + \frac{\bar{g}}{\bar{y}}\hat{g}_t + \xi\hat{x}_t = \hat{y}_t \quad (34)$$

Firms production function:

$$\hat{y}_t = \hat{\gamma}_t + \theta\hat{k}_{t-1} + (1-\theta)\hat{n}_t \quad (35)$$

Government tax revenues:

$$\begin{aligned}\frac{\bar{T}}{\bar{y}}\hat{T}_t &= (1-\xi-\frac{\bar{g}}{\bar{y}})(\bar{\tau}^c\hat{c}_t+\breve{\tau}^c_t) + (1-\theta)\breve{\tau}^n_t + (\bar{\tau}^n(1-\theta)+\bar{\tau}^k\theta)\hat{y}_t \\ &\quad + \left(\theta - \frac{\delta\xi}{\psi-1+\delta}\right)\breve{\tau}^k_t - \frac{\bar{\tau}^k\delta\xi}{\psi-1+\delta}\hat{k}_{t-1} \quad (36)\end{aligned}$$

Government budget constraint:

$$\frac{\bar{g}}{\bar{y}}\hat{g}_t = \frac{\bar{T}}{\bar{y}}\hat{T}_t - \frac{\bar{b}}{\bar{y}}\bar{R}^b\hat{R}^b_t - \frac{\bar{s}}{\bar{y}}\hat{s}_t \tag{37}$$

Exogenous AR(1) processes:

$$\{\breve{\tau}^c_t, \breve{\tau}^n_t, \breve{\tau}^k_t, \hat{s}_t, \hat{\gamma}_t\}$$

with $\sigma_{cc} = \frac{-U_{cc}\bar{c}}{U_c}$, $\sigma_{cn,n} = \frac{-U_{cn}\bar{n}}{U_c}$, $\sigma_{nn} = \frac{U_{nn}\bar{n}}{U_n}$, $\sigma_{nc,c} = \frac{U_{nc}\bar{c}}{U_n}$ and $\xi = \frac{(\psi-1+\delta)\theta(1-\bar{\tau}^k)}{\bar{R}-1+\delta(1-\bar{\tau}^k)}$. Equations (29) to (37) plus the exogenous shocks determine the dynamics of the model which can be solved with Uhlig (1999).

In order to determine the dynamics of the models, we need the following 15 parameters respectively steady state variables:

$$\sigma_{cc}, \sigma_{cn,n}, \sigma_{nn}, \sigma_{nc,c}, \bar{\tau}^c, \bar{\tau}^n, \bar{\tau}^k, \psi, \delta, \theta, \bar{R}, \tfrac{\bar{g}}{\bar{y}}, \tfrac{\bar{T}}{\bar{y}}, \tfrac{\bar{b}}{\bar{y}}, \tfrac{\bar{s}}{\bar{y}}.$$ [27]

Some of these 15 parameters are free whereas others are tight down by the data or the model. Following tables (1) and (2) the data restricts $\bar{\tau}^c, \bar{\tau}^n, \bar{\tau}^k, \psi, \bar{R}, \delta, \theta$. Table (3) reveals that σ_{cc}, $\sigma_{cn,n}$, σ_{nn}, $\sigma_{nc,c}$ are functions of other parameters and steady state variables. I.e., for C-D utility we obtain two new parameters - η and α. However, the parameter α must be used to pin down $\bar{n}_{us} = 0.25$ for the baseline calibration. It turns out that for the case of C-D utility only η is a free parameter. Likewise for POW and GHH, κ' and κ'' pin down $\bar{n}_{us} = 0.25$ so that free parameters in these cases are η', η'', ϕ' and ϕ''.

Once we know $\bar{n}$ in our models we can calculate $\bar{y}$ and hence from equa-

[27] Note that in equilibrium $R_t = R^b_t$ and thus $\bar{R} = \bar{R}^b$.

tions (22), (23), (24), (26) and (27), we can derive

$$\frac{\bar{g}}{\bar{y}} = \frac{1}{1+\tau_c}\left(\frac{\bar{b}}{\bar{y}}(\psi - \bar{R}) + \bar{\tau}^c(1-\xi) + (1-\theta)\bar{\tau}^n + \bar{\tau}^k(\theta - \frac{\delta\xi}{\psi - 1 + \delta}) - \frac{\bar{s}}{\bar{y}}\right) \tag{38}$$

and as well as

$$\frac{\bar{T}}{\bar{y}} = \frac{\bar{b}}{\bar{y}}(\bar{R} - \psi) + \frac{\bar{g}}{\bar{y}} + \frac{\bar{s}}{\bar{y}} \tag{39}$$

which pin down $\frac{\bar{g}}{\bar{y}}$ and $\frac{\bar{T}}{\bar{y}}$. However, our choice for $\bar{b}$ as well as $\bar{s}$ is restricted by the fact that for the baseline calibration $\frac{\bar{b}}{\bar{y}}$ as well as $\frac{\bar{s}}{\bar{y}}$ must match the data as given in table (1).

To summarize η, η', η'', ϕ' and ϕ'' are the only free parameters in our models. However, as outlined in section 3.3 we set η, η' and η'' such that the intertemporal elasticity of substitution is unity. In addition we set ϕ' and ϕ'' such that $\frac{\partial \bar{T}^{US}_{C-D}}{\partial \bar{\tau}^n} = \frac{\partial \bar{T}^{US}_{POW}}{\partial \bar{\tau}^n} = \frac{\partial \bar{T}^{US}_{GHH}}{\partial \bar{\tau}^n}$. As a consequence of our calibration/parameterization discipline table (3) reveals that $\sigma_{cc}, \sigma_{cn,n}, \sigma_{nn}, \sigma_{nc,c}$ are identical for C-D and POW utility for the US model. Hence, the dynamics are locally identical for these models. By contrast, for GHH preferences only $\sigma_{cc} = 1$ is identical with the other preference specifications and hence the dynamics will not be identical with the other preferences in general. However, implied by our calibration/parameterization discipline that $\frac{\partial \bar{T}^{US}_{GHH}}{\partial \bar{\tau}^n} = \frac{\partial \bar{T}^{US}_{C-D}}{\partial \bar{\tau}^n}$ we know that for labor income tax cuts the dynamics will be identical with the other preferences.

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